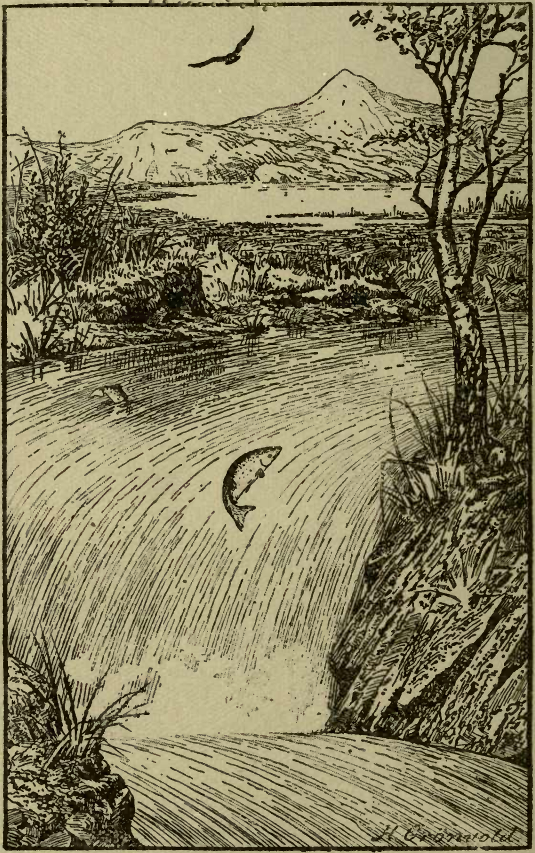
FISH LIFE



THE STORY OF FISH-LIFE

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WITH EIGHTEEN ILLUSTRATIONS

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PREFACE.

Every reader who takes up this little volume is certain to be more or less familiar with the animal which we know as a fish. But this familiarity will have been acquired through many channels, varying with the individual. One will have much to tell of angler's lore, of knowledge gained by long hours of silent watching and waiting, ruminating on the mysteries of Nature, and perfecting deep-laid plots to snare her scaly children. He will talk with animation of a well-filled creel, and recount wondrous tales of mighty fish lost when capture seemed a certainty; fish whose shades grow larger each time the memory revives them, just as their solid selves have doubtless been doing ever since, making their capture less and less likely as they gain in bulk. This must be so, for fish such as loom so large in these stories never seem to be landed! He will regale us with delicious word pictures of stream and lake and sea, and curious facts of the ways and customs of fish of all kinds, and of all lands. Another will have much that is worth knowing to tell, concerning fish as a food supply, and of the industries connected therewith, of which enough might be said to fill another book of the size of this little volume. Yet others could add curious facts gained in our various fish-hatcheries, or facts encrusted but too often by painful memories of days of peril and exposure encountered in that great arena, where men war with Nature, and take from her as by force—the deep sea-fisheries.

All these, in their respective spheres of knowledge, will learn but little, probably, from this little book. Its aim is quite other. Briefly, its purpose is, as its title implies, to tell the Story of Fish Life. Man's relations thereto is thereby excluded. We are to take a peep into fish world, and see, as far as may be, how they fight the battle of life, how they "live and move and have their being."

Certain technicalities have been, here and there, unavoidable, and will, I am sure, be patiently tolerated by my readers. They are used only when their omission would be at the expense of clearness.

In the preparation of this little volume I have found much help from Dr A. S. Woodward's "Vertebrate Palæontology"; Dr Bashford Deans' "Fishes Living and Fossil"; Dr A. Günther's "Study of Fishes"; Dr R. H. Traquair's Presidential Address at the Bradford meeting of the British Association (1900), as well as his numerous and valuable contributions to the proceedings of various learned societies; and to Mr Lydekker's "Royal Natural History." All these works can profitably be consulted by those of my readers who may be induced to pursue this fascinating study further.

Finally, I have to record my grateful thanks to many kind friends for much kind help in seeing this little book through the press. And especially am I indebted to Dr A. L. Günther, F.R.S., who has guided me through many dark places, and in every way lightened my labours by giving me the benefit of his own rich experience.

W. P. PYCRAFT.

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CHAPTER I.

INTRODUCTION.

THE Story of Fish Life began ages and ages ago. Of this we are assured, not by any written record, but through the labours of those who spend their lives in exploring the dried basins of ancient lakes and seas, searching for the dead which may incidentally have been preserved therein. The accumulated results of these explorations have provided us with a rich material for study in the shape of the hard parts, at least, of fishes of many kinds, the like of which, in many cases, we shall never see again. But some of these may be traced through a long series of geological formations, up to their living descendants; and serve to fill gaps otherwise incomprehensible. They enable us to weave out of the whole of the collected evidence a story, as plainly as though we had transcribed it from the more familiar print.

But our story is even now by no means a connected story: there are many gaps which we can never hope to fill. For instance, the earliest of the known fishes was most certainly preceded by still more primitive forms, whose structure did not permit of preservation, lacking hard parts such as bones or scales. The remains of certain other early types leave us yet in doubt on very important points, such as whether the mouth had jaws, what was the position of the eyes, and so on. Answers to many of these questions may, however, yet come to hand, for the examination of rock systems of the world is by no means exhausted yet.

These remains, then, we know as fossils, and the hardened mud in which they are embedded we call rock. How these rocks came to be does not concern us here. Those who would know more on this head should read Prof. Seeley's little book, the "Story of the Earth," published in this series. Suffice it to say, that the various kinds of mud with their peculiar fossils represent different periods of time of great duration. These periods we shall refer to here under their scientific names, as "Devonian," "Carboniferous" or "Cretaceous," and so on as the case may be. We shall find that as we proceed from the oldest to the newest of these formations that the fossils therein will increase in number, variety and complexity of structure. This increased complexity has resulted from the gradual modification of simple types as they become more and more perfectly adapted to their environment.

Those of us who can spell out more or less connected portions of these riddles have gathered one fact of prime interest. We cannot fail to be impressed with the conviction that Nature has pressed the plastic mystery which we call Life into many moulds, and many creatures into the same mould. Earth, air, and water are all peopled, and the inhabitants of each of these three worlds frequently bear very close resemblances one to another without being in the least degree related. That is to say, there is evidence of conformity to the mechanical needs of the environment, resulting in a superficial conformity in external appearance.

The fishes afford us an admirable object lesson. They are creatures fashioned by a series of gradual improvements to dwell in water. To move freely in this comparatively dense medium entails conformity to certain mechanical needs. This conformity has resulted in the characteristic "fish-like" form: the compressed head and trunk, tapering gradually to the tail, giving the whole the form of a rounded wedge; to this wedge-shaped body keels have been added along the back and along the belly, as well as balancing and steering organs projecting from the sides. These keels and balancers we call the fins, and because we shall have to make frequent reference to these fins it would be well to pause here to study their arrangement and distinctive names in the accompanying picture (fig. 1). The fins, which we have likened to keels, are known as the median fins, whilst those which act as balancers and for steering, are known as the paired fins. These are never more than four in number, and correspond with the arms and legs of terrestrial animals. But the fish is, so to speak, balanced in the water, and needs no support from the limbs, which owe their peculiar form to adaptation to their special requirements. The terrestrial limbs have probably arisen by a modification of these balancing organs. Poised in the water the fish is free to move in all directions. To adapt the fish still more perfectly to its environment a very peculiar organ, known as the air-bladder, has been developed, at least in the majority of living forms, as well as in the more modern fossil types. This air-bladder seems to render the specific gravity of the fish the same as that of the surrounding water. Modifications which the air-bladder may undergo will be found on a later page.

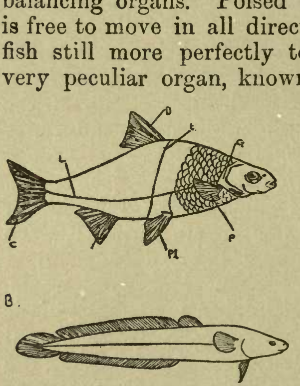


FIG. 1.—*A.* Common Roach, showing arrangement of fins, and general shape of body. *D.* dorsal fin; *C.* caudal or tail fin; *A.* anal fin; *Pl.* Pelvic or ventral fin; *P.* pectoral fin; *G.* gill cover; *L.* lateral line; *t.* transverse line. The significance of the transverse and lateral lines is explained further on. Only a few scales have been indicated, in order that the transverse and lateral lines may be rendered more conspicuous.
B. An outline figure of the Burbot (*Lota vulgaris*), for comparison with fig. *A.*, note the difference in the shape and position of the fins and the absence of scales.—After Günther.

Further adaptation to aquatic needs has resulted in a complete investment of slime; how copious this secretion may be bream-fishers will testify! This slimy coat reduces friction to a minimum. Beneath this slime we can generally descry a series of overlapping plates—the scales; these fit closely one over the other so as to offer a perfectly smooth surface.

The fish, as we have just remarked, being nicely balanced in the water, needs no support from limbs as do terrestrial animals, neither are the limbs needed to propel the body through the water. Locomotion is effected in one of two ways. Much elongated fishes, like sharks or eels, for instance, move with great speed by rapid undulations of the body. The forward motion is effected by the pressure of the body against the water, enclosed in the several incurved planes arising from the undulations. This undulatory movement is well expressed in the diagram, fig. 2.

FIG. 2.—Diagrammatic figure of an Eel, showing the nature of the undulatory movement of the body.

Relatively shorter fishes progress by powerful side to side movements of the tail; and since the majority of fishes seem to have shortened up the body, for the sake of using the tail as a propeller, it is probable that this is the more useful form of movement of the two.

If any doubt the reasonableness or probability of the characteristic "fish-like" form having arisen as a result of adaptation to the mechanical needs of the environment, let him pause and consider what has happened to certain aquatic mammalia—to wit, the whales and porpoises. These animals are so peculiarly fish-like in form that they are very commonly regarded as fish. The authorities at the Natural History departments of the British Museum are being constantly appealed to, to settle arguments such as whether or no the whale is a fish. The same spindle-shaped tapering form of body, the presence, in many cases, of a dorsal fin, and the peculiarly fin-like fore-limbs render this mistake a very natural and quite pardonable one. But it is not a fish, because it suckles its young like all the rest of the mammalia, consequently it is with this group that we must place the whale and its allies. But there are yet other reasons which forbid us to regard the whale as a fish, and compel us to recognise it as a mammal. If we examine a skeleton of one of these creatures we shall find it differs fundamentally from that of the fish, and agrees closely with that of the mammalia. The points wherein it differs from the type all show undoubted adaptation to and specialisation for particular mechanical needs. Thus the fore-limb is obviously a mammalian fore-limb, which has undergone certain changes, converting it into a paddle for swimming purposes. The whale, being poised in the water like a fish, has ceased long since to need support from its sometime functional legs. The fore-limbs being useful have been transformed into paddles, the hind-limbs not being required have disappeared long ago, leaving only slight traces of the hip-girdle imbedded in the muscles of the body. The structure of the skull, backbone, ribs, breastbone all tell the same tale; so do the brain, heart, lungs, and other viscera—all point emphatically, beyond all possibility of doubt whatsoever, to the irresistible conclusion that the whale and its allies are *not* fish but mammals. The seals point the way in which this peculiar modification has come about, being half-way stages between the typical walking mammal and the highly specialised floating one. The seal is amphibious, but the hind-limbs are already losing much of their power of support on land, and the fore-limbs are becoming more and more paddle-shaped.

The old ichthyosaurus is but one of many forms amongst the extinct reptiles which have undergone a precisely similar modification to that of the whale in the shape of the body and limbs. Certain living snakes again, by adopting an entirely aquatic existence, have become quite eel-like in form, rendering it very difficult to distinguish eel from snake. But there is no need to go on multiplying instances of this kind. The facts are beyond dispute. The fish, there can be no doubt, owes its peculiar form to the gradual adaptation to the needs of its environment.

Fishes hold, says Dr Bashford Dean, an important place in the history of vertebrate or backboned animals; their group is the largest and most widely distributed; its fossil members are by far the earliest of known vertebrates; and amongst its living representatives are forms which are believed to closely resemble the ancestral vertebrate.

The origin of new groups of fishes yet remains a mystery, but certain facts connected therewith afford us food for reflection of extraordinary interest. These facts have lately been set forth with telling force by Dr A. Smith Woodward. He points out that in tracing the history of the evolution of any given group of animals, say of fishes, we find that during different geological epochs one particular type will have the ascendency over all the others, this he calls the "dominant" type. He then proceeds to show that a dominant old race, at the beginning of its greatest vigour, seems to give origin to a new type, showing some fundamental change; this advanced form then seems to be driven from all the areas where the dominant ancestral race reigns supreme, and evolution in the latter becomes comparatively insignificant. Meanwhile the banished type has acquired great developmental energy, and finally it spreads over every habitable region, replacing the more effete race which originally produced it. The period of greatest vigour of the "dominant old race" represents the flowering out of new species stimulated into being, by the occupation of new territory, the new species developing as a result of adaptation necessary to obtain a hold on this or that particular area. Now, adaptation spells specialisation, and the cessation of the growth of the dominant race after this sudden burst of activity points to inability to further development, a balance being struck between the organism and the environment. The banished form which suddenly springs up in force replacing the parent type is also the result of adaptation. Born of members of the parent form, but possibly far removed from the environment which was slowly shaping the typical dominant forms, they developed along the new lines demanded by the new environment, which eventually appears to have slowly replaced the old order of things and the highly specialised forms dependent thereon.

Dr Woodward gives some striking examples of this rise and fall of tribes of fishes, which may be likened to the rise and fall of nations amongst mankind. A certain type of fishes known as the ray-finned fishes (p. 176) furnishes the first of his examples. The earliest known members of this type belong to a genus known as *Cheirolepis* (p. 178). This appears as an isolated form in the Lower Devonian fish fauna, where the dominant fish are of two quite distinct types: the one known as the fringe-finned (p. 176), and the other as the lung-fishes (p. 25). When these latter begin to decline, in the Lower Carboniferous (coal measures), "the sub-order to which Cheirolepis belong suddenly appears in overwhelming variety." From Cheirolepis we derive our modern sturgeons. The period of the Upper Permian witnesses another change. A group of fishes, for the most part heavily armoured, now first makes its appearance, "but only a solitary genus is observed among the hosts of the dominant race." In the Trias the new type becomes supreme, and constitutes the dominant fishes of the Jurassic period. From thence onwards it gradually declined, leaving but a solitary survivor in the mud-fish or bow-fin of certain North American rivers (p. 183). Out of the teeming hordes of the bow-fin type, of the old Jurassic seas, new forms have silently appeared to give battle to the old so soon as they shall have gained a firm hold. These have put off the old armour plate of enamelled scales, and have adopted a peculiarly modern habit. Many are scarcely distinguishable from the living members of the herring tribe, which indeed trace their origin to this stock. With these herring-like forms in the Cretaceous period appeared numerous other familiar shapes, which differ only in small points from their living descendants of the seas and rivers of to-day.

"The evolution of fishes," says Dr Bashford Dean, "has been confined to a noteworthy degree within rigid and unshifting bounds; their living medium, with its mechanical effects upon fish-like forms and structures, has for ages been almost constant in its conditions; its changes of temperature and density and currents have rarely been of more than local importance, and have influenced but little the survival of genera and species widely distributed; its changes, moreover, in the normal supply of food organisms cannot be looked upon as noteworthy.

"When members of any group of fishes became extinct, those appear to have been the first to perish which were the possessors of the greatest number of widely modified or *specialised* structures. Those, for example, whose teeth were adapted for a particular kind of food, or whose motions were hampered by ponderous size or weighty armouring, were the first to perish in the struggle for existence. On the other hand, the forms that most nearly retained the ancestral or tribal character—that is, whose structures were in every way least extreme—were naturally the best fitted to survive. Thus *generalised* fishes should be considered those of medium size, medium defences, medium powers of progression, omnivorous feeding habits, and wide distribution; these might be regarded as having provided the staples of survival in every branch of descent. . . . A generalised form is like potter's clay, plastic in the hands of nature, readily to be converted into a needed cup or vase; but, when thus specialised, may never resume unaltered its ancestral condition. The clay survives; the cup perishes."

CHAPTER II.

HOW FISHES BREATHE.

FRESH air is as necessary to a fish as to ourselves, and this air is needed, just as with us, for the sake of its oxygen. The taking in of this life-sustaining gas is known as Respiration. The process of respiration, or breathing, in the fish is performed by means of gills, not, as with us, by means of lungs; and although the difference between these two forms of respiration may seem to be very considerable, we shall see that the former is the more ancient practice, and gradually gave place to the latter.

Vertebrated or backboned gill-breathing animals are always aquatic, although the converse—that lung-breathing vertebrates are always terrestrial—is by no means true.

Breathing organs of whatever kind are always intimately associated with the upper end of the alimentary canal or food-pipe. Sometimes this association remains throughout life; as in the fish, sometimes it is but a temporary phase, as in the higher animals.

Fish, then, are gill-breathing animals, and these gills are, it has just been hinted, in some way connected with the tube into which the food is taken. Let us now look closer into this connection.

Everybody knows, of course, that a fish's gills are to be found in its head. Many will be further able to point out that they can readily be seen by raising a bony flap or plate lying on either side of this head, but that they have anything to do with the food-pipe, or, as we prefer to call it, the alimentary canal, is a fact which doubtless will be new to many. Let us make clear, then, the nature of this association at once. Food is taken in at the mouth, and thence, as everybody knows, passes down a tube into a more or less extensive and sometimes complicated bag called the stomach. This is true equally of the fish, and of ourselves. But fish, and some other lowly backboned animals, have a series of slits in the wall of this tube, situated at the back of the mouth, just before the region where the tube suddenly narrows to become the gullet,—the passage leading to the stomach. The wall of the tube in the fish, between every slit, becomes strengthened by a solid support, which takes the form of a half-hoop, and from every one of these half-hoops there arises a series of slender rods, closely packed, so as to form a kind of fringe to the hoop. These rods support closely plaited folds of skin richly supplied with a series of fine blood-vessels, through which the venous and impure blood of the body is forced. The walls of these blood-vessels are of exceeding thinness, so that the contained blood is brought into very close contact with the water, which, entering in at the mouth, is forced, as soon as this is closed, through the slits in the wall of the alimentary canal, and in thus escaping bathes the vessels. The oxygen contained in the air suspended in the water is seized upon by the blood as the water flows past, and at the same time the carbonic acid is given off and carried away in the stream. And in this way, by the passage of a stream of water over blood-vessels, supported in the manner just described, is the blood purified.

The form of gill arrangement just sketched is such as is found in, say, a perch or cod-fish. But in the sharks and dog-fish and rays, or skates as they are often called, we find a yet more primitive arrangement. Here each gill-slit opens from the mouth into a kind of pouch; and the water which gains admission is forced out through a slit in the outside of the animal. Since there are a series of these slits, as in the higher fish, so we get on the outside of the fish a series of slits corresponding in number to those on the inside—five to seven. These pouches are formed by a double-walled partition or septum extending outwards from every one of the solid arches or half-hoops already described, to the outer wall of the body. The rays or rods of the arches run up between the double walls of each septum. The opposite walls of each pouch support closely plaited folds of skin supplied with blood as in the higher fishes, and are divided by the cavity through which a stream of water is constantly passing for the aeration of the blood. In the higher fish, as in the perch, for instance, the septa or walls which constitute the pouches have been dispensed with, and only a single slit at the side of the head remains.

In the sea-horses and pipe-fish the typical gills are replaced by curious rosette-shaped tufts.

The climbing perch (*Anabas*), serpent-heads (*Ophiocephalus*), and some cat-fishes have curious accessory structures enabling their owners to quit the water for a more or less prolonged sojourn on land. The accessory breathing-organs of *Anabas* may serve as a type. If the outer wall of the gill-chamber be removed, a cavity will be exposed containing, below, the true gills, and above a more or less rosette-like structure. This rosette lies in a special air-chamber, and is well supplied with blood-vessels for the aeration of the blood whilst the fish is out of the water.

Breathing by gills may be aided by breathing through the skin, or breathing through the intestine, or by structures that correspond to our lungs.

Breathing through the skin or the intestine may seem strange to many, but much of the improbability that suggests itself at first will disappear when we remember that "breathing" is really the process of exchange of gases by the blood. These gases can pass with the greatest readiness through their membranes, such as the skin, and so gain access to the blood almost as easily as by the lungs. The common loach of our streams is an instance of breathing by the intestine. In this case air is swallowed by the fish, which, frequently rising to the surface, thrusts its mouth above the level of the stream and gulps down a mouthful of the precious fluid. This passes at once to the intestinal tube, when the oxygen is quickly extracted by minute blood-vessels. Certain cat-fishes and carps also transform the intestine into an accessory breathing-organ. Some fishes, it is contended, are more easily drowned than such an essentially land animal as the adult frog. For Milne Edwards, the great French naturalist, assures us that a frog, though immersed in a wire cage in the bed of a stream, will if it be supplied with food thrive prodigiously, respiration being carried on through the delicate skin; whilst the fish enclosed in the same cage would speedily die.

The wonderful little walking-fish (*Periophthalmus*) passes the greater part of its life on land, skipping about the mud-flats of mangrove swamps. To render this amphibious existence the more perfect, the gill-chamber has become somewhat enlarged, and whilst the fish is out of the water the chamber is kept filled with air. Gill-breathing is said to be further supplemented by respiration through the skin of the tail.

Now let us take a peep at the lung-like structures. Before we can rightly understand these, however, we must consider the organ to which they themselves are due—the air-bladder or more correctly perhaps the *gas*-bladder. The air-bladder must be familiar enough to many of my readers.

It is the long cylindrical body which lies in the body cavity, immediately below the vertebral column or backbone. Puncture it, and see what happens! In a moment its once glistening and silvery walls collapse, and nothing but a crumpled mass of skin remains. That it contained air or gas, there can no longer be any doubt. The changes of form and other details which concern the air-bladder are many, but too technical to be discussed here. We must, however, pause a moment to notice two very interesting and very important points concerning this organ.

The first and most important of these points which we will examine deals with the fact that the air-bladder is intimately associated with the gullet.

If we were to watch the course of development of the fish within the egg we should see that at one stage of this development the gullet would send up a little bud, which, growing larger and larger, at last would become the air-bladder. As it grew more and more towards perfection, so it would gradually separate off from the gullet; at last it would remain attached only by a narrow tube. This tube in many fishes remains open throughout life so that air can pass from the gullet to the air-bladder; in some it closes up, and in others it disappears altogether. In cases where the connection between the bladder and the gullet is lost, it becomes a nice question as to the means by which the gaseous fluid gets into the bladder. It is supposed that the difficulty is surmounted by the bladder making its own gas.

In some bony fishes, and in sharks and rays, the air-bladder is wanting altogether.

But what has all this to do with lungs and lung-like structures?

A great deal. In the first place the mode of origin of both air-bladder and lung is precisely similar—as an outgrowth of the gullet. In the second, we can follow by a series of gradations the gradual evolution of the former from a simple air-bag, as in the perch, for instance, to a true lung such as is found in certain remarkable fishes known as the lung-fishes. These fishes are found in muddy rivers, whose waters are often charged with foul gases. At such times the lung-fishes come from time to time to the surface to breathe atmospheric air. When the water is less impure they breathe by gills as other fish. But the details of this matter belong rather to text-books of comparative anatomy than to a little work like the present.

One point more about gill-breathing before we leave this subject. So far, the gills which we have examined have been what are called internal gills. That is to say, they have been concealed within, and protected by, either a series of pouches or chambers communicating with the outer world by slits, or by a single large plate. In the young of many fishes, *e.g.*: the young dog-fish, the gills are at first external, and take the form of long delicate filaments protruding through the outer gill-slit. In the young bichir, or *Polypterus*, of the Nile, these gills are retained for a somewhat longer period, and are quite large (fig. 3); but in the adult, as in all other fishes, they disappear, being exchanged for the more easily protected internal gills. These external gills become still more interesting when we remember that the larval frogs and newts also breathe by external gills, whilst in certain aquatic salamanders (*Necturus* and *Proteus*) these external gills are retained throughout life.

The breathing of fishes is attended by some very characteristic movements of the mouth rarely properly understood by the lay mind. "He drinks like a fish" is a charge, and a very serious one, often launched by one man against another. Often it is as false and unfounded as the comparison. To begin with, fishes when they drink—if they drink—drink water. But it is not the nature of the draught but the frequency of its repetition to which allusion is made in this quotation. It is apparently supposed that the constant and rhythmical opening and closing of the mouth is a proof of the act of drinking. Nothing could be further from the truth. This is the outward sign of the act of breathing, and corresponds to the heaving sides and the steaming nostrils of the galloping horse. In opening the mouth water is drawn in; in closing it, it is forced out through the gill-slits in the gullet, over the gills, that the oxygen may be extracted by the blood, and out by the gill-slits or slit, as the case may be. No water is

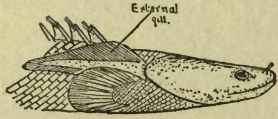


FIG. 3.—Head of a young *Polypterus* (bichir), showing the external gill.

swallowed by this act, because the gullet, just behind the hindmost slit which pierces its sides, is able to contract itself so tightly as to prevent the entrance of any water whatever. This contraction is performed by muscles, which bring about the same result as the double string running round the mouth of a bag, the which it closes by drawing the mouth smaller and smaller. When the fish desires to swallow food this is pressed against the centre of this closed-up gullet, albeit ever so lightly. The touch signals to the nerves controlling the muscles to relax their hold somewhat, and at the same time to seize upon the newly arrived solid refreshment. This it does so perfectly that little or no water is swallowed therewith. The gullet presses round so tightly that the matter being swallowed might be likened to a cork being thrust down into a bottle with a flexible neck, which closed up as the cork passed lower and lower down.

This chapter has surely left us in possession of some very interesting facts. Thus we may take it for granted that the gills of fishes were originally formed by delicately waving branches projecting on either side of the head, and that, for protection's sake, they came to be withdrawn into a series of little pockets, communicating with the outer world by a series of slits. The next stage in their history is that in which the walls of these separate gill-pockets or pouches become removed, so that the gills come to lie in a single large cavity, opening by one slit behind the head. Lastly, we must remark that about the time when gill-pouches went out of fashion, a new improvement was introduced—the air-bladder. This in turn can be followed through a series of transformations which gradually change it into a lung, and so more or less completely do away with the need of gills at all. If we had the time we could go further still, and follow these lungs into still greater stages of perfection; but this must be left for another day.

CHAPTER III.

HOW FISH ARE CLOTHED.

SOME fish, such as the lampreys, many eels, and all fishes provided with well-developed electric organs, have the skin entirely naked. These are, however, exceptions, and there is good reason to believe that this nakedness is, at least in most cases, a degenerate character. That is to say, scales were once present, but have now disappeared. Thus, in many eels, if the skin be carefully (microscopically) examined, minute scales will be found embedded therein. These, we infer, are remnants of once much larger structures, which served, at the heyday of their development, to completely invest the body.

The typical scaly clothing of a fish may perhaps best be studied in a roach or perch. In such a fish we should notice that the whole body, save the head and fins, was covered by a series of horny plates overlapping one another like the tiles on a roof. If we removed one of these plates we should find—if it was taken from a roach—that it partook somewhat of the shape of a human nail. Furthermore, we should probably have noticed before removing it that its anterior end was thrust deep down into a sort of pocket in the skin, whilst its posterior, or hinder end, was free, and could be easily raised by any pointed or blade-shaped instrument. Such an arrangement of horny plates or scales may be taken as typical of the majority of living fishes. Any variation of this arrangement may be regarded, roughly speaking, either in the direction of further specialisation or of degeneration.

Instances of degeneration are numerous. Probably we should be correct in regarding the first indication of degeneration to be the isolation of the scales. In such cases the scales, instead of overlapping, remain perfectly distinct from one another. The African lung-fish (*Protopterus*), and certain wrasses, are instances of this kind. In some carp—known as "mirror-carp"—this isolation of the scales is very marked. Those along the sides of the body have assumed relatively enormous proportions; those along the top of the back are smaller, but all are widely separated from their neighbours. In many eels, as we have just remarked, the scales have become so reduced in size that they must be sought for with a microscope, and then are found to be deeply embedded in the skin.

Of instances of specialisation we have a great variety. Thus, to take a few of the most striking. One of the cat-fishes of tropical South America, known as Callichthys, has the scales modified—probably by fusion of many to form one—so as to form a complete coat of armour. These fused scales take the form of broad bars, or perhaps they had better be called shields. They are arranged in a double series, an upper or back shield, which extends downwards to the middle of the body; and a lower shield, which clothes the lower part of the body or abdomen, the lower shield commencing at the point where the back shield terminates. There are a great number of these shields following one behind the other, from the head backwards. They are what is called metamerically arranged. That is to say, if the body were cut into a number of pieces corresponding to the number of the bones in the vertebral column, there would be one pair of shields—a dorsal and ventral—to every vertebra. This metameric arrangement is a point of deep significance.

In the coffer-fish (*Ostracion*) of the West Indies, the scales have been modified into a series of hexagonal plates, fitting closely together like mosaic work. As a result, the fish is enclosed in a kind of box, hence its name coffer-fish. From this box only the fins and tail project, or are capable of movement.

In a species of Diodon (*Chilomycterus reticulatus*), of tropical seas, the scales are small, very dense, and have broad tri-radiate bony roots, so that the scales are widely separated one from another, touching only at three points representing the tip of each root. In another species of this same genus (Diodon), called the porcupine fish, the scale grows to a greater length, forming a bony rod resembling the quill of a porcupine—hence its name.

In the sea-horse the scales are cruciform in shape, and interlaced so as to form an outer skeleton, which, when complete, may be compared to filagree work.

In another very remarkable form, the tortoise-fish (*Amphisile*), of the waters of the Indo-Pacific, the scales have become completely replaced by a bony cuirass, which is prolonged backwards into a spine beyond the tail. This remarkable cuirass has been shown by Dr Günther to be formed entirely by the bones of the skeleton, like the carapace of the tortoise.

But the scales of a fish, like every other part of its body, must have had a beginning, and if we cannot exactly say what was the nature of this beginning, we can, at least, with tolerable certainty, point to the fish which bear to-day the most primitive form of scales. Such fish we find in the sharks and rays. With the sharks, of course, we include also the dog-fish. Here, in fishes of this type, we find the scales of the higher forms represented by dense nodules, varying greatly in size, embedded in the skin. If one of these nodules be examined (fig. 4, *B.*), two distinct parts will be distinguishable—a bone-like base, embedded in the skin, during life, and a superficial more dense enamel-covered portion, which is generally spine-like. If one of these primitive scales be compared with a tooth from the same fish, we shall be struck with the very close resemblance between the two. On account of this resemblance, these scales are known as "denticles" or "odontoids"—little teeth (p. 34). We shall show in the next chapter, furthermore, that there is more than a resemblance in the likeness between the teeth and scales; that the two, in short, are really to all intents and purposes identical.

In some of the rays, or skates, as they are more commonly called, and in the spinous shark (*Echinorhinus*), these primitive scales are distributed unevenly over the body, sprinkled over, we might almost say, and vary much in size. But in the dog-fishes and sharks, where the scales are very small, they are arranged more definitely, generally running in oblique rows from the middle of the back downwards and backwards. It is this closely-packed mass of tiny "scales" which furnishes us with what is known as "shagreen."

In the Orkneys, Dr Günther tells us, the "larger" and "lesser spotted dog-fish" are captured in large numbers. Their skins are removed, spread on the rocks to dry, and used for smoothing down cabinet-work—in place of the more general sand-paper.

There is yet a third form of scale, which we may regard as intermediate between the horny somewhat disc-like plates which are noticed in the roach, and the spine-bearing nodular scale which we have just described in the sharks and rays. The third form is found in certain very ancient types of fishes once very numerous, but now represented by only a very few living forms. It can best be studied in the "gar-pike" of the fresh waters of North America, or in the

Polypterus or "bichir" of the Nile. In form, it may be described as rhomboid. As in the representative of the scale in the shark, so here the main part of the scale is made up of dense bony tissue. This is covered externally by a hard glistening substance known as "ganoine," a substance which bears some resemblance to, but differs from, the enamel coating which we found in the shark.

These ganoine-covered plates are closely packed, investing the body in a kind of mosaic, and forming a most perfect armour. In many of the old fossil fishes these scales were still more perfectly united one to another by an arrangement which constituted a peg and socket joint.

The gradual rise, perfection and decline of the heavy armour plating, so conspicuous a feature amongst the earlier fishes, is a matter of very considerable interest. Of the condition which fostered the development of such cumbrous clothing we know nothing. In some cases, as in fishes of the genus *Mesodon*, for instance, only the head and forepart of the body were thus protected, but in the majority, as in the surviving forms, *Polypterus* (fig. 15, *B.*) and *Lepidosteus* the whole body was completely invested. Amongst some recent fishes we find armour-plating has once more been adopted, as in *Amphisile* (tortoise-fish), the coffer-fish and its allies, and the sea-horses, but in all these cases the armour is of a quite different type.

The ancient scale-mail, if we may so call it, recalls forcibly the ancient chain-mail and kindred forms of armour adopted by our ancestors of the middle ages, and likewise long since out of fashion, or rather out of harmony with the times. The need for such has not passed, but the end it was intended to serve is now no longer attainable, and hence its disappearance like all other useless structures. What led to the disappearance in the fish we cannot say.

It is interesting to note here that at one time the character of the scale was an important feature in the classification of fishes. Thus, the horny, disc-like scale of the roach was known as a cycloid scale. When scales of this type possessed a number of fine tooth-like processes along the free edge, they were known as "ctenoid," or comb-like scales. When they took the form of thick square plates with an enamel-like surface, they were described as ganoid; and when they were of the form which we have seen in the sharks and rays, they were called "placoid." It was supposed that these various forms could be regarded, more or less truthfully, as representing at least three distinct types of fishes. Thus the cycloid and ctenoid scales were held to be typical of the higher fishes; the ganoid of an intermediate type; and the placoid of the lowest type of fishes. This is now known to be an erroneous view. *Ætheolepis* has been shown by Dr Smith Woodward to possess cycloid scales. Moreover these, by a gradual change of form, pass from the cycloid to the characteristic rhombic plate with peg and socket joints characteristic of the "ganoids."

This study of the scales of fishes provides us with an interesting lesson in evolution. Thus, in the sharks and rays, we meet with the earliest and simplest form of skin-covering, in the shape of small bony bodies provided with a projecting spine on the outer surfaces. The projecting spine is the first part to be developed, and arises from the outermost layer of the skin; the basal bony portion is developed later by the deeper layer of the skin in which it is embedded. This basal portion serves for the support of the spine. At first these separate "placoid" scales are distributed unevenly over the body. Later—in the higher forms—they arrange themselves definitely in oblique rows, closely packed. The culminating point in the arrangement of this solid scale type is met with in those fishes once known as the "ganoid fishes," of which we took the gar-pike of the American rivers as a type. Here the scales from mutual pressure have assumed either a lozenge or a rhomboid shape, and for further completeness of connection have developed peg and socket joints. In the higher fishes, such as the roach, perch, cod, herring, and so on, the development of enamel by the outer surface of the skin is dispensed with, the bony portion formed in the deepest layers of the skin is greatly reduced in thickness and otherwise modified, resulting in a thin flexible plate, deeply embedded in the skin by its anterior end, and projecting backwards and outwards to overlap its fellows on either side and behind, so as to form the characteristic tile-like arrangement with which we started.

As birds renew their feathers by "moulting," so many fish—*e.g.*: salmon—renew their scales by "shedding" them and replacing them by new ones.

The number and arrangement of the scales are important characters in the determination of fishes. In most fishes they are arranged in obliquely transverse series, and as the number of scales, writes Dr Günther, in the lateral line, see below, "generally corresponds to the number of transverse series, it is usual to count the scales in that line. To ascertain the number of longitudinal series of scales, the scales are counted in one of the transverse series, generally that running from the commencement of the dorsal fin, or the middle of the back, to the lateral line, and from the lateral line down to the vent or ventral fin, or middle of the abdomen."

No one who is observant can fail to have noticed a peculiar and often well-defined line extending from the head to the tail of a fish. Sometimes this runs more or less down the middle of the body, sometimes it is curved, sometimes disconnected, the upper portion of the line terminating abruptly, and the lower portion commencing again below it, to terminate as usual on the tail. This is known as the "lateral line." This line is formed by a series of perforations in the scales. When closely examined these are seen to be filled with mucus, and richly supplied with nerves. From this it is generally held that the lateral line is to be regarded as an organ for the reception of mechanical stimuli transmitted through the surrounding water. In the head this sensory organ is represented by a series of interconnecting tubes, which open along definite tracts, not always easily traced, on to the surface. In the sharks the lateral line is represented by a groove protected by overlapping shagreen denticles. In the higher fishes the organ communicates with the exterior through apertures in the scales, apertures often tunnel-shaped in form, and on this account rendering the line more conspicuous.

CHAPTER IV.

TEETH AND SPINES.

In the preceding chapter it was remarked that there existed an intimate relationship between the bony spine-bearing tubercles or "placoid-scales" of the sharks and the teeth of these fish. Let us now look at this statement a little more closely.

This relationship is certainly not difficult to follow, though it is as certainly one that would not at first have seemed probable. In certain of the shark tribe, the dog-fish, for instance, we noticed that the skin was covered by innumerable closely set nodules of bone embedded in the skin, and bearing each a small enamel spine. If a young dog-fish be examined just before hatching, it will be seen that the skin with its closely set spiny scales is continued actually into the mouth and covers the jaws. As growth proceeds, and the lips develop, the original continuity of the skin surface is interrupted; at the same time the scales gradually assume the form of teeth, eventually increasing greatly both in size and solidity, whilst the scales on the outside of the body remain unchanged.

This insight into the evolution of the teeth is one of first-rate importance. It is very rarely that we get so complete a chain illustrating the development of one organ from another. As a rule, we can only guess at origins. Thus, as we shall see, in seeking for the origins of the fins and limbs of vertebrated animals, we have not yet got beyond the boundaries of hypothesis. We cannot believe that they came into being at once; on the contrary, we feel sure they have become what they are by a transformation of some pre-existing structures. Teeth, then, are highly specialised modifications of the scaly armour covering the surface of the body, and are to be found in their simplest condition in the shark tribe.

The changes of form which the teeth of fishes undergo are very remarkable. Even amongst the sharks and rays there is a wealth of variation that is quite wonderful. Often we meet with several forms of teeth in the jaws of a single fish, and the combinations of these different forms are not seldom of real beauty.

To correctly interpret the meaning of these forms is a difficult matter, for though some seem obviously enough directly related to the nature of the food, in one instance, at least, it would seem that it is sex, and not food, which has been responsible. Thus in the thorn-back skate

(*Raja clavata*) the males have the jaws covered with sharply-pointed teeth, whilst in the females they are tiny, rounded and flattened plates.

In the Port Jackson shark (*Cestracion*) of Australia, and in the *Rhynchobatis* of the Indian Ocean, we have instances of the combinations of teeth resulting in patterns of undoubted beauty, though we must remark that this beauty is entirely an accidental feature (fig. 4).

In the first-mentioned of these two fishes—the Port Jackson shark—the teeth, when seen in position on the jaws, present a wonderful gradation, beginning with a series of small spines at the anterior end of the jaw, and passing backwards into large, rounded, oval seed-like bodies, forming a sort of raised mosaic work. A reference to the figure, p. 40, *F.*, should make this clear. In one of the rays, known under the scientific name of *Rhynchobatus*, the tooth-covered jaws are of a most remarkable shape. Here the upper jaw is alternately hollowed and swollen, the lower presents a corresponding swelling and depressions to fit into upper jaw. The teeth are uniform in size. In the sting-ray (*Trygon*) the teeth take the form of a number of Λ-shaped bars fitting closely together, and in the eagle-ray (*Myliobatis*), of a number of long hexagonal bars bounded on either side by rows of small teeth of hexagonal form. In the comb-toothed shark (*Notidanus*) the teeth have many cusps or tiny comb-toothed-like processes along the cutting edge, hence its name. In the shark's teeth, by the way, we meet with a great range

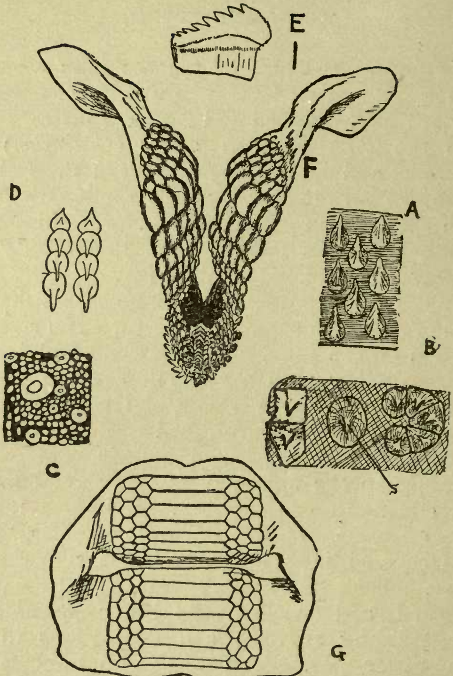


Fig. 4.—The Evolution of Teeth and Scales. *A.* Portion of skin of a shark showing symmetrically disposed shagreen denticles. *B.C.* Shagreen denticles of varying form and size; showing how clusters of scales are formed: these may later conjoin to form either (*a*) large bony plates investing the skull—skull bones; or (*b*) more or less complete teeth. *D.* Two rows of shagreen denticles (teeth) from the jaws of a shark (compare with *A.*). *E.* is a tooth of a shark (*Notidanus*), and shows the result of fusion of a row of separate denticles such as in *D.* to form a single comb-like tooth. *F.* The jaws of the Port Jackson shark (*Cestracion*), to show the remarkably modified teeth for crushing purposes. *G.* The jaws of an eagle-ray (*Myliobatis*), also showing teeth modified for crushing purposes. In fig. *B.* note the spine *s.* resting in the bony base of the isolated "odontoid."

in size and form. In the Greenland shark, for example, they are comparatively small. In the larger sharks they are either spike-shaped or triangular in form, and in some fossil sharks the triangular type of tooth reached huge proportions. They form terrible weapons in many living sharks; an instance is on record where a man has been bitten in two at a single bite!

The origin of the curious comb-like teeth, and of those teeth of sharks which have a large middle cusp or point with a smaller one on either side, is peculiar; being due to the fusion of three or more of the primitive single teeth into one. How this came about we can see by a study of the coarse "shagreen" of say the spiny shark (*Echinorhinus*). Here it will be found that little groups of these tubercles, which are scattered irregularly over the surface, become welded or fused together at their bases—here a group of five, forming a long patch armed with as many tooth-like spines, there a group of two or three, and here and there a single tubercle (fig. 4). On the jaw similar fusions have taken place though they are always of denticles lying side by side. As a result we get the "comb" teeth of *Notidanus*, or the Λ-shaped teeth of other sharks. The large plate-like crushing teeth of many fossil and recent sharks, as well as of fishes belonging to higher groups, have been formed in this way.

Amongst the bony fishes, of which we may take the perch, pike or cod-fish as examples, the variations in the form of the teeth are quite as numerous as in the shark tribe. In some instances we find quite complex structures. In the porcupine globe-fish (*Diodon*), for example, the teeth are formed by the fusion of a series of plates piled one above the other; the lowermost of this series, deep down in the jaw, are quite separate, the uppermost touch one another, and finally fuse into a solid mass. This form of tooth is derived by modification of the order of succession of which we shall speak presently on p. 43.

So far all the teeth which we have passed in review have been attached to the jaw. But, amongst the fishes, teeth are by no means confined to this region. Thus, in the lung-fish (*Ceratodus*), large teeth are found in the roof of the mouth. In the higher bony fishes, such as the pike, the palate is crowded with teeth; and not only the palate, but even the gill-bars are thickly set with teeth. The gill-teeth of the sun-fish, for instance, are of extraordinary size.

Some fish, such as the roach and carp, have no teeth in the jaws, but very large ones in the throat.

The nature of the attachment of the teeth is quite worth a hurried notice. We need, however, only institute a few comparisons. We have already remarked that in the lowest fishes, such as the sharks and dog-fishes, the teeth rest upon, but are not firmly attached to, the jaws. In the higher fishes the teeth have acquired an intimate connection with the jaws, often as complete as in ourselves. In some, as in the angler-fish (*Lophius*) and the pike, the teeth are held in place by an elastic ligament, which permits of their being bent backwards into the mouth in swallowing food, but prevents any escape thereof from the mouth most effectually. More frequently the teeth are immovably fixed to the jaw, as in the eel, haddock and mackerel. Only rarely are the teeth implanted in sockets, as in the file-fish (*Balistes*).

Everybody must be familiar with the deadly-looking weapon like a double-edged saw displayed in the windows of the natural history and curiosity dealers. These have been taken from a kind of shark known as the saw-fish, an inhabitant of tropical or sub-tropical seas.

The teeth forming this saw are set in sockets, but are not replaced by a regular succession of new teeth; instead they grow continuously, probably as long as the fish lives. This saw is formed by an outgrowth from the head, and is a very powerful and terrible weapon. By its aid other fish are attacked and ripped open, and pieces of jagged flesh, or protruding viscera, are then nipped off and seized by the comparatively feeble teeth borne by the mouth.

The growth and succession of the teeth has already been hinted at; we must now briefly survey the main fact concerning these processes.

Of all the teeth-bearing animals except the mammalia, we may say with tolerable certainty that the teeth which we see at any given time have not been long in use, and will soon be replaced by others. That is to say, provision is made for a constant supply of new teeth to replace those in use, and this succession goes on throughout life. A most enviable arrangement!

In the sharks, the young teeth will be found adhering to the inner surface of the jaw, within a cavity closed by membrane. Herein they lie, closely packed, row upon row, with their points downwards in the lower, upwards in the upper-jaw. From this position they slowly erect themselves, as they approach the edge of the jaw, until the last row of teeth are actually vertical. The picture of a section through a jaw exposing one of each of these several rows may help to make this clear. In sharks only one row, in the rays and skate several rows are in use at one time.

In the Greenland shark (*Lœmargus*) the teeth interlock one with another, and on this account one complete row is shed at a time. But in other sharks where this interlocking arrangement does not obtain, every alternate tooth is shed and replaced at once. So that two rows continue to form one single functional row.

With the higher fishes the succession of the teeth presents yet other modifications.

In socketed teeth the succession is vertical, somewhat as in ourselves, the new tooth being formed immediately below the functional tooth, and taking its place when this falls out. In the majority of bony fishes, where the teeth are numerous and closely packed together, the succession is irregular. When the teeth are less closely packed the succession is alternate—there is a young tooth placed between any two adult teeth, and ready to replace them as soon as they fall out.

To pursue this subject further would be to overstep the aim of this little work. Those who may have found the facts herein set down interesting will find that interest increased twofold by an examination of the actual specimens—such as are displayed in the series of beautiful preparations in the Natural History Museum of London. To compare side by side the tooth and the scale, and to trace the infinite gradations leading from a tiny scale-like tooth to the great triangular cutting tooth, as can be done in many sharks, is a lesson in transformations that will not be soon forgotten. So great is the difference between the two extremes that, if they were examined apart from the intermediate forms, they would be set down as teeth of totally distinct species. This is a mistake which has actually occurred in the identification of the teeth of fossil fishes—and we can well understand it!

Spines, like teeth, are for the most part modified scales. It is believed that the spines which occur immediately in front of the dorsal fins, as in the dog-fish for instance, owe their existence to the fusion of the shagreen, or scales, covering the front of these balancing organs. They begin by forming a dense "cut-water" for the support of the fins, and ultimately acquired an independent position in the body. Fin-spines play an important part in the study of fossil fishes. Indeed, the spines are often the only record we have left. Some of these fossil fin-spines attained huge proportions. Thus the fin-spine of an extinct shark, *Oracanthus pustulosus*, from the carboniferous limestone of Bristol, was *three feet* in length!

CHAPTER V.

HEADS AND TAILS.

THE heads and tails of fishes, if looked at from the right point of view, will force upon us still further the truth of the story of evolution. Moreover, the history of the making of these very essential parts will serve us for object lessons of patience, as exhibited by Dame Nature; very profitable for contemplation. The old adage, "Rome was not built in a day," is equally true of the fish.

To get at the real inwardness, so to speak, of the fish's head, we must start with an examination of this, as we find it in its most primitive form. The dog-fish will serve us beautifully for this purpose.

If we remove the skin and muscles from the head of a dog-fish we shall find, in the first place, *not* bones, as some might have expected, but a much softer material known as cartilage or gristle. The skeleton of the dog-fish's head is, therefore, not bony but cartilaginous. Furthermore, it is made up of several separate elements: those which go to make the skull or cranium, and those which constitute the upper and lower jaws respectively, and form the arches or supports of the gills and tongue.

The true skull or cranium forms the receptacle for the brain, and the organs of hearing, sight and smell. It is box-like in form, and hollow. Within its central cavity lies the brain. On the outside of this box we shall notice two pairs of projections, one pair at its hinder, and one at its anterior end. The former are the capsules which lodge the organ of hearing; the latter, which have a form something like an inverted saucer, lodge the organ of smell. Between these capsules for the organs of hearing and smell lies a cavern-like hollow for the lodgment of the eye, and is called the orbit. At the extreme hinder end of the skull is a small hole from which the spinal cord emerges from the brain. So much for the cranium.

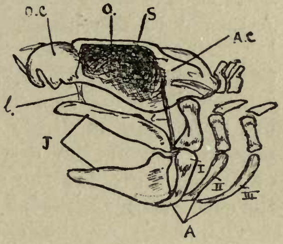


FIG. 5.—Skull of Dog-fish, showing the separate cranium containing the brain and organs of sight, smell and hearing, and the distinct jaws and gill arches. *S.* skull; *Ac.* auditory capsule (hearing); *Oc.* olfactory capsule (smell); *O.* orbit; *J.* jaws; *A.* gill arches. The 1st pair are for the support of the jaws, attaching them to the skull, the 2nd pair, represent the 1st pair of true gill arches, the solid supports in the wall of the alimentary canal, p. 20.

We turn now to the series of arches which, as we have already seen, form the supports to the anterior region of the mouth and the gullet. These are arranged in pairs. The first pair form what we know as the jaws. They differ from those of ourselves in several particulars, but the differences are rather those of degree than of kind. In the dog-fish we should find the upper jaw quite distinct from the skull, and connected therewith only by ligaments. Attached to the hinder end of this jaw is the lower jaw. In the very young dog-fish these two formed one piece, and only later became jointed to form separate jaws. In ourselves the upper jaw is firmly fixed to the skull, not separate as in the dog-fish. The next pair of arches serve for the support of the tongue; the succeeding arches for the support of the gills.

This form of skull—a cranial box for the lodgment of the brain and organs of hearing, sight and smell, and a series of arches embedded in the upper region of the mouth and gullet—represents the simplest of all types, and is the starting-point in the study of the skulls of all other vertebrated animals. Let us now rapidly sketch the outlines by which the complex combination of bones, with which we are more or less familiar, came into being.

An examination of the head of a sturgeon, which has been carefully dissected, would show that it differed in no important respects from that of the dog-fish. But, if we turned to a freshly killed sturgeon, we should meet with a very great surprise. In the first place it would be found that the head was not covered by a "shagreen-like" skin as in the dog-fish, but by an exceedingly dense bony armour. Secondly, this armour, when closely examined, would be seen to be made up of a number of separate and symmetrical plates. These removed, as we have already remarked, would reveal a skull differing only in some smaller particulars from that of the dog-fish. In the cavity of the mouth we should see, furthermore, thin plates of bone investing the arches of the gills, and ensheathing the floor of the cartilaginous brain-case. How did this external armour plating come to be? We cannot say for certain. Possibly, even probably, by the fusion or welding together of numerous "placoid scales" or shagreen denticles. The advent of these bones marks a very important epoch in the history of the development of the skull. It is well, therefore, to make careful note of their presence at this stage, and of the relations which they bear; for from this time onward the part which they play in the protection of that all-important organ the brain, and the perfection of what we may call the machinery of mastication, becomes greater and greater, ending only with ourselves.

Our next stage in the development of the skull, then, we find in the lung-fishes, where bony centres have established themselves in the ear-capsules—till now cartilaginous, and there is a slight advance in the bone-sheath of the mouth parts. The skull of that remnant of an ancient house, the bichir or polypterus, adds more links to the chain. The quantity of bony matter has now greatly increased, but the cranium is still cartilaginous. As we work higher and higher, however, this cartilage becomes less and less conspicuous till, if we traced the development of the skull into the higher vertebrated animals, such as the reptiles or birds, or mammals, we should find a skull made up entirely of the bones whose arrival we have just been watching. They have slowly and quietly displaced the cartilage, converting the soft cartilaginous cranium into a strong bony box, and welding with this, in greater and greater perfection, the jaw apparatus; till at last the upper jaw becomes firmly and immovably fixed to the front end of the cranium, and only the lower jaw, now ensheathed in bone, remains movable. Perhaps one of the most interesting features in this transformation of the skull is that which has resulted in the intimate relationship of the plates which originally were only superficial—being modifications of the skin—with the bony portions of the skull which first appeared within the cartilage forming the capsule of the ear, and the hinder wall of the brain-case. These two kinds of bone, of quite different modes of origin, in all the higher vertebrates form a complex whole, giving no trace of their original very different derivation.

Those whose work it is to study the history of the development of animals within the egg tell us that much of the history of this development of the skull which we have traced "in time," as we may call it, is repeated in the development of the individual. Thus the bones which we found made their first appearance *in* cartilage, do so still, and slowly replace it. Those, however, which made their appearance as plates, developed as modifications of the skin, are not preceded by cartilage, but by thin membrane. They have not only thrust themselves completely into the warp and woof of the skull, but they have in some way strangled, as it were, the development of the cartilage altogether. In the lower jaw we have an admirable object-lesson, showing how the cartilage is replaced by bone.

In the sharks, the lower jaw is cartilaginous, and supports numerous specially modified scales called teeth. In the higher fishes this cartilage is invested, or surrounded, by bone, and the teeth have not only undergone considerable change in form, but have entered into complex relations with the bone-sheathed jaw, as we have shown in chapter iv., p. 37.

Now let us turn our attention to the tails of fishes. The tails of adult fishes may assume one of three forms, known respectively as the diphycercal, heterocercal and homocercal forms. How much of meaning there is behind this apparently dry-as-dust information we will now proceed to set forth.

To begin with, we will take the diphycercal tail (fig. 6), this being undoubtedly the most primitive form. A reference to the somewhat diagrammatic figure will show that the diphycercal represents that form of tail wherein that portion of the vertebral column, which forms its support, is continued straight backwards to its farthest extent. Around it are arranged a series of firm rods, which support, in turn, a membrane, thus forming the fin.

The heterocercal tail can be well studied in a dog-fish (fig. 5) or sturgeon. Herein the vertebral column, instead of being continued straight backwards, turns sharply upwards, and the single fin becomes differentiated into two lobes, an upper and larger—the dorsal lobe; and lower

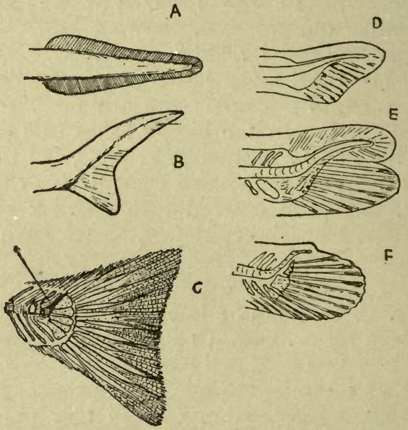


FIG. 6.—The Evolution of the Fish's Tail. *A. B. C.* Shows how tail has passed from primitive elongated symmetrical form, through the unsymmetrical (*B*), to the modern falsely symmetrical form (*C*). The false symmetry being due to the excessive development of the lower lobe marked *l. l.* in *B.* The upturned portion of the tail in *B* has gradually disappeared, and is represented only by the black portion marked *N.* in *C.* *D. E. F.* Stages through which the tail of a modern fish successively passes during its development, being practically a repetition of the stages *A. B. C.*

and much smaller—the ventral lobe. The ventral lobe, it will be noticed, takes its origin, entirely from the lower side of the upturned vertebral column.

The homocercal tail is found in the higher fishes, such as the flounder, the salmon (fig. 6, *C.*), and the perch, for instance. In this we meet again, apparently, with the same perfect symmetry that characterised the diphycercal tail of *Protopterus* and some primitive sharks. This apparent symmetry has been arrived at by some exceedingly interesting stages, fraught with a deep significance when we come to look below the surface. The lessons which these stages have to teach we will now proceed to discuss.

In our investigation we must begin with the larval fish—that is to say, with a very young fish, just before, or soon after, it has left the egg. The tail of such a fish—that of a young flounder, for instance—is, we shall find, truly diphycercal. This we will call stage No. 1. In stage No. 2 the axis of the tail—*i.e.* the end of the vertebral column, begins, though ever so slightly, to turn upwards, and from its lower surface numerous rod-shaped processes are beginning to make their appearance (fig. 6, *D.*). Our stage No. 3 exhibits the tail in a bi-lobed form (fig. 6, *E.*). The upper lobe is developed around the extreme end of the axis of the tail, the lower from its ventral surface. Passing to stage 4, we notice the upper lobe has undergone a great decline, whilst the lower has relatively increased in size. In stage 5 the disproportion between the two is enormous, the upper lobe having almost entirely disappeared. In stage 6, our last, the dorsal lobe is barely traceable, whilst the ventral lobe has come to assume a superficially perfect symmetry (fig. 6, *F.*). Thus, in the life-history of a single fish, all three forms of tail are represented, beginning with the diphycercal —stage 1—passing through the heterocercal—stages, 2, 3, 4—and ending in the homocercal—stage 6. But our story must not end here. We naturally ask: Is there any explanation for this series of phases? Is any lesson to be derived from these facts? Well, in the first place, it cannot be denied that we have, in studying these phases, an admirable illustration of the evolution of a tail. Here, in the flounder, we have watched its gradual transformation from a perfectly symmetrical organ, through an asymmetrical, and back to an apparently symmetrical form again. We say apparently advisedly, for this last stage is but a superficial symmetry, brought about by the excessive development of one part at the expense of the other. But what gain can the result of this series of evolutional phases be to the fish? Or, rather, if these changes be for an ultimate end, why cannot this be attained at once, without the transformations?

The gain to the fish is possibly a double one. In the first place, in passing from the diphycercal to the heterocercal tail, the vertebral column is shortened, and hence there is effected at once a saving of material, and a greater rigidity and power added to the tail. So much for the gain. But why, it may be asked, cannot this gain be effected at once? Why this need for circumlocution? The answers to these questions are not easily set down in a few words; but, nevertheless, answers—most satisfactory answers—are forthcoming. Moreover, they not only set at rest these questions, but at the same time they throw a flood of light upon questions of evolution which confront us at every turn. They will bear us back to the misty past and compel us to compare afresh the revelations of the rocks with the revelations of the microscope.

The fish of to-day, then, is "the heir of all the ages," and the last of a long line, every member of which was bound, albeit unconsciously, to contribute something towards the greater perfection of his race. But there is no royal road to perfection, and none may do more than bear a share in its attainment. Furthermore, that each may be perfect after his own kind, it is necessary that each should proceed towards the desired goal along definite lines. Thus it comes to be that every animal, in the course of its development, is obliged, as it has been said, to climb its own ancestral tree. Thus it comes to pass that what was the adult condition at one period, is represented only as a passing phase in later periods, and out of this phase a new form is evolved. This rule is not, however, absolute, for occasionally omissions are made, and newer developments come into being without recording the track along which they have come, or without revealing the frame on which they were modelled, so to speak. Generally speaking, however, the forms of animals are reached by a route along definite lines—by addition to previously existing structures.

And so then with the fish's tail. If we turn to the earliest known fossil fishes, we shall find the tail diphycercal in type. The heterocercal type, however, soon made its appearance, as a slight upward bend of the vertebral column, with a large ventral and a smaller dorsal lobe. Such a tail is seen in the ancient sturgeon-like forms, and the sharks, and persists to this day in their living representatives. The homocercal type was, however, well on the way towards perfection so far back as that period of the world's history known as the Lower Lias. Many of the fishes of the ancient seas of that time, such as the *Dapedius*, have acquired an almost perfect homocercal tail. But we may confidently believe that the homocercal tail of the ancient *Dapedius* acquired its special characteristics in precisely the same way as the flounder—by a gradual passage from the primitive diphycercal to the ultimate homocercal type, through heterocercy.

But one or two of the ancient fishes who swam about in the ancient seas, whose dried and hardened floors now form the rocks of what we call the Triassic and Liassic formations, were blessed with two tails apiece, or, to be quite correct, with two tail-fins. The most interesting of these was that of the *Diplurus*. In this fish the true tail slowly dwindles in size, terminating in little more than a filament, bearing a tiny tail-fin. But in front of this we find what was probably the functional tail-fin, and this fin appears to have derived its origin in a rather curious way. It will be remembered that the fins which project from the middle of the back are known as the *dorsal* fins, and may vary in number; whilst the fins which project from the middle of the abdomen are known as the *anal* fins. Now, in *Diplurus*, the hindmost dorsal and anal fins increased greatly in size, and apparently at the expense of the caudal fin, which they gradually superseded. *Undina*, whose remains occur in the rocks of the Lower Lias, had similar false and true tails, the false tail being functional.

CHAPTER VI.

FINS: THEIR USES, AND WHAT THEY TEACH US.

It seems almost like presumption to think of drawing attention to, or in any way describing, the fins of fishes. They are such obvious, and we think, at first, such inseparable appendages, that no fish is complete without them. What fisherman is there who could not discourse upon fins? If he be a fisherman of any experience, he will have much to say concerning their offensive possibilities, in some fish at any rate; or he will tell how useful, or sometimes undesirable, they are in live bait fishing, how some are soft, some hard, how there may be few or many, and so on.

But all are not fishermen of experience, and there are doubtless many who have never realised what an immense amount of interest is to be found in tracing out the modifications which the fins undergo in different fishes, or what may have been their origin.

To these inexperienced our remarks are now addressed, and for their benefit we will begin at the beginning. The fins of fishes, then, are divisible into two kinds: (1) The median fins—the fins which take their origin in the middle line of the back and abdomen, and the tail or caudal fin; and (2) paired fins: these are four in number, and correspond to our arms and legs—these fins we know as the pectoral and pelvic fins. We will accordingly discuss the median fins first, and begin with those of the back, the *dorsal* fins, as they are usually called.

In our typical fish, the perch or salmon, the dorsal fins are two in number, called the first and second dorsals respectively. If we raise, say the first dorsal of a perch, we shall have an admirable illustration of the constitution of a typical fin—a thin sheet of membrane, supported by numerous stiffened rods. On raising the second dorsal we shall at once be struck with the fact that the rods supporting these fins differ conspicuously. In the first dorsal the rods were exceedingly hard and sharp-pointed, in the second they are comparatively soft, and if we examine them further, we shall find that towards the tip each rod breaks up into a number of little branches, closely pressed one against another. In some fishes, as in the cod-fish, for instance, both fins have these "soft rays," as they are called. Sometimes, as in the salmon, the second dorsal fin is very small and composed entirely of fatty tissue, without any supporting structures. This is known as an "adipose" or fatty fin. In the mackerel, and the tunny, and other allied forms, the second dorsal is followed by a large number of smaller fins. In the bichir (*Polypterus*) of the Nile, the dorsal fins were represented by a large number of separate fins, each consisting of a spine supporting a saillike flap of membrane (fig. 15, *B.*, p. 178). In many fishes only one dorsal fin is present, as in the bream of our fresh waters. This single fin sometimes attains huge proportions. In an extinct fish of the Eocene age of the world's history, named *Semiophorus*, the single dorsal fin was longer than the whole body! It is of enormous size in one of the sword-fishes, *Histiophorus* (fig. 13, p. 135). The dorsal, like the ventral fins, as we shall see presently, are sometimes modified to form a sucker, as in the sucking-fish, *Echeineis*. In this, the spiny rays of the dorsal fin are composed of two halves, bent the one towards the right, and the other towards the left, and forming a support to a double series of transverse lamellæ; the whole sucker is of an oval shape and surrounded by a membranous fringe. By means of this disc, writes Dr Günther, the sucking-fishes "are enabled to attach themselves to any flat surface, a series of vacuums being created by the erection of the usually recumbent lamellæ. The adhesion is so strong that the fish can only be dislodged with difficulty, unless it is pushed forward by a sliding motion. The 'suckers' attach themselves to sharks, turtles, ships, or any other object which serves their purpose. . . . Being bad swimmers they allow themselves to be carried about by other animals or vessels, endowed with a greater power of locomotion." In the "fishing-frog" (*Lophius*) the spines or rays of the dorsal fin are separate, one from another, and bear flag-like membranous appendages resembling short fronds of sea-weed. By their means the fish comes to harmonise so completely with its surroundings that other fishes, upon which it preys, approach near enough to be seized before they are aware of its presence. Sometimes the fishing-frog will bury itself in the mud, leaving only the "flags" exposed. By skilfully waving these, fish are attracted and suddenly engulfed.

The dorsal fin in the sea-horse (*Hippocampus*) is quite peculiar, being used as a propeller, its vigorous movement serving to drive the fish through the water in its characteristic upright (vertical) position. The tail or caudal fin is absent. The tail itself is used as an organ of prehension.

If we were to examine the skeleton of one of the median fins, we should find that every one of the supporting columns or fin-rays was attached at its base to a second pointed rod or spike, which, in turn, projecting downwards among the muscles of the body, became attached to yet another spine which grew upwards from the vertebral column.

The caudal or tail-fin we have already studied in discussing the tail proper. We need only say here that, like the dorsal fins, it is made up of stiff fin-rays supporting a thin membrane. But there is one point which has not yet been noticed, and that is, its position. In the fish then it is vertical. There is nothing wonderful in this someone will remark. But wait; compare it with the caudal fin of the porpoise or the whale. It will then be seen that its vertical position after all has probably a lesson to teach. In the whale or the porpoise the tail-fin is *not* vertical but horizontal in position. Why is this?

Because the fish swims, generally, parallel with the surface of the water. There is no need to come to the surface for air periodically, since the breathing is performed by gills. But the whale and his kind swim by alternately rising and diving in a sort of undulating course. This is necessary, because the whale breathes by lungs, and must accordingly rise frequently to the surface. The vertical tail drives the fish forwards; the horizontal drives the whale upwards or downwards as the case may be.

The last of the median fins to be considered is that which lies between the caudal and paired pelvic fins. Like the dorsal, this may be divisible into two or more portions. Sometimes the rays of the first anal are spiny, whilst those of the second anal are "soft," and branched like those of the second dorsal. Spiny rays, then, associated with "soft" rays, are always confined either to the first anal, or the first few supports of the first anal. But they are never preceded by "soft" rays; in other words, soft rays always *follow* spiny rays. Sometimes the anal fin is wanting altogether.

So much for the median, we turn now to the paired fins. These, as we have already remarked, correspond to the arms and legs of the higher animals. In our typical fish—the salmon or perch—the pair which correspond to the arms, the pectoral fins, as they are called, and will be called here henceforth, are situated one on either side of the body, just behind the gill opening. The pair which correspond to the legs, the pelvic fins—or ventral fins as they are sometimes called

—lie below and behind the pectorals; and project downwards from the ventral or under side of the body. But the position of the pelvic or ventral fins varies much. Thus, they may be seated much further back than in the perch: as in the salmon, for instance, where they lie in the middle of the abdomen, behind the level of a line drawn across the body from the base of the dorsal fins. They are then said to be abdominal in position. In the perch they are thoracic in position; that is to say, they lie far forward in the region of the chest. But in the burbot (*Lota vulgaris*) they actually lie *in front* of the pectoral fins, and are then said to be jugular in position (throat-fins) fig. 1, *b*. But why this stress upon the jugular fins? A moment's reflection will show. If the pelvic fins really correspond to the hind-limbs in higher animals, then the hind-limbs in such a fish as the present *lie in front of the arms*!

If the question were asked—What is the function or use of the fins? probably the majority would reply to swim with, as organs of locomotion or rather propulsion. Well, this reply would be partly, but only partly, true. The fins are organs of locomotion; but it is chiefly the tail and caudal fin that serves this purpose: these drive the fish forward by rapid and vigorous strokes of the tail, which is lashed from side to side alternately. When the fish is moving slowly these movements can readily be seen. A twist of the caudal fin alone is sufficient for gentle forward movement, the fin working like the blade of a screw. The pectoral fins serve, occasionally, like the propellers of a ship when put full speed astern, to check further forward movement, or to move actually backwards. The chief use of the pectoral fins is to serve as steering agents. When the fish wants to turn to the right, for instance, he gives a sudden turn of the tail to the left, the left pectoral fin acting at the same time, whilst the right remains closely pressed against the body. But the chief function of the paired fins is that of balancers. Thus, when the pectoral, or pectoral and pelvic of one side are removed, the fish at once loses its balance and falls over to the opposite side; if both pectoral fins are lost, it seems the fish's head sinks; if the dorsal and anal fins are lost, the course of the fish at once becomes very erratic. The loss of all the fins causes the fish to float belly upwards, like a dead fish.

The forms which the fins take are very varied. Let us begin our study of the variation of the fins with the pectorals. These, by an enormous increase in size, may serve as parachutes, enabling the fish to take long parachute-like flights through the air as in the "flying herrings" and "flying-gurnards." Or some of the rays may be modified to form finger-like organs for creeping along the sea-floor as in the gurnards; or some, or all of the rays, may be enormously elongated to form delicate organs of touch. Thus in *Pentamerus* from the West Coast of Africa, and West Indies, some five of the pectoral rays may be produced into long hair-like filaments much longer than the body. The South American cat-fish (*Doras*) goes to the other extreme, and has the pectoral modified into a sharp spine. In one of the fishing-frogs (*Malthe*) the pectoral and pelvic fins are modified for walking on the sea-floor.

The pelvic fins, like the pectoral, sometimes have the rays drawn out into filaments to serve as organs of touch, as in the "gourami" (*Osphromenus olfax*), and the dwarf cod-fish *Bregmaceros* of the Indian Ocean. Sometimes, as in the *Monocentris* of Japanese waters, the ventral fin is represented by little more than a stout bony spine. In the lump-suckers of our seas, the ventral fins are modified to form a sucking-disc. This sucking-disc is very powerful, it being exceedingly difficult to remove a fish from any object to which it may have attached itself. In the "gobies" the ventral fins also serve as a sucker, but they have not so completely lost their fin-like appearance as have the lump-suckers. In the little sucker-fishes of our coast (*Lepadogaster*) the ventral fins form the rim only of the sucker, the rest being formed by a modification of the bones of the shoulder-girdle. If these fishes be caught with the hand they at once attach themselves thereto by this sucker.

We have now surveyed the principal facts concerning the fins of fishes, and the modifications which they undergo to fit them to perform new functions for which they were not originally intended. The fact that these fins are capable of modification is a very significant one, and very naturally leads to the suggestion that this adaptability may be traced in another direction, and show us that the fins, normal fins, such as we see in our type, the perch, or the salmon, may themselves be but modifications of some earlier structures. In other words, the facts disclosed in this study of transformations lead us to hope that we may get some insight into the origins of fins.

Scientific experts are generally agreed that the earliest fishes possessed no true fins. Locomotion was performed by means of vigorous side to side strokes of the tail, aided by undulatory movements of the whole and probably much elongated and cylindrical body. In other words progression was eel-like. This mode of progression was soon followed by the appearance of the first fin. An attempt to account for the origin of this was the subject of an ingenious experiment adopted by Mr J. T. Cunningham. He took an ordinary penholder and coated it evenly and thinly with wax. Then holding it by one end, he moved it rapidly from side to side in a basin of hot water. The pen being held in a horizontal position, soon a vertical ridge made its appearance above and below, and this gradually increased in size till, in about five minutes, there was an upper and under ridge half-an-inch in height, corresponding, as he points out, to the median fins—the dorsal and anal and caudal or tail-fins described on p. 12. The presence of these median fins was a distinct gain to the fish. A still further advance took place, when the lower or undermost vertical fin, near the middle of the abdomen, divided into two and ran forwards on either side of the abdomen as a pair of thin membranous folds terminating at the head (fig. 7, *A.*). The fish was now really well-balanced, but improvement was yet possible. Numerous rods or bars of cartilage now appeared

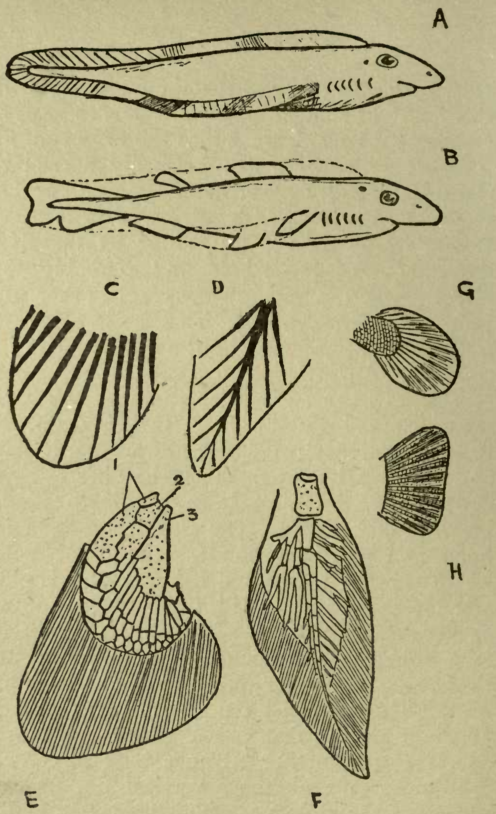


FIG. 7.—The Evolution of Fins. *A. B.* represent ideal shark-like primitive fishes. In *A.* there are no separate fins, only continuous folds of membranes. In *B.* separate fins have been derived by the disappearance of certain portions of the once continuous membrane. *C. D.* show how the paired fins gradually increased in complexity, separate bars of cartilage in the earliest type of fin (*C.*) have gradually grafted themselves on to one simple bar which form an axis as in *D.* *E. F.* show the difference between the fin which has three distinct articular elements at its base (*E.*), and that which has but one (*F.*). *C. H.* show the difference between the fringed fin (*G.*) and the fan fin (*H.*).

serving to stiffen these balancing membranes, and obviously make them more effective. At about this time, however, there was a tendency to diminish the extent of the lateral or side membranes, and this tendency became more and more pronounced till certain portions entirely disappeared leaving four separate or detached folds or lobes. In these four separate lobes we have the origin of the paired fins, the two immediately behind the head becoming the pectoral and the two near the tail the pelvic fins (fig. 7, *B.*).

We have seen already that the fins of modern fishes act primarily as balancing organs; in addition they serve also as accessory steering organs. For this purpose they have become freely movable in various directions. In this mobility we have one great distinction between the fixed, newly isolated balancing organs, the evolution of which we have just traced, and the freely movable fin of the modern fish. How did this mobility come about? To this question we have at present no definite answer. We may, however, endeavour to trace the improvements which accompanied this mobility. One of these improvements was the blending together of certain of the supporting rods of cartilage to form a central and definite axis, and the arrangement of certain of the remaining rods on either side of this in the form of rays, as shown in the accompanying fig. 7, *C. D.* The size of the fin became next enlarged by the addition of hair-like fibres outside the rays, as in fig. 7, *F.* This form of fin can be studied to-day in the lung-fish *Ceratodus.*

But other modifications of the fin took place at about this time, and the rays of the primitive supporting rods grew stronger on one side of the axis than the other, whilst the axis itself became slowly transformed, ultimately resulting in a series of flattened plates supporting jointed cartilaginous rods, fringed by the hair-like rays already described. Fins of this kind are present in our modern sharks and dog-fishes (fig. 7, *E.*). This form of fin in turn became modified into that which we find in the typical bony fishes such as the perch, pike or cod-fish; and in the ancient but still surviving "Bichir" or *Polypterus* of the Nile.

In examining the fins of the perch, either the median or paired fins, we should miss the hair-like rays which fringe the border of the fin, and we should find in the dorsal fin, for instance, as we have already noticed (p. 60), that the fin supports were solid and bony and rested upon smaller spike-like bony supports which in turn were connected with, and corresponded in number with, the spines of separate vertebræ of the vertebral column. It is generally believed that these external bony fin-supports have been formed by the fusion of clusters of these original hair-like rays, the hair-like stage preceding the osseous rod-stage.

Thus, by insensible gradations, we may trace the origin and evolution of the fins of fishes. Let us recapitulate these stages. First then to arise are the vertical fins. These being profitable to the fish lead to a further extension of the fin system by the addition of lateral folds.

Next appears a discontinuity in these fins, gaps appearing which isolate certain portions. The cause of the gaps is unknown, but is probably in some way connected with the undulating movements of the fish. From simple balancing—we next proceed to movable balancing—organs which take on the new duties of steering. These become more and more perfect as we work up the scale of fish life.

In the earlier part of this chapter we saw how these fins, gradually, in response to new demands, became transformed sometimes into organs of touch, sometimes into weapons of offence, and sometimes into organs of prehension, as in the suckers of the gobies, lump-fish and remora.

CHAPTER VII.

FISH-LIVERIES, AND WHY THEY ARE WORN.

PROBABLY in thinking of birds we do so as often as not in terms of their most conspicuous forms. Thus we recall such birds as peacocks, pheasants, parrots, canaries, and kingfishers at once; a further sifting of our memories brings up from its darker recesses more sombre forms. Now in dealing with the birds in this series of little volumes, it was pointed out that this colouration had a deep significance. Thus, we found that it often happened that in the case of a brilliantly coloured bird it is the male only which is resplendent, whilst the female is quite dull.

The reason being, that the female by her inconspicuous colouration escaped the notice of prowling enemies, a great necessity when she is performing the all-important task of incubating the eggs. When this danger can be averted the female may, and often does, assume the same bright colours as her mate.

Sometimes in place of colour we met with some other form of decoration, such as simply elongated feathers or wattles; sometimes, again, certain tufts or ruffles of feathers, not necessarily brilliantly coloured, were developed for a short time only and then discarded. Or, again, what appeared at first sight to be cases of decoration turned out, on closer examination, to be instances of protective colouration.

So is it with the liveries worn by fishes. Whether dull as the proverbial ditch-water, or rivalling the hues of the rainbow, there is an explanation behind it. The creatures of nature reflect the tone of their surroundings.

Before all things it is necessary to observe caution in formulating hypotheses to account for the brilliant colouration of fishes; or of any animal. Let us take certain cases which illustrate the necessity for this caution first.

It comes natural to assume that brilliant colouration,—whether permanent, as in the case of parrots (to take our illustration from the birds again), or seasonal, as in many of the plover tribe, *e.g.*: the golden plover,—is to be interpreted as due either, as in the last-mentioned instance, to the exigencies of courtship; or to the need for protection. Thanks to the observations of naturalists all over the world, we now know that brilliant colouration is as often a form of protective colouration as is the sober style wherein the colours harmonise with rocks, or mud, or reeds, and so forth, as the case may be. Thus birds often appear to be very conspicuously coloured, because they are seen *apart* from their surroundings. The hoopoe and the parrots are admirable examples of this. The zebra, amongst the mammals, is another wonderful illustration.

When we turn to the fishes we discover that the same rules appear to obtain. This is conspicuously the case with fishes which inhabit the neighbourhood of coral reefs. Here we meet with the gaudily striped and barred scaly-finned fishes, the *Chætodontidæ*, and the brilliant wrasses or lip-fishes. These live in a world of colour, for the coral animals themselves are also brilliantly coloured. The gurnards and mullets of our own coasts are other instances of brightly hued fishes.

It is significant in this connection to note that those fish which pass most of their time in mid-water, like the herring, for instance, have the under parts silvery or white and the upper parts darker. This, again, appears to be a form of protective colouration, for the dark upper surface tends to screen them from the view of enemies above, whilst the light under part performs a like service against enemies below, which look upwards towards the light. Many young fishes, as we shall see, are perfectly transparent, and therefore invisible.

But the interpretation of colour is by no means an easy matter, and contains many pitfalls and puzzles, for many cases appear to be capable of bearing more than one interpretation. Amongst the most interesting cases of this kind are the instances where the male and female are both brightly or even gaily coloured, but in different ways. Thus in the ornate coffer-fish (*Ostracion ornatus*) the male has a ground colour of grass-green, with spots and stripes of brilliant blue, whilst the female, often mistaken for a different species, is pale yellow or flesh colour with brown markings. In one of the parrot fishes again we have a similar twofold form, or case of dimorphism; the male being green and red, and the female blue and yellow. Usually, of course, where the sexes differ, the male is brightly and the female dull coloured. One instance, at least, is on record where the markings of the young are more ornamental than in the adult stages; this is the case in the young of certain eagle-rays of the genus *Myliobatis.*

One of the most remarkable of all brilliantly coloured fish is a small wrasse-like form, the amphiprion. It is vividly coloured, being vermilion red banded with three cross-bands of white. This seems about as conspicuous a colouration as possible, as if it had been adopted on this account. At any rate, this fish plays the part of a decoy for the mutual benefit of itself and a gigantic sea anemone of some *two feet* in diameter, which inhabits the coral reefs of Thursday Island. It appears that this little monster resides within the body of the anemone. When hungry he emerges, swims about till he attracts the notice of some carnivorous species, and so soon as he is chased rushes back and plunges headlong down the mouth of his kindly host. This brings his would-be captor within reach of the tentacles and paralysing stinging threads of the anemone, from which there is no escape. The fish and the anemone apparently then share the spoil!

We have seen that the colours of fishes may become more brilliant during the season of courtship; and we may now turn to the consideration of some cases in which the colouration may undergo sudden changes in brilliancy during periods of excitement; much as we ourselves turn colour from a deathly white to scarlet when possessed by some sudden emotion. But the methods in which these changes are made differ very much in ourselves and in the fish. With us the sudden change to scarlet is due to an increased supply of blood to the face; its sudden or complete withdrawal causes pallor. With the fish, change of colour to begin with is not necessarily from red to white, or *vice versâ*, but varies as the colour of the fish. Furthermore, as we have already hinted, the change is not connected with the blood-supply, but with the deeper layer of the skin and the colouring matter contained therein. And in this fact we have a point of exceeding interest, for this colouring matter is contained within certain little bag-like structures, whose form can be suddenly changed from a globe to a disc by means of the contraction of numerous little strands of muscular fibres attached to the outside of the bag. Now, when these little bags of colour, which are scientifically known as chromatophores, are at rest, they allow the general ground colour to play a more or less conspicuous part; but so soon as the proper stimulus is applied, the little strands or cords contract on all sides and pull the bag flat, at the same time, of course, causing its contained colouring matter to be spread out in a thin layer and cover the ground colour beneath. This power of changing colour is of great use, for by this means the animal is enabled to assume the general tone of its immediate surroundings, and so obtain a measure of protection against its enemies.

Many animals have this power of changing colour by means of contractile pigment cells or chromatophores. Thus, a species of shrimp (*Atyoida*) has been described, which is dark green when among weeds, but changes to a pale brown when resting in dark rocks; a dark brown form placed in a tank containing numerous greenish forms changed at once to this colour. Frogs also change colour according to the nature of the ground on which they rest. The action of these chromatophores is, perhaps, nowhere seen so well as in the *Loligo*, one of the cuttle-fishes—not a fish, of course, but a mollusc allied to the *Nautilus*. Here the expansion and contraction of these very active cells goes on with great rapidity. All the blue or all the yellow or all the red-containing cells may be expanded and the others remain at rest, but so quickly do the changes follow one upon another, that a dazzling brilliancy is the result. Sometimes the contraction of these cells leaves a generally brilliantly coloured fish of a quite dull hue, which remains for some time.

The colours in the scales of a fish depend much on its surroundings, says a writer in the "Encyclopædia of Sport." "A trout taken off a muddy, weedy bottom will often have a general shade of rich yellow over its sides and belly; while even in the same lake a trout taken from the opposite shore which, let us say, is rocky and sandy, will be of a steely blue colour. A trout swimming in deep water over a peaty bottom will have a dark back; while fish which inhabit shallow, bright, gravelly streams will have a light brown back, in fact, almost gravel colour. This is without doubt a provision of Nature to disguise the fish as much as possible from the keen eyes of herons and other fish-eating birds."

"In many bright-shining fishes," writes Dr Günther, "as mackerels, mullets, the colours appear to be brightest in the time intervening between the capture of the fish and its death; a phenomenon clearly due to the pressure of the convulsively-contracted muscles on the chromatophores. External irritation readily excites the chromatophores to expand—a fact unconsciously utilised by fishermen, who, by scaling the red mullet immediately before its death, produce the desired intensity of the red colour of the skin without which the fish would not be saleable."

The red mullets have been esteemed for their colour from time immemorial. So great was the admiration it excited in the breasts of the Romans that the wealthy had it brought to table alive that they might watch the brilliant display of colour which it afforded during its death struggles.

Some colours are due to a combination of two or more pigments. Thus the exquisite green colour of the mackerel, so familiar to us all, is due, not to a green pigment, but to a blending of black and yellow chromatophores.

But the colours of fishes are not all due to pigment. Some are what is called structural. For instance, the silvery iridescent appearance of many fishes is due to the presence of crystals of a substance known as guanin, derived as a waste product of the blood. These guanin crystals figure very conspicuously in the coloration of fishes.

We may gather then that the coloration of fishes must be regarded as largely reflecting, and determined by, their need for protection. It may be either permanently dull or brilliant, or more or less rapidly changed from one to the other extreme.

Sometimes the coloration may be brilliant at one season of the year and dull at another, and then is generally connected with the niceties of courtship. In such cases fleeting changes from dull to brilliant or *vice versâ*, due either to excitement or sometimes fright, are common. These changes are, we have seen, due to the action of contractile cells containing colouring matter called chromatophores.

But, it may be remarked, although it has been shown that fishes undergo rapid and marked changes of colour, of such a nature as to cause them to resemble that of their immediate surroundings, no indication has as yet been given which will explain why the change takes place so soon as a lack of harmony is established. That is to say, how the various colour cells of the fish, or other animals which change rapidly, are affected by the colour of the world outside. Much has yet to be done by experiment before a thoroughly complete answer can be formulated; but practically we may say these colour changes are due to stimulations through the eye. This is shown by the fact that instances are on record where fishes which did not correspond in colour either with their fellows or their surroundings were found to be blind.

Some colours may be what we might call accidental. They represent waste products thrown off from the blood, and the fact that they lend their aid to more or less beautiful colour schemes is an accidental result. Protective coloration has probably resulted from the advantageous disposition of this waste colouring matter, a distribution determined by the needs of the individual. Thus, to take a simple case, such as that of a normally-coloured fish, one that is white below and dark above, the silvery white is due, we have seen, to the presence of crystals of guanin. The dark coloration due to dark pigments of various kinds, is derived, as some believe, by decomposition of blood corpuscles. Now, it is possible that the distribution of these was originally diffuse, that is to say, not definitely confined to one region, as in the fishes of to-day. If this were so, it is certain that there would have been great variation amongst individuals, some of which would tend to produce more dark pigment above than below, and this would lay the foundation for natural selection to work upon. Natural selection would operate by rendering those fishes with darker backs and lighter underparts less conspicuous than their fellows, who would sooner fall a prey to other fish from below, and fish-eating birds and mammals from above.

We have done no more than touch upon the fringe of this question in this chapter. It is one that would well repay further study, for there are many puzzles to be solved.

CHAPTER VIII.

HOW FISHES FEED.

All living things must eat, and whether it be dirt—the dust of the earth mingled with raindrops, such as forms the diet of an earthworm, or whether it be of the dainty dishes set before the king, that which we eat must contain some nourishing properties. But what is good to eat and what is hurtful is knowledge which comes of experience. Knowledge bought sometimes at a great price—even the death of the purchaser. The pages of the history of mankind furnish us with many lessons in the dangers as well as the delights of eating.

Sight, smell, taste and memory are the council board which determine the menu for the higher forms of living things. We ourselves, consciously or unconsciously act upon the knowledge of this fact, as we are told the serpent did of old to beguile the unwary. One of the first queries we make about any strange animal is: What does it feed on? Next: how does it procure its food? Often we have to depend largely, if not entirely, upon our stock of knowledge of this kind for the capture of other creatures, either for our personal wants or to satisfy our deep-rooted love of killing something. This is especially true of the capture of fishes, and none will be more convinced of this than the angler. A successful angler must know much, not only of the nature of a fish's food, but also of the faculties employed in its discovery. He acts upon the old proverb: "The belly hath no ears when hunger comes upon it."

It is difficult to say whether sight or smell play the most important part in the capture of food amongst the fishes. There seems to be no doubt but that many fishes depend mainly, though not entirely, upon sight for the capture of their food. The success of the fly-fishers is a sufficient proof of this. The salmon, for instance, it is regarded as unsportsmanlike to take by any other means than with the "fly," except under special circumstances. This fly is cunningly devised of feathers, so as to imitate as nearly as possible some real fly well known and esteemed by the fish. There can be no doubt that sight, not smell, is the broken reed upon which the poor victim trusted in cases where this deceit is successful. But salmon apparently sometimes hunt by smell as well as by sight. Thus, old

Isaac Walton relates an experience of his anent a fellow-fisherman, "I have been a-fishing with old Oliver Henley, now with God, a noted fisher both for trout and salmon, and have observed that he would usually take three or four worms out of his bag, and put them into a little box in his pocket, where he would usually let them continue half-an-hour or more before he would bait his hook with them. I have asked him his reason, and he has replied: 'He did but pick the best out to be in readiness against he baited his hook the next time'; but he has been observed, both by others and myself, to catch more fish than I, or any other body that has ever gone a-fishing with him, could do, especially salmons. And I have been told lately, by one of his most intimate and secret friends, that the box in which he put these worms was anointed with a drop, or two, or three, of the oil of ivy-berries, made by expression or infusion; and told that by the worms remaining in that box an hour . . . they had incorporated a kind of smell that is irresistibly attractive enough to force any fish within the smell of them to bite." Some two hundred and forty years after this was written, actual and very careful experiments were made by Mr Gregg Wilson in the Plymouth Marine Biological Station, with a view to gaining more definite information in this very interesting and important matter. The more interesting of his results may be briefly and profitably transcribed here. He says: "So far as I could determine, fish that are not *very hungry* habitually smell food before taking it. The pollack seems usually to be ready for a meal, and on almost all occasions when anything eatable is thrown into the tank in which it is swimming, it rushes towards it and bolts it. It does not hesitate to take stale food, or food that has been steeped long in strong-smelling fluids; and time after time I have been amused to see its too late repentance, after it had swallowed clams that had been saturated with alcohol, chloroform, turpentine, etc. It is only when it is satiated with fresh food, or disgusted with what is nauseous, that it takes the precaution to smell before eating. On the other hand, various fish that are equally keen-sighted, and habitually recognise their food by the use of their eyes, are more prudent. The whiting (*Gadus merlangus*), for instance, appears to pay much more attention to smell, and, as a rule, turns about and withdraws on approaching within a few inches of high-smelling objects that the pollack would take without hesitation. Even whiting, however, cease to be delicate if they are very hungry, and if other fish are present to compete for the food that is thrown to them. In such circumstances bait that is very distasteful may be taken by even the most cautious of sight-feeders; and likewise, in such circumstances, a quite odourless artificial bait may be successfully employed. Where large shoals of fish are, there are likely to be many that are very hungry, and the consequent keen competition will lead to hasty feeding by sight alone; and hence it is, probably, that lead-baits are successfully employed in cod-fishing in the Moray Firth and off the northern islands, while they are of no avail among the scanty fish further south.

"It may be said that in these cases the fish actually *search* for their food by sight alone, and merely test the quality of what they have found by smelling it. . . . But more is possible: *habitual sight-feeders can be induced to hunt by smell alone.* The pollack, which is such a pronounced sight-feeder that it will take a hook baited with a white feather or a little bit of flannel, and trolled along the surface, is yet able, when blinded, to get his food with great ease. Several blind specimens in the Plymouth tanks were carefully watched by me, and I had no difficulty in deciding that it was by smell alone that they found their food. Their conduct was exactly such as was seen in the smell-feeders. . . ."

The cod-fish is generally believed to feed more by night than by day, hence we may conclude it is a "smell-feeder."

Mr Gregg Wilson has also placed on record the results on some of his experiments with certain other fish, which throws yet more light on this subject. Thus with the dabs (*Pleuronectes limanda*). "That they were sight-feeders," he says, "was evidenced by their behaviour when I lowered a closed tube full of water, and with a worm in the middle of it, into their tank; time after time they bumped their noses against the glass at the very spot where the worm was situated. That they could also recognise the smell of food, apart from seeing it, was demonstrated in various ways. First, if instead of a closed tube . . . one open at the bottom was used, after a short interval the 'nosing' at the part where the worm was seen ceased, and the *lower end of the tube*, from which, doubtless, worm-juice was diffusing, was vigorously nosed. If, again, instead of putting worms into a tube, I placed a number of them into a closed wooden box with minute apertures to let the water pass in and out, there was a similar excitement produced, and the dabs hunted eagerly in every direction. When water in which many worms had lain for some time was simply poured into the tank through a tube that had been in position for several days, and by a person who was out of sight of the dabs, the results were most marked. In a few seconds hunting began, and in their excitement the dabs frequently leapt out of the water, apparently at air-bubbles, and on one occasion one even cleared the side of the tank, which was about two inches above the water, and fell on to the floor of the aquarium. Yet there was nothing visible to stimulate the quest."

A very remarkable instance of sight-feeding is that afforded by a fish known as the archer-fish (*Toxotes jaculator*). This name has been bestowed upon it on account of its remarkable habit of squirting a drop of water at flies and other insects perched on the water-plants above the water. It is said to be able to strike down into the water a fly as much as six feet distant. The Malays call it "Ikan sumpit," says Dr Günther, "and keep it in a bowl, in order to witness this singular habit, which it continues even in captivity."

From the means by which fish aescry their food we may well pass to the method of seizing the same, and its disposition. And it will be interesting to note, as we pass from one illustration to another, how numerous are these methods, and the modifications of structure which have often been induced thereby.

One of the sea-breams of the Mediterranean (*Chrysophrys*) or the gilt-head—which, by the way, sometimes occurs on the south coast of England—is said to stir up the sand with the tail to discover the buried shell-fish. Its favourite kinds are mussels, and it is said that its near presence is ascertained by the fishermen by the noise which it makes in crunching their shells between its teeth.

The "fox-shark" or "thresher," one of the commonest and largest of the sharks which periodically appear off our coasts, hunts in a peculiar fashion: a fashion by the way first recorded by Dr Günther. It preys upon the shoals of herrings, pilchards and sprats, of which it destroys incredible numbers. These shoals the fox-shark follows on their migrations. Swimming round and round the unlucky shoal with ever decreasing circles, and accompanying its gyrations with a violent beating of the water with its enormous tail (hence its name of "thresher"), the intended victims are swiftly huddled together in a dense crowd, when they fall an easy prey. This fashion of hunting recalls the "rounding up" methods of the sheep-dog. The thresher attains a length of some fifteen feet, about one-half of which is represented by the tail.

The teeth of fishes are often profoundly modified for the purpose of crushing shell-fish. Many of the brilliantly-coloured wrasses have these modified teeth. Thus they have an inter-maxillary tooth which is used for the purpose of grinding shells against the lateral and front teeth. One of the parrot-wrasses—a vegetable-feeder — reduces its food to pulp within the mouth, by means of specially modified teeth. The food is slowly worked backwards and forwards till thoroughly masticated. This has given rise to the notion, says Dr Günther, of its being a ruminant. His further remarks on this fish are well worth quoting here, though we may be accused of making a digression in doing so. "In the reign of Claudius, according to Pliny, Optatus Elipentius brought it from the Troad, and introduced it into the sea between Ostium and Campagna. For five years all that were caught in the nets were thrown into the sea again, and from that time it was an abundant fish in that locality. In the time of Pliny it was considered to be the first of fishes (*Nunc Scaro datus principatus*); and the expense incurred by Elipentius was justified, in the opinion of the Roman gourmands, by the extreme delicacy of the fish. It was a fish, said the poets, whose very excrements the gods themselves were unwilling to reject. Its flesh was tender, agreeable, sweet, easy of digestion, and quickly assimilated; yet if it happened to have eaten an aplysia (a species of mollusc), it produced violent diarrhœa. In short, there is no fish of which so much has been said by ancient writers. In the present day the Scarus of the Archipelago is considered to be a fish of exquisite flavour; and the Greeks still name it *Scaro*, and eat it with a sauce made of its liver and intestines."

The teeth have undergone innumerable modifications in accordance with the nature of the food to be ingested. The nature of these modifications, and other features, such as the attachment to the jaw and so on have been already dealt with.

The point we wish to emphasise here is the evolution of strange forms evidently adapted to peculiar ends and purposes. Thus, for instance, some of the shark-tribe, the eagle-rays (*Myliobatis*), are remarkable for the possession of a peculiar pair of processes projecting forwards from the head, which are said to be used for scooping food from the sea-floor and conveying it to the mouth.

Another fish of this group, the "saw-fish" (*Pristis*), has developed a most remarkable and most powerful weapon, by a modification of the beak-like process of the front of the head. This is produced forwards into a series of from three to five hollow tubes placed side by side, tapering towards the end, and covered by shagreen, the nature of which we have already discussed. In deep sockets along each side of this enormous beak are implanted large conical flattened teeth, thus forming a double-edged saw. This saw is sometimes a foot broad at the base, and as much as six feet long. It forms, it is needless to remark, a very terrible and most effective weapon, rendering its owner, as Dr Günther justly remarks, most dangerous to all other large inhabitants of the ocean. It is used in tearing off pieces of flesh from its victim's body, or for ripping open the abdomen. The detached fragment, or protruding pieces of viscera, are then seized by the mouth and swallowed. The teeth of the jaws framing the mouth are, it should be remarked, too feeble to inflict wounds, or to be in any way useful as weapons of offence.

Another large powerfully-armed and really dangerous fish is the sword-fish (*Xiphias*). They bear the name of sword-fish on account of the great development of the upper jaw, which forms a huge tapering sword-like weapon. It might be noted here that this is of quite different origin to the blade of the saw of the "saw-fish" which we have just discussed. The sword of the sword-fish is covered along its under surface by numerous and small teeth; and the weapon, as a whole, is a very terrible and very powerful one. They attack apparently, without provocation, whales and other large cetaceans, which they invariably succeed in killing, by repeated thrusts of the sword. Battles of this kind remind one of the stories in "Gulliver's travels"—this puny antagonist, of some twelve to fifteen feet in length, ferociously assailing the giant whale of sometimes seventy or eighty feet. It appears that occasionally sword-fish make a mistake, and, after the fashion of Don Quixote, tilts at windmills in the shape of large vessels, under the impression that they are whales. For this most grave error of judgment it pays a heavy penalty; in that having no power to make effective backward movements, the sword remains fixed and is eventually broken off in the struggle for freedom. Frank Buckland reminds us that in the Museum of the College of Surgeons is a section of the bow of a whaler impaled by one of these swords. That portion of the sword which remains is a foot long and five inches in circumference. "At one single blow," he writes, "the fish had plunged his sword through, and completely transfixed thirteen and a half inches of solid timber. The sword had of course broken off and prevented a dangerous leak in the ship. In the British Museum is a second specimen of a ship's side with the sword of a sword-fish fixed in it, and which has penetrated no less than twenty-two inches into the timber. When his Majesty's ship *Leopard* was repairing in 1795, after her return from the coast of Guinea, a sword of one of these fishes was found to have gone through the sheathing one inch, next through a three-inch plank, and beyond that four and a half inches into the firm timber; and it was the opinion of the mechanics that it would require nine strokes of a twenty-five-pound hammer to drive a bolt of similar size and form into the same depth into the same hulk; yet this was accomplished by a single thrust of the fish." Mr Lydekker reminds us that there are instances on record of bathers having been transfixed by these fish, one such instance occurring in the estuary of the Severn about the year 1830. The normal use of this sword is for the capture of food. Cod and other fish being spitted thereon, but how they are removed from the sword still remains a mystery.

The teeth of the sword-fish, it should be remarked, are either small or vestigial.

Those who have the good fortune to be within easy reach of a museum, where a skeleton of the sword-fish is exhibited — such as the Natural History Museum, London—should make a pilgrimage thereto for the purpose of inspecting the wonderful vertebral column of the sword-fish. It has undergone great and peculiar modifications obviously designed to give strength and power to resist the shocks of the violent and deadly charges which the living fish is known to make.

Two fish bearing a superficial resemblance to the sword-fish are worthy of mention here. These are the gar-pike (*Belone*) and the half-beak (*Hemirhamphus*). Both, however, differ from the first-mentioned in that it is not the upper jaw only that is elongated but both jaws. In the gar-pike the upper jaw is longer than the lower. They capture their prey whilst skimming along the surface of the water. In the half-beaks the proportions in the length of the jaws are the reverse of what obtains in the gar-pike, the lower jaw being longer than the upper.

It is interesting here to note that in all three forms of these long-beaked fishes the jaws are of equal length, and not elongated in the young. In the young gar-pike, strangely enough, for a short while after the increased length of the jaws has begun, the lower is longer than the upper jaw. Thus, during this stage it resembles the half-beak (*Hemirhamphus*). As we have just remarked, the resemblance between the sword-fish and the gar-pike and half-beak is a superficial one. In the former it is the upper jaw only which is elongated, and this is used as a spear; in the two latter *both* jaws are elongated, and used as a pair of forceps, like a bird's beak. We have now a third form of the elongation of the jaws to examine. In this type the jaws are

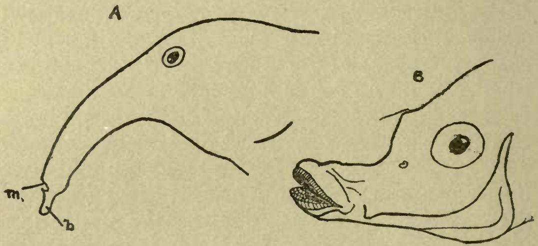


FIG. 8.—*A*. Head of *Gnathonemus elephas*, one of the Mormyridæ from the Congo, to show the extraordinary modification of the jaws (after Boulenger). *B*. Head of *Histiopterus recurvirostris*, after Günther, also showing modification of the jaws.

drawn out into a long and often curved tubular beak or trunk, at the extreme tip of which is a tiny cleft—the mouth. This beak resembles the long drawn-out head of that curious mammal the great ant-eater, even to the cleft-like terminal mouth. This curious tubular beak is apparently an adaptation enabling the fish to explore and drag out from holes and crevices creatures which lie hid therein. The "boar-fish" (*Histiopterus*) and the chelmo of Australia, and some members of the genus *Mormyrus* of the African rivers and lakes, represent the most striking instances of this curious bizarre type. One or two of the most wonderful of these latter forms are sketched in the accompanying figures (fig. 8). The mormyrus, it should be remarked, was well-known to the ancient Egyptians, and occurs not infrequently in the hieroglyphic figures. It was regarded as an object of veneration. The Egyptians, Dr Günther tells us, "abstained from eating it because it was one of three different kinds of fishes accused of having devoured a member of the body of Osiris, which, therefore, Isis was unable to recover when she collected the rest of the scattered members of her husband." Since, then, there has arisen a people who knew not Osiris and his mournful history, and these eat the mormyrus with great relish, pronouncing its flesh most excellent eating.

Some fish procure their food by stealth, and the craft and cunning displayed in a study of these instances is something diabolical, and hardly to have been expected at first sight in animals of this low grade. Take the cunning of the skate, for example. The skate is a cousin of the shark, but the shark is what we may call a round fish, moving swiftly by virtue of a violent side to side sculling action of the tail, whilst the skate may properly be called a "flat" fish. Its change of form has been brought about by the enormous development of the pectoral fins, which form huge fleshy lobes on each side of the body, tapering off at their outer margins to a thin edge. These great fins have superseded the tail, and propel the body by a series of undulatory movements, resemblng those of the lateral fins of the plaice or sole, for instance. Like the shark, however, the skate is carnivorous, but is unable to pursue and catch swiftly-moving animals; instead, it preys upon slow-moving or stationary animals, such as shell-fish (*mollusca*) and crustacea (crabs and lobsters). It may be that this modification is a result of adaptation, fitting it for a new mode of life when competition was less. But the craving for the flesh of animals of its own class, or even species, has not been lost, though it is one which could never be gratified were it not for the fact that it is protectively coloured. That is to say, the colour of its upper surface closely assimilates with that of its surroundings. Taking advantage of this fact, the skate lies quietly at the bottom, so quietly that unwary fishes approach near enough to be suddenly pounced upon. With a swift sudden spring the crafty ghost-like monster throws itself upon its unsuspecting victim, so as, to quote Dr Günther, "to cover and hold it down with its body, when it is conveyed by some rapid motions to the mouth." Thus the poor victim is both smothered and swallowed at the same time. The position of the mouth on the under surface of the flattened body, and the weak jaws and teeth render this method of enveloping the prey absolutely necessary.

But the death-traps of the sea are many. Down in its silent depths we seem to see "nature red in tooth and claw," urging her children forward to deeds of blood as relentlessly as on land. Or rather perhaps these should be looked upon as the degenerate ones—those upon whom the struggle for life has told adversely. Keen competition and the consequent stimulus of hunger have developed a certain low cunning and deception, shared even by the "lord of Creation," man himself. Some others of the past-masters of this art of deception we will pass in review now. One of the chief of these is the "angler-fish" or "sea-devil," of which we may take a very widely distributed form (*Lophius piscatorius*) as an example. This species is found all round the coasts of Europe, Western North America, and the Cape of Good Hope. It has an enormous flattened head, with a huge mouth, and a tapering body. Around this head project numerous short loose appendages resembling little bits of sea-weed. From the middle of the head there arise three or four slender stalk-like and freely movable shafts, the foremost of which bears a little flag-like blade. As this monster lies close and quiet at the bottom the flag-like pieces of sea-weed-like skin along the head and sides of the trunk tend to divert suspicion from the body, whilst the foremost spine, with its attached "flag," is slowly waved about. Little fishes in the neighbourhood gather round this flag, and whilst busily engaged in inspecting it, and speculating on its probable palatability, are suddenly engulfed, being sucked in by the mere opening of the huge mouth, till now concealed. There are some anglers who hold that fish have no curiosity! It is interesting, but puzzling, to note that in young angler-fish all the elongated dorsal spines are beset with lappets of skin, and that the fins are much longer and their supporting rays are produced far outwards beyond the fin-membrane in the form of long slender filaments. The cavern-like mouth of this ugly and repulsive monster, it should be noticed, is liberally beset with teeth; they fringe its jaws, and cover the roof of its mouth. Moreover, they are hinged so as to move freely backwards on pressure, allowing ready ingress but no escape, for any backward wriggling of the newly injected victim would impale him in their inturned points.

The voracity of fishes varies much. Sea-fishes would appear on the whole to be more voracious than fresh-water species; since the latter may survive without food for weeks or even months, sea-fishes will succumb to a fast of a few days. The capacity of the stomach of some marine fishes is almost beyond belief. This is especially the case with many deep-sea forms, where food is but seldom to be come at, and as much as possible must therefore be taken at a time. Our illustration affords us a graphic example of this, wherein the swallower, known as *Chiasmodus niger*, has succeeded in stowing away a fish more than twice his own size (fig. 9). The stomach and external skin in such species is remarkably distensible. Note the position of the displaced pelvic (ventral) and anal fins. The action of swallowing is performed, not as is usual with fishes, by means of the muscles of the gullet, but by the action of the jaws as in snakes. These fishes, as Dr Günther has remarked, cannot be said to swallow their food, but rather to draw themselves over their victim, in the fashion of the star-fishes or sea-anemones. Another deep-sea fish (*Melanocetus*), mentioned by Dr Günther as occasionally taken at depths of from 360 to 1800 fathoms, is equally successful in these feats of swallowing. From the stomach of a specimen not quite four inches in length,

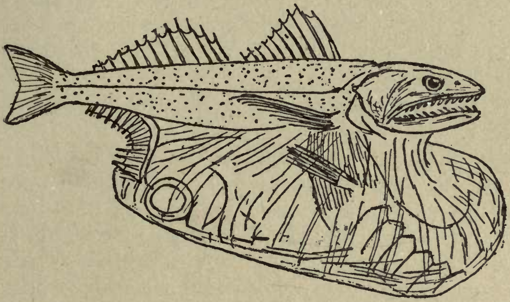


FIG. 9.—*Chiasmodus niger*, a deep sea fish (1,500 fathoms) from the N. Atlantic. It has swallowed another fish—a species of *Scopelus*—much larger than itself, which can be seen through the walls of the body, made transparent by distention. Note the displaced ventral fin of Chiasmodus (after Günther).

another fish *seven and a half inches* in length and one inch in depth was taken. It was spirally coiled into a ball. From the stomach of the fishing-frog of our coasts other fish have frequently been taken which equalled their destroyer in size.

Another of these victims to an insatiable hunger is the *Plagyodus ferox.* Some six feet in length, he is a monster to be dreaded; the nameless terror of the mysterious dark shades and regions of awful stillness and eternal night. From the stomach of one of these fish were taken several octopods, crustacea and sea-squirts, a young bream, twelve young boar-fishes, a horse-mackerel, and one young of its own species!

The "skip-jack" (*Tenmodern saltator*), like some carnivorous mammalia, seems to have developed a thirst for killing for killing's sake. A voracious feeder, destroying an immense number of other shore fishes, yet it kills many more than it can possibly eat.

The common stickle-back is likewise a voracious feeder. Dr Günther relates that a "small stickle-back, kept in an aquarium, devoured in five hours' time seventy-four young dace, which were about a quarter of an inch long and of the thickness of a horse-hair. Two days afterwards it swallowed sixty-two, and would probably have eaten as many every day could they have been procured."

In some fishes, it is interesting to note, the nature of the food actually influences the colour of the flesh. The truth of this is particularly well seen in the case of the salmon. These fishes feed, at any rate at times, exclusively on crustacea, and the peculiar colouring substances which pervade the system of these animals, and to which they owe their characteristic red colour when boiled, *e.g.*: lobster seems to undergo similar chemical changes in the stomach, and to pass from thence into the flesh of the fish, imparting thereto its wonderful "salmon" colour.

The evidence of these various modifications of, and departures from, the typical fish, leads very naturally to the query: Why have they come to be? This is not easily answered.

What is undoubtedly a factor of prime importance in the evolution of new forms and types is the stimulus of hunger. We eat to live. Food must be had at all costs. If the normal food is scarce, an attempt will be made to find a substitute. This will be more successfully done with some individuals than with others; *because* of the fact that no two individuals of the same group are exactly alike in all particulars. This unlikeness, will be a positive advantage to some, enabling them to seize upon new points of vantage, from which their neighbours, by varying unfavourably, will be excluded. Something of the truth of this we may gather from the fact that the further we trace back the history of any group of animals, in time the more divergent branches approach one another in form and likeness.

The evolution of the prehensile organs of the mouth is exceedingly instructive. We have seen already that the teeth arose by gradual modification of the scales, or rather denticles, which make up the shagreen of the skin of the most primitive fishes. These denticles on the region of the skin covering the jaws gradually changed their form, shape and method of attachment, becoming more and more intimately connected with the skeleton of the head, till finally their primitive origin became obliterated. This evolution of the teeth was brought about by the modifications demanded to enable them to perform new duties. To-day we have the triangular flesh-cutting tooth of the shark, the shell-crushing mosaic of the skate, and the needle-like teeth of the pike for holding prey, to take only a few instances. On the other hand, by atrophy of the outer teeth, we have evolution in a new direction, resulting in the toothless jaws of vegetable-eating forms, and the development of fresh teeth in a new position—the throat. That the teeth have been lost in these, we gather from the fact that they appear in the embryo.

We can imagine how these changes came about. In the beginning, amongst the early and very similar fishes, there would soon be great competition for existence; the demand for food tending to exceed the supply. If now certain combinations of variations tended to permit of some of these competing forms to supplement their normal diet by the addition of, say, shell-fish, and some of sea-weed, we can well imagine that the progeny of these same would be still better adapted in this new direction, and would in time find a completely nourishing diet on the new fare. The variation which favoured this change would, of course, be now very marked, and in course of time the annectant forms would die out and leave these now specialised types. Thus the vegetable feeding types would have become toothless as to the jaws, and have developed new teeth in the throat, as in the present-day vegetable-feeders. The shell-fish feeding fishes would have exchanged sharp-pointed teeth for broad flat crushing teeth.

The course of ages has witnessed the gradual evolution of countless variations of this kind;

variations which have gone on increasing in intensity in the new direction, till it becomes more and more marked; and this of necessity, as each new generation became further and further removed from the old method of feeding. As a final result, we get the highly specialised structures delicately adjusted to the purposes they are required to fulfil. This adaptation to requirements we call specialisation. As instances of specialised structures, we have the crushing teeth of various kinds, the beak of the saw-fish and sword-fish, and the remarkable tube-mouth of the sea-horse, mormyrus, the curious tactile barbules of the siluroids, and a hundred more.

The importance of the part played by the stimulus of hunger is shown by the fact that the mouth parts of all animals vary most, and that other modifications in the form of other parts of the body are largely modifications connected with the capture of the food.

CHAPTER IX.

COURTSHIP AND NURSERY DUTIES.

THE period of courting or mate-hunting with many fishes, as with birds, is signalised by special activity on the part of the males. Sometimes this is manifested by quite unusual aggressiveness; sometimes by the display of brilliant colours, combined very often with greatly elongated, or otherwise specially modified and developed fins or membranes. If the variations of these modifications are less notable than the modifications of the epidermal structures of birds, full compensation is found in the marvellous range of brilliancy in the hues of the skin which we have already discussed.

The difference in the size of the sexes of fishes is a very noteworthy feature, and naturally one of the first things which would attract our attention in this connection. Thus, among what are known as the "bony" fishes, *e.g.*: salmon, perch, the females are larger than the males; among some of the carp tribe the female is often as much as six times as large as her mate; sometimes, however, as in the cod, haddock, angler, and cat-fish the males are larger, but only slightly so. Occasionally, the female appears to be more perfectly armed than the male; thus, among certain rays which are armed with bucklers or pointed scales, it is the female on which they are found, the male being almost or completely smooth.

With the fishes as with the birds, the possession of a mate seems to be accomplished in one of two ways, conquest by battle, or conquest by blandishment.

One of the best known and most interesting of the instances of conquest by battle is afforded us in the salmon of our rivers. The male salmon fight ferociously amongst themselves, the strongest driving away all rivals. So serious are these engagements that Mr Darwin was informed, on one occasion, as many as 300, all males with one exception, were found dead in the Tyne during the month of June, killed by fighting. The male salmon is further remarkable on account of the fact that during this season of the year—when he is fighting—the lower jaw becomes elongated, and turns upward and backward into the mouth, hook-fashion. When the mouth is closed, this hook-like projection is received into a special cavity in the upper jaw. The purpose of this hook is not very clear, but it seems to be that of stiffening the jaw to prevent dislocation, which might otherwise follow one of the desperate charges which they deliver, ram-fashion, upon their opponent in fighting. An American species of salmon develops large tusk-like teeth, which inflict serious wounds. Besides this peculiar hook to the jaw, the salmon also, at this time of the year, becomes more brilliantly coloured.

The little stickle-back (*Gasterosteus*) of our streams and ditches battles fiercely with his fellows for the possession of his chosen.

By a natural sequence we pass from these fierce battles or ecstatic cortortions, harlequinades and displays, the tokens of what we may call love-sickness, to a review of the more important facts concerning the deposition of the eggs, and the often elaborate preparation for their reception and safe-keeping. The range of variation in the form, number and size of these eggs is enormous. Much of this variation is due to the fact that the egg of the fish differs from what we may regard as the typical egg—the hen's egg—in that it is never enveloped in a hard limy shell, but, on the contrary, is generally quite unprotected. Such eggs are globular in form, and always relatively small, sometimes minute. Instances of an outer covering are, however, numerous, but in such cases the covering is of a horny character, and is, furthermore, often produced into frills, thread-like processes,

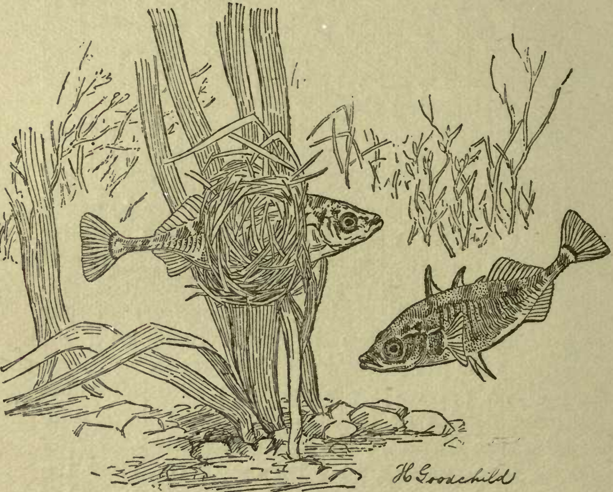


FIG. 10.—Sticklebacks and Nest.

or other excrescences. The size of the egg depends upon the number produced. This is a quantity which may vary from several millions to less than a dozen. When the number is large the eggs, after they leave the parent, are left more or less to chance; when the number is small they are often jealously guarded. How and why this reduction of the eggs has come about, and the causes which have fostered development of the parental instinct, are points which may be more conveniently left till we have digested the following instances.

We will begin with an account of those fishes which have acquired the habit of nest-building.

The stickle-back of our ponds and streams will afford us an admirable object lesson, illustrating the perfection to which the parental instinct has risen amongst the fishes. The stickle-back is more than usually provident, for before he commences his courting he provides the home, in the shape of a very perfect nest, to which he proposes to bring his bride (fig. 10). This nest he builds entirely by his own efforts. The sides are raised and finally a top is added, a small hole being left at one side for an entrance. This is certainly remarkable for a fish; but, if possible, a still stranger fact about this nest is the fact that the materials of which it is constructed are held together by a curious sticky secretion which comes from the kidneys. In a similar way, the nest materials of swifts and swallows are held together by the secretion of the glands near the mouth. The nest being complete, the new householder casts about him for a mate. Having sighted what he regards as one worthy of his attentions, he conducts her, as it has been described, with tender caresses to the nest, and persuades her to enter through the doorway. This done, she lays therein two or three eggs, then bores a hole through the opposite side of the nest and departs. This second doorway proves useful, for it enables a continuous current of fresh cool water to pass through and keep the eggs constantly bathed. Next day he persuades her, or a new mate, to repeat this ceremony. This goes on till a large number of eggs have been stored in the nest. Every time the female enters, the male rubs his side against her and passes over the eggs. When the nest is full he mounts guard over the entrance, and stays at his self-imposed sentry-duty for almost a month, defending his treasures with great spirit against all comers. Strange to say, the most dangerous of these assailants are his own mates, his wives, who would greedily devour every egg if they could but get the chance. When the eggs hatch out he watches for some considerable time over the young, never leaving them till they can fend for themselves. It seems that in order to ensure a constant supply of fresh water to the developing eggs, he hovers over the nest driving the water through by means of a fanning motion of the pectoral fins and lashing of the tail. Frank Buckland tells us that in a nest he watched this vigilant little sentinel kept "constant watch over the nest, every now and then shaking up the materials and dragging out the eggs, and then pushing them into their receptacles again, and tucking them up with his snout, arranging the whole to his mind, and again and again adjusting it till he was satisfied."

But the stickle-back by no means relaxes his care on the hatching out of the eggs. On the contrary, his efforts for their protection are now redoubled, and his vigilance is taxed to the extreme. How hard the poor little fellow is worked has been graphically told by Mr Warrington, who had the good fortune to watch the whole sequence of events during this most critical period of the fish's life. The nest he watched was built in a large aquarium containing, besides several others of his own species, two tench and a gold-finch. "The other fish," he writes, "three of them some twenty times larger than himself, as soon as they perceived that the young fry were in motion, used their utmost endeavours, continuously, to pounce upon the nest and snap them up. The courage of this little creature was certainly now put to its severest test, but nothing daunted he drove them all off, seizing their fins, and striking with all his strength at their heads and at their eyes most furiously. . . . Another circumstance which appeared to add greatly to the excitement that he was constantly subjected to arose from the second female fish . . . endeavouring most pertinaciously to deposit her ova in the same locality, and hence rushing frequently down towards the spot; but the male fish was ever on the alert, and although he did not strike at her in the furious way he attacked the larger ones, yet he kept continually under her, with the formidable back spines all raised erect, so that it was impossible for her to effect her apparent object.

"The care of the young brood was very extraordinary . . . if they rose by the action of their fins above a certain height from the shingle bottom, or flitted beyond a certain distance from the nest, they were immediately seized in his mouth, brought back, and gently puffed or jetted into their place again. This was constantly occurring, the other fish being continually on the watch to devour these stragglers, and make a savoury morsel of the lilliputian truants. Indeed, the greater number of the whole brood must have fallen a prey to their voracity, as it was only some three or four that reached a size to place them beyond the power of these destroyers.

"As soon as the young fry could swim strongly the parent fish gradually relinquished his duties, though a constant watch appeared to be still quietly maintained on their motions as they swam about near the surface of the water. . . . It is a curious circumstance that very soon after these young stickle-back were left unmolested by their companions, both the parent fish disappeared, and I presume have died in some hiding-place among the rock-work; as though their allotted functions, namely the propagation of their species, having been completed, their period of existence must terminate."

Those crafty and subtle monsters, the skates, furnish us with a striking instance of parental affection. Thus one of the "devil-fishes" (*Dicerobatis*) will defend its young with great ferocity. Its capture, at all times attended with danger, is especially perilous when it is accompanying its offspring, at such times they have been known to attack and capsize a boat.

The spotted goby or polewing (*G. minutus*), which occurs in the Thames, is a nest-builder. Here, however, an old cockle-shell is made to do duty for a nest. The shell is placed with its concavity downwards, beneath which the soil is removed, and cemented together by, it is said, a special secretion of the skin. In the stickleback, it will be remembered, the *kidneys* furnished the necessary cement. Access to this nest is gained by a cylindrical tunnel, and the whole structure covered by loose sand. The eggs are fixed to the shell by the female, and left to the care of the male, who mounts guard over them and remains on duty till hatching, which takes place from six to nine days.

Crenilabrus, one of the wrasses or lip-fishes, builds a nest of sea-weed and shells, etc., in which the eggs are deposited. But it is interesting to note that in this instance at least both male and female are engaged in its construction.

One of the angler-fishes (*Antennarius*) builds in the floating "gulf-weed" off the Bermudas, a very beautiful nest. This is suspended by delicate silken fibres, quite strong enough to support the large grape-like clusters of eggs within. "Each nest is made of one seaweed, the different twigs being brought together and made fast to each other by the fish by means of a pasty sort of substance provided by the animal itself."

Perhaps one of the most remarkable of fish-nests is that of one of the Chinese paradise fish (*Macropus*). This is fashioned by the male, and takes the form of a little disc of froth formed by blowing air and mucus out of his mouth. The nest made, he proceeds to collect the now fertilised ova, dropped by the female, into his mouth, and deposits them in his froth-like nest. This done, he jealously watches over the eggs till they hatch, renewing the froth from time to time, and then, like the stickle-back, transfers his affections to the young, guarding them with great care.

One of the beaked fishes of tropical Africa, *Gymnarchus,* builds a floating nest in about three feet of water. Mr Budgett, who discovered this, describes it as of about two feet long and a foot wide ; the walls of the nest stood several inches above the surface of the water, on two sides and at one end. The opposite end was low, and at this end was the entrance to the nest.

The males of some of the cat-fishes carry the eggs about in the mouth, or in the gill-chamber, thus ensuring both protection and perfect aeration !

Amongst the fresh-water fishes known as chromids, tropical of Africa and America, the *males* of certain species build shallow nests, *and sit upon the eggs.* This fact was discovered by Lostert in one of the chromids of Lake Tiberias. What is also unexpected in this connection is the fact that although these males undertake the duties of incubation, they do not adopt a dull coloration as is so often done amongst the birds. It is, of course, possible that the brilliant coloration of the male may after all prove to be not conspicuous, but protective.

Instances of the female taking care of her offspring are, according to the high authority of Dr Günther, exceedingly rare in fishes. Only a few examples appear to be known. One of these is a cat-fish, one of the siluroids. In this fish (*Aspredo batrachus*), at about the time that the eggs are ripe, the skin of the abdomen becomes very swollen and tender, assuming a soft spongy nature. As soon as the eggs are laid, the aspredo presses them into the spongy tissue by lying on them. When fixed she carries them about with her, attached to the belly, till they are hatched. As soon as this occurs the skin shrinks to its former dimensions, and the abdomen is once more perfectly smooth.

The Surinam toad of tropical America, strangely enough, adopts a precisely similar method of guarding the eggs. But in this case they are embedded in the swollen skin of the back instead of the belly. They are placed on the back by the male. Embedded in the skin the egg then undergoes its full course of development. That is to say, it does not compel the young, at the tadpole stage, to turn out and support themselves, but contains sufficient food material to allow the tadpole stage to be dispersed with, the young emerging as fully formed though tiny toads.

Another instance of a female fish caring for the eggs is that of an ally of the pipe-fish, the *Solenostoma cyanopterum*, of the Indian Ocean. These, according to Dr Günther, are borne on a pouch formed by the ventral fins, and for further security the inside of this pouch is beset with numerous long filamentous appendages. In a third case the female shares with her mate the anxieties of watching the eggs.

Amongst many species of true pipe-fish the care of the offspring, as seems to be usual with fishes, devolves upon the male. In some, as in the common pipe-fish (*Syngnathus acus*), the eggs are placed by him in a pouch formed by a fold of skin, which develops along each side of the abdomen, and finally meets in the middle line. Here the eggs remain till they are hatched. But the pouch is by no means done with on this event, for the young continue to occupy it for some considerable time, leaving it at once and returning if danger threatens. Mr Yarrell relates a very curious fact that he was told by some fishermen. To wit, that if they take a pipe-fish, open the pouch, and drop the young into the sea, these will not disperse, but hover around the spot, as if waiting for their parent. Then, if they hold the newly-opened fish in the water, the young immediately return to it and enter the pouch. In the sea-horses (*Hippocampus*) this is more completely closed than in the pipe-fishes, only a small anterior aperture being present. In some pipe-fish, *e.g.* the tropical *Doryichthys*, the eggs are said to be "glued" to the skin of a broad groove on the under surface of the males. This groove would seem to indicate the beginning from which the complete pouch has been developed.

Some fishes, as in the viviparous wrasses, many blennies and carps, the eggs are hatched within the body of the parent, so that the young are produced alive.

The roach-like bitterling (*Rhoderis amarus*), of European waters, is remarkable on account of the fact that the oviduct is produced into a long tube, which serves the purpose of the ovipositor of the insect. By this means the female is enabled to deposit her eggs within the open valves of fresh-water mussels, and thus the eggs are placed out of the reach of enemies.

We may now turn our attention to that vast majority of fishes which neither build nests nor, in the majority of cases, show any sustained regard for their progeny, save only a certain caution in the selection of the site for the deposition of the eggs, which suggests but little more than a kind of obedience to custom. That there is something more than this at work we must, however, feel convinced when we come to review the facts which have been gathered together on this subject. There seems to be ample proof that the parental instinct is by no means sluggish, and that the deposition of the eggs is often only accomplished after the severest obstacles have been surmounted.

The eggs of the lamprey, which we distinguish by the scientific name of *Petromyzon marinus*, are very tiny, and enclosed in jelly-like membranes. But the eggs of the allied forms, *Bdellostoma* and *Myxine*, are quite different. In the first place, they are very large and cocoon-shaped structures. Furthermore, they are remarkable for the fact that at each end of the egg there is a bundle of thread-like processes terminating in little hooks. These hooks are for the purpose of interlocking with the corresponding processes of other eggs, and with sea-weed at the bottom of the sea.

The eggs of the sharks, and rays or skates, must be familiar to all, since those of the skate, at least. are commonly to be seen strewn along the beaches of our shores, and are known as "mermaid's pinboxes." They may be likened to padded stretchers, being oblong in form, with the corners produced into four short handles. Sometimes these will, if opened, be found to contain a young skate comfortably stowed away inside. The eggs of the dog-fishes resemble those of the skate, but the four handle-like processes are much longer, and serve as anchors by twisting round sea-weed. The egg of the Port Jackson shark, *Cestracion*, is quite remarkable, being cone-shaped, and encircled with a broad spirally-twisted fold running the whole length of the egg. The egg of the chimera (*Callorhynchus*), an ally of the sharks, is perhaps the only egg with a mimetic resemblance to foreign an object. It is elliptical in form, and bordered by a fringe, so as to give a close resemblance to a piece of sea-weed.

Amongst the more highly specialised bony fishes, the dominant forms of the present day, the eggs may either be enclosed within a horny capsule, as in the sharks—though the form and size of the capsule differs—or are quite unprotected.

The blennies afford us an instance where the eggs are enclosed within a horny capsule. This capsule is attached by its base to sea-weed or other fixed object, till the young hatches out. The eggs form little clusters of small, upright, and somewhat pear-shaped bodies.

Sometimes, as in the case of the fresh-water perch (*Perca fluviatilis*), the eggs are invested by a gelatinous envelope of a viscid nature, causing the eggs to stick together in masses. These masses take the form of long tube or net-shaped bands, which are deposited on, and adhere to, water-plants at the bottom of the stream. It is interesting to remark that, rope-like masses of this kind are also laid by the common toad. The eggs of the fishing-frog (*Lophius piscatorius*) are similarly invested by a gelatinous outer coat, and form a floating sheet of from 60 to 100 square feet. Floating masses such as this are rare amongst fishes. The eggs of the herring are laid comparatively near land, and in masses. They are viscid externally, and adhere to any object with which they may come in contact on the sea-bottom.

In the plaice and cod-fish and the allied species, the eggs are buoyant, and laid in enormous numbers at a variable distance from shore. They float just below the surface, and drift accordingly at the mercy of wind and tide.

The size of the egg depends probably upon the number; and the number varies probably as the risks to which they are exposed. How variable the number may be we may gather from the fact that in the closely allied members of the lamprey tribe, Myxine and Lamprey, the former lays probably not more than 30, the latter about 30,000. The sturgeon lays about 7,000,000; the herring about 25,000; lump-fish, 155,000; halibut (which lays a relatively large egg), 3,500,000; cod-fish, 9,344,000; ling, 150,000,000.

The number of the eggs deposited by each particular species of fish, it has just been remarked, depends largely upon the risks from destruction to which they are exposed. These risks are greatest, obviously, in the case of pelagic eggs, *i.e.* eggs deposited far out at sea, and which are left, untended, to drift about at or near the surface, at the mercy of wind and tide, or rather current. Countless as may be the eggs of, say, the cod or ling, thousands and thousands must perish from one cause or another long before hatching; they will have served as food for other fishes, or been borne away by adverse currents and cast ashore; change of temperature will exterminate many more, and so on. Professor G. O. Sars has recorded cases in which myriads of cod's eggs have been thrown up on to the beach, forming a long glistening line at high-water mark.

Many fishes have succeeded in escaping these manifold dangers by fixing their eggs to seaweed, or rocks at the bottom of the sea. Many of these demersal, or deep sea eggs, are also, however, subjected to a heavy tax. They are accordingly produced in great numbers, for though the danger of being carried away in adverse currents has been insured against, there is still provision to be made against the depredation of other fishes. Thus the spawning herrings are followed by countless shoals of haddocks, all greedily contesting for the newly-shed spawn. And to these natural enemies must now be added man himself, who, with the deadly trawl-net, sweeps away tons of eggs yearly.

Those fishes, it will have been remarked, which guard their eggs, either by placing them in a nest, or carrying them on the body, lay but few —comparatively few—for these have eliminated the dangers that threaten pelagic and demersal eggs, and need only provide against accidents at the hands, or rather mouths of carnivorous neighbours in the immediate neighbourhood.

Many marine fishes leave the crowded sea, and its innumerable dangers, to seek safety for their offspring in rivers. Such, for the most part, retain the old pelagic habit of leaving the eggs uncared for, consequently they are produced in large numbers to resist the inroads made upon their numbers, and upon the young fry, by enemies of all kinds. What these inroads are like we shall show in the next chapter.

The salmon is one of the best known instances of a marine fish which ascends rivers to deposit the eggs. Considerable care is manifested in the disposal of these. They are laid in a rough sort of nest called a redd. This is trench-like in form, and made by the female, in exactly what way seems uncertain, but apparently by ploughing out the gravel—the soil always chosen for this purpose—with the under surface of her body. The eggs, which are large, are deposited herein a few at a time; and after having been fertilised by the male, become heavier, and sink to the bottom of the trench. Being somewhat sticky externally they adhere to the bottom, and are then lightly covered over with gravel and left to hatch. The loose gravel soil allows a complete aeration, necessary for the development of the egg. The burying of the egg is a precaution against the raids of birds and other fishes, which greedily devour these exceedingly delicate and nutritious tit-bits.

The life-history of the salmon has been vividly sketched by Mr Rooper, from whom we append the following details:—

"Arrived on the spawning-ground the female, then called a baggit, alone proceeds to form the nest, or 'redd,' as it is termed. This she effects by a sort of wriggling motion of the lower part of her body working in the loose gravel. . . . The redd, a deep trench, being formed, the female proceeds, attended by the male fish—frequently by two kippers, as they are then called—to deposit her eggs. This she does, not all at once, but in small quantities, at intervals, frequently returning to the redd for the purpose. The eggs are at once fecundated by the melt of the kipper, this process going on for two or three days, the fish sinking down occasionally into the pool below to rest and recover their strength. The effect of fertilisation of the ova is to add greatly to their specific gravity; the eggs sink, and are at once covered with gravel by a similar motion on the part of the baggil to that used in the formation of the redd. Here the process being completed, the eggs remain during a period of from one hundred and twenty to one hundred and forty days, according to the temperature of the water. At the expiration of that time the little fish come into existence, and, after a few days, wriggle out of their gravelly bed, and seek refuge under an adjacent rock or stone, where they remain in safety for some twelve or fourteen days longer. . . . Buckland calculated that the number of eggs laid by a salmon was about one thousand to the pound weight, a fish of fifteen pounds, therefore, producing fifteen thousand eggs. . . . After spawning, the fish speedily recover their colour, and to a great extent their condition; the baggit at once losing her dark complexion, and the kipper discarding his hideous livery, his great beak being rapidly absorbed, his sides becoming silvery, and his back assuming a dark bluish tinge."

Pelagic eggs, as we have already remarked, are carried about by the drift of currents. In these currents we may distinguish two kinds, accidental and purposeful. By the former, eggs are seized and borne away to ultimately perish; by the latter, they are gradually carried to a region favourable to development, and to the requirements of the larval fish. The plaice affords us an instance of the nature of pelagic eggs, and their dependency upon favourable currents. These fish lay their eggs far out at sea, whence they slowly drift shorewards, meanwhile developing. By the time they have reached the shallow water bordering the shore the young fish have hatched-out and remain in this shallow water for some considerable time, when they slowly move off-shore into deep water. The precise movements of plaice have been carefully studied, and some very important facts have come to light. It has been shown that the eggs of the plaice laid off the east coast of Scotland drift southwards and shorewards till hatching time. The larva then slowly move northwards along the coast, and then outwards to sea as they reach maturity, to lay their eggs in turn. Thus the breeding area is kept constantly stocked.

It is to this sojourn by the shore that most of us owe our acquaintance with the living plaice, sole and flounder. For it is not the lot of many to "go down to the sea in ships and see the wonders of the deep"—at least, not the kind of ship that goes wonder-catching. The young fry which make their nursery off our coasts are caught in hundreds in the "long-shore" nets, which are assiduously worked throughout the summer months from favourable spots wherever they occur. Who has not watched, and with something of infection too, the groups of excited, bare-legged, holiday-making youngsters, as they seize upon the poor little wriggling and flopping victims, tossed contemptuously out of the nets as "rubbish" by the brawny and thoughtless grey-beards, who earn their daily bread—and not much more—by the continual effort to catch the bigger fish in the sea than they ever succeed in getting out of it? What reckless waste! It is time that some form of instruction, say by means of simple lectures, was instituted to show these same grey-beards — and youngsters too — who do but transgress in ignorance, how tenderly and speedily these young fry should be rescued and restored to the sea: for our food supply is being sorely tapped by the present wasteful fashion of leaving them to die upon the beach.

As Mr Masterman remarks, in writing of the cod's eggs: "It is evident that, for the successful development of the young fish a concatenation of favourable circumstances is necessary, which depends in the main upon such essentially fickle phenomena as wind and temperature. Let the wind blow shorewards with abnormal strength and duration, and untold millions of unhatched cod may perish, or let the temperature, for a few weeks during the summer months, be abnormally low, and the same fate may overtake hosts of embryonic gurnards. Under such conditions it is only by the selection of suitable spawning-sites, a prolongation of the spawning-time (on the principle of not putting all the eggs in one basket), and other devices, that the pelagic spawning fishes have held their own."

The floating, or pelagic eggs, it is interesting to note, are provided with an oil globule which serves to diminish their specific gravity. But it would seem that under certain conditions, as yet unexplained, the specific gravity of pelagic eggs, relative to sea-water, may undergo sudden changes resulting in a sinking or rising. Thus eggs which normally are found only floating at the surface, may occur floating some distance below this, in mid-water, or deeper, even on the bottom. In the Baltic, according to Mr Masterman, "the eggs of the plaice have been found far below the surface, floating underneath the stratum of brackish water." The eggs of the common eel again, which are deposited in the deep sea in 250 fathoms of water, remain suspended in the water at that depth, and there hatch (see p. 129.)

One of the gobies (*Latrunculus pellucidus*), common on the coasts of the British Islands, is remarkable for the fact its whole life's course is run in a single year. In June, July it deposits its eggs, these hatch in August, by December the young have attained their full development. At this period both sexes are alike, having very small teeth, and feeble jaws. In April, however, the male loses his small teeth and replaces them by very long and strong teeth, and with the advent of these new teeth increases the size of the jaws. The teeth of his mate remain unchanged. July and August sees the death of all the adults, so that in September only young fry are to be found. Thus in this goby we have at least one instance of an *annual* vertebrate. The fifteen-spined stickle-back (*Gasterosteus spinachia*) is said likewise to run its life's race in the course of a single year.

Some other fish appear to spawn but once and then die, but these take more than one year to come to maturity. The eels appear to belong to this category.

CHAPTER X.

LARVAL FISHES AND THEIR METAMORPHOSES.

FISHES are born into the world in what is called a larval condition, that is to say, in a condition differing more or less from that of the adult, which is only reached after a series, of frequently well-marked, stages or transformations. Larval vertebrates only occur amongst the fishes and amphibia—the frogs and toads and their kindred: but amongst the invertebrates we have quite a large variety of larvæ. The caterpillar is a larval form with which every one must be familiar. Marine "worms," star-fishes, sea-urchins, "shell-fish," and crustacea-crabs and lobsters and their kind, furnish us with many most curious and often wonderful and complicated larval forms.

When we come to reflect upon this matter a little, we remark that larvæ are characteristic of those animals which lay small eggs, whilst those which lay large eggs produce young which resemble the parents in all respects save size and perhaps colour, or other minor details.

But what has the size of the egg to do with the matter? Just this. That which we know as the egg, the hen's egg for example, contains within the familiar shell two very important parts—the germ which is to develop into the chick, and a large store of food material, which we call the yolk. The amount of this yolk in the bird's egg is, relatively to the size of the germ—enormous; quite sufficient, indeed, to support the developing chick for a comparatively long period. By the time this yolk is all absorbed the development of the chick is almost complete, little more than increase in size being now necessary. The eggs of fishes, on the contrary, never contain much yolk, only sufficient to support embryonic development—as opposed to larval development—for a short time. So soon then as this yolk is all absorbed embryonic development ends, and the larval development begins. The larval development often begins so early that special or temporary feeding and locomotory apparatus have to be introduced to serve whilst the permanent organs are being built up.

This is well seen amongst the invertebrates. With the vertebrates changes of this kind also occur, but not on quite so marked a scale. As Prof. Miall has aptly put it, the choice between embryonic or larval development depends "upon the number of the family and the capital at command. These are animals which are like well-to-do people who provide their children with food, clothes, schooling and pocket-money. Their fortunate off-spring grow at ease, and are not driven to premature exercise of their limbs or wits. Others are like starving families, which send the children, long before their growth is completed, to hawk matches or newspapers in the streets."

The young fish then, being the product of a small egg, ill-provided with nutritive yolk, comes into the world in a larval condition. The precise form of larva may be described as the tadpole-larva, and it is interesting to note that this form is common to larvæ lower in the scale than the fishes—to wit, those remarkable creatures which lie in the borderland between the vertebrate and invertebrate—the ascidians or sea-squirts; and the larvæ higher in the scale, the amphibia, such as the frog and toad or the newt, for example. The tadpole in its simplest form is a long-tailed animal strengthened by a kind of fibrous rod running down its body from the head to the tail, immediately below the spinal cord. It breathes by gills, and has a mouth in the form of a sucking disc. "It is a cheap form of larva," says Prof. Miall, "when reduced to its lowest terms, requiring neither hard skeleton, nor limbs, nor neck, yet it can move fast in water by means of its sculling tail."

In more than one instance these larvæ have been mistaken for adult species, their immature condition being unsuspected.

A case in point illustrating this is afforded by one of the lowest of the fishes—the fresh-water lamprey (*Petromyzon planeri*). For a long while the young of this was regarded as a distinct species, the ammocetes. Its true nature was discovered by a German ichthyologist, Aug. Müller. The young ammocetes, like the typical tadpole larva of our text, has a sucker-like mouth devoid of teeth, and in many other respects differs from the adult form. It is further remarkable in that the full-grown larva may even be larger than the adult! Its larval life is a very prolonged one, lasting often as long as five years. Its transformation into the adult form seems to be as sudden as it is radical. Amongst the more important of these changes are the introduction of conical horny teeth, and the development of the eyes, which in the larval form lie beneath the skin, like those of the young of many of the higher vertebrates, *e.g.*: the cat, dog and rabbit. Changes in the form of the skeleton, of the gill-pouches, and of the alimentary canal and kidneys also take place, and are changes of great significance. We might mention here that the adult life of the lamprey is very brief, and terminates directly after the deposition of the eggs or sperms, as the case may be.

The sucker-like mouth, or suctorial mouth, as we may more conveniently call it, is a feature of great importance, and occurs in a considerable number of the larvæ or embryos of the lower vertebrates. When the mouth itself is not directly suctorial, as in the lamprey which we have just discussed, it is associated with a more or less well-developed suctorial disc. For instance, in the tadpoles of the frog, there is a disc of this nature situated behind—tailwards—of the mouth; in the larval lepidosteous, or bony pike of America, there is a similar disc in front of the mouth. The larval ascidian, or sea-squirt, has an adhesive disc, also situated in front of the mouth. Traces of this disc appear in the young sturgeon. It is believed, from these facts, that the ancestral vertebrates probably all had the mouth bounded by a suctorial disc, which is therefore a primitive organ of some importance. Of this disc a part only is developed in modern larvæ or embryos, which may be either that part bounding the front of the mouth, or that behind—tailwards—of it. Furthermore, the mouth itself was also probably suctorial in character, like that of the young lamprey; later, it became further modified for biting purposes and developed jaws. The function of the disc is for the purposes of attachment to weeds or other objects, while the larva is at rest. The action of these discs can be readily studied by anyone who will take the trouble to collect a few young tadpoles from the nearest pond during the spring months. Artificially hatched, "bony-pike" all attached themselves to the sides of the glass vessel in which they were placed, by their discs. The young sea-squirt soon after hatching attaches itself to a rock by this disc, and remains fixed whilst it undergoes the very extraordinary and remarkable changes which ultimately end in its transformation into the shapeless mass from which the adult form takes its name. The curious tactile organs or barbels, described elsewhere, are probably structures arising from the modification of this disc. The larval sturgeon shows how this has came about.

We may turn now from the mouth to a consideration of the gills of the larval fish, since in these we have again characters which are shared in common with their allied but less humble relatives, the amphibia. In the young shark, and, to a certain extent, the sturgeon, and in the young bony-pike (*Lepidosteous*) mud-fish (*Protopterus*), and "bichir" (*Polypterus*) fig. 3, p. 26, the breathing organs or gills, like those of the larval frog or newt, take the form of more or less branched or feather-like organs, the branches springing from a common shaft, or of delicate filaments projecting from the gill-slits.

It is to be noted, however, that it is the so-called "ganoid-fish" and lung-fish larva which most nearly resembles the amphibian: the delicate filamentary gills of the shark, it is believed, probably represent secondary and not primary structures. These gills are in all cases but temporary outgrowths, being replaced in the fishes either by internal gills—which have already been described (p. 20)—or by gills and lungs, *e.g.*: lung-fishes, or by lungs only, *e.g.*: amphibia. These permanent breathing organs, it appears, require time for growth, hence the temporary structures which gradually become absorbed in proportion as the permanent structures assume their duties. In the case of some of the amphibia, *e.g.*: the axolotl of Central America, the larval condition—and hence the external gills also—is rarely exchanged for the adult form, all the functions of life including the reproduction of the species being fulfilled by the larva. The young of the higher (*Teleostean*) fishes never produce external gills.

Besides the suctorial mouth disc and the external gills, we have yet another larval character, one which not only carries us back to, but actually connects the larva with, the egg itself. The larval condition, as we have already remarked, is consequent upon the fact that the egg from which the young is produced contains only a limited amount of food material insufficient to enable the growing embryo or unhatched fish, to complete its growth into a fully formed fish. For this reason, as soon as the process of hatching has become an accomplished fact, certain temporary structures have to be developed in order that the processes of further development may be completed. The nature of some of the more important of these temporary structures we have just discussed. Some of them undergo further transformation and development into adult structures, and some are purely larval organs and are put away with other childish things, if we may be permitted the metaphor, when the adult stage is reached. The newly-hatched young of the shark tribe will best bring home the nature of the relation between the larva and the egg.

Fishes of this kind, often for several months after they leave the egg-shell, bear about with them a very considerable amount of the remains of that portion of the egg which constitutes what is called the food yolk, in a flask-shaped bag with a long neck, attached to the under surface of the body (fig. 11). The mouth of this flask opens into the intestine, and thence the contents of the bag pass up into the gut as required. At least this is the state of things at first; later the connection with the gut is cut off, and the last remains of the yolk are absorbed by the blood-vessels alone.

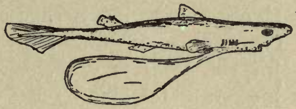


FIG. 11.—A larval dog-fish.

Why this curious method of absorbing the yolk should be, depends upon the very extraordinary fact that, the gullet or food-pipe, at first quite tubular, later closes up and becomes quite solid, so that all swallowing becomes absolutely impossible. During this period the advantage of the pendant yolk-sack in open communication with the gut is obvious. Its absorption later, after the reopening of the proper food passage by the blood-vessels, is as much a matter of convenience as for the sake of nourishment. The explanation which has been given to account for this curious closure of the gullet cannot be discussed here. In other larval fishes, such as lung-fish, "ganoids," and the higher "teleostean" forms, of which we may instance the salmon, perch or cod-fish, the yolk-sack is relatively smaller and packed away beneath the body, not pendant as in the shark, but the same curious history with regard to the closing of the gullet is repeated here.

This matter of the relation between the larva and the egg is somewhat of a digression, albeit necessary. Besides the circular suctorial mouth disc—which, however, as we have seen, may be represented only in part, either by that portion in front of, or behind the mouth, or more primitively still, by a suctorial mouth—and the external gills, our larval form is conspicuous for the absence of limbs, and the presence of a long tail fringed by a delicate membrane, the tail-fin. This tail is the only organ of propulsion. Such a form is one of peculiar interest, and of first-rate importance, since it is characteristic of many very different, and only distantly related, animals. Occurring as a phase in the life history of the tunicates or sea-squirts, fishes and amphibia. This fact is regarded by scientific experts as a reasonable proof that these early stages, common to such different forms, represent the primitive vertebrate model out of which all the vertebrata have grown by gradual modifications, and transformations. The nature of these transformations we have already hinted at. Thus, to take the breathing-organs. These are first represented by external gills, which are gradually replaced by internal gills, whose duties are in great part transferred, in some fishes, to still more internally removed respiratory organs, which we call lungs. In the frog tadpole external and internal gills each in turn pass away, and are completely and slowly supplanted by lungs, whilst the internal gill supports become modified to serve as supports for the tongue. In the higher vertebrate, for many reasons into which we cannot enter now, the gill-breathing stage is entirely suppressed, but even in man himself the gill-slits and arches still appear during the early stages of his development. Out of these last indeed, as in the frog, the supports for the tongue are made. The nature of the transformations and modifications which give rise in turn to continuous fin-folds and fins, and the gradual evolution of the latter into walking limbs, for the support and carriage of the body on land, we have already sketched in an earlier chapter.

So much for the typical and primitive larval stages. Let us now turn to some of the more interesting of the stages through which some larval fish pass, on their way to the adult condition. Perhaps one of the most remarkable of these is that of the young of our common fresh-water eel.

Until quite recently the early history—the babyhood, so to speak—of the common eel was enshrouded in mystery, and was regarded as a zoological puzzle which would reveal itself in due time. Some, anxious to hasten this longed for time, allowed their imagination to carry them beyond the sure grounds of fact into the domains of romance; or, at any rate, setting aside all caution, they gave full vent to fancy, with the result that fact and fiction were woven together with dire results to truth. The outcome of this unholy combination (in science) was a theory to the effect that eels were developed from horse-hair, which dropped into the water from the tails of horses when they came to drink. After long soaking they became endowed with life, and turned into worms. These worms, almost hair-like in thinness, were known as "hair-eels," and they in course of time completed the wondrous transformation by developing into true eels!

There never was a mystery but some one was ready with an explanation. The above effort to throw light in a dark place was regarded as quite satisfactory by people of not so very long ago. In that explanation we see now a suggestion of that love of the fantastic, and the wonderful, characteristic of the older generations. A readiness to accept any hypothesis that presented itself without much question or demand for credentials. But, as in so many other instances, there is an element of truth permeating this untruth. This truth is represented in so much as concerns the hair-eel. The "hair-eel" belongs to a group of commonly parasitic nematoid worms, the early stages of existence of which are passed within the bodies of aquatic insects, from which they ultimately emerge to pass the adult condition as free-swimming organisms. In this adult condition the males at least bear a very remarkable resemblance to horse-hair, being very slender, hard, and shining black in colour. Now, in the days when men believed that life could be engendered from non-living matter, given favourable conditions, there seemed no reason to doubt but that horse-hair might become, by sufficiently prolonged soaking, transmuted into its living prototype, the "hair-eel," and this, by continuous growth, might in turn become the true eel. When the belief that non-living matter could, under certain conditions, beget living organisms, was shown to be untenable, the source of origin of the common eel became more mysterions than before. And a mystery it remained until the year of Grace 1864. In that year Mr Gill read to us the riddle of all the ages, at least since Aristotle. He showed us that some forms at least of certain curious, rare and very delicately framed fishes, which had long been a stumbling-block to scientists, were none other than the long-sought-for larval eels. They had already received the name of *Leptocephali*, but were regarded as monstrosities, the victims of uncongenial surroundings. Thus Dr Günther, one of the most profound authorities of our time on all matters pertaining to fishes, wrote of them: "We must come to the conclusion that the Leptocephalids are the offspring of various kinds of marine fishes, representing not a normal stage of development (larvæ), but an arrest of development at a very early period of their life; they continue to grow to a certain size without corresponding development of their internal organs, and perish without having attained the characters of the perfect animal." A year after this was written Dr Günther himself was enabled to add further confirmation of Mr Gill's discovery. But it was not till 1896 that certain Italian naturalists, by a very careful and exhaustive study of a large series of Leptocephalids were enabled to establish beyond fear of dispute, that these remarkable and puzzling fish were larval eels —not only of fresh water, but marine forms also. These larvæ, furthermore, brought to light some very extraordinary facts, one of the most important of which concerns the law of growth. Thus they go on increasing in size and favour daily, up to a certain point, when they actually begin to grow backwards, that is to say, they decrease in size from day to day up to a certain point, then growth recommences; with this new growth they assume the characteristic round, eel-like form, ascend to the surface of the sea, and in the case of the fresh-water species, make their way with all speed up the rivers, in which journey we shall follow them in the next chapter (p. 144). The accompanying figures give an indication of the delicacy and transparency of these fish at this early stage, the internal structures in the living larva being quite distinct (fig. 12). The curious changes in the rate of growth and the small size of the head, very striking features of the larvæ at this stage, are also well brought out in the figures. When a Leptocephalas has completed the first stage of

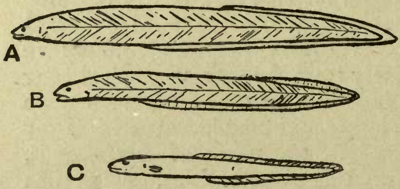


FIG. 12.—Fish Transformations. *A. B. C.* Three stages in the life history of the Eel: showing the gradual decrease in size as the fish grows older. With the decrease in size the eel-like shape is gradually acquired. At *C.* the minimum decrease has been reached. The young fish has now reached the "Elver" stage and ascends rivers to complete its growth into the adult eel.

its growth it ceases to feed, and thereby loses considerably in bulk. At the same time it develops what has hitherto been lacking—pigment or colouring matter, then it discards its larval teeth, and replaces its soft membranous backbone by a series of hard and complicated bones. Much of what these Italian naturalists have told us was the result of direct observations of living specimens kept in an aquarium.

The manner of capture of these living fish is curious. The majority are procured from the Straits of Messina by a series of fortunate accidents, which are constantly repeated. These "accidents" are due to the fact that mighty currents every now and then boil up in the narrow straits, bringing with them the strange inhabitants of these unexplored regions—eggs, larvæ and fishes of many kinds, besides other forms of animal life. But besides this there is yet another source from which Leptocephali are obtained; one of these is, curiously enough, from the stomach of that grotesque monster the sun-fish (*Orthagoriscus mola*); another way is by dredging.

It is certain that there can be few fish with which we are more familiar than those which we know as "flat-fishes"—the sole, plaice, turbot, halibut, and flounder tribe. Yet, probably few people have any idea of the wonderful course of events which leads to the characteristic "flat-fish" shape. Into this shape then we must look a little more closely. To begin with, the familiar "dark" side and "white" side do *not* represent the dorsal and ventral aspects of the animal.

That is to say, they do not represent the back and the belly, but *the right and left sides.* In some fish it is the right side which is uppermost, in some the left. When the fish swims it does so by an undulatory motion of the body; that is to say, progressing by means of wave-like movements passing from head to tail. But it does not swim vertically, but retains the position which it holds when at rest—the dark side being kept uppermost. Another point about the adult, which we shall appreciate now, is the fact that the eyes are not on opposite sides of the head, but lie side by side on the upper surface. How this comes to be, and how it is that the fish comes to lie always on one side or the other, we may discover from a study of the larval fish. This, when it emerges from the egg, is perfectly symmetrical, and gives all promise of developing into the typical fish-like form. Soon, however, a change becomes obvious, for there is a marked tendency to lie at rest on one side, right or left, which becomes more and more pronounced daily. Simultaneously with this new position, the left or right eye begins to migrate from what is now fast becoming the under to the upper side, and the attainment of this end is accomplished at the expense of the symmetry of the skull, which eventually, with the complete migration of the eye to the upper surface, becomes quite asymmetrical. The reason for the really wonderful transformation exhibited by the young flat-fish is one of nature's mysteries which no one has yet succeeded in solving.

But eels and flat fish do not exhaust the list of transformations to be found amongst the fishes, though in these two particular instances we have

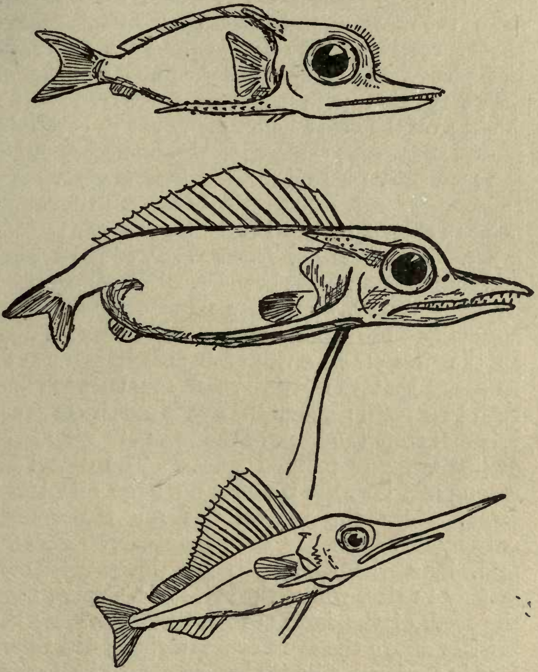


FIG. 13.—Three stages in the development of the Sword fish (after Günther).

the most interesting of them all. The significance of transformations is in some cases more or less obvious and intelligible; but as often as not we have to rely mainly on conjecture in endeavouring to find an explanation of their meaning. In some cases it would indeed seem as if the now almost discarded recapitulation theory received some support. That many of the phases of these transformations have a direct relation with the past there can be no doubt; on the other hand, many are as certainly special adaptations belonging to, and necessary to, the particular phase in which they appear. An exceedingly instructive series of stages in development is shown in the life history of the sword-fishes. The young of *Histiophorus*, of the Pacific and Indian Oceans, has been beautifully illustrated by Dr Günther, and these figures, by his kind permission, have been reproduced here (fig. 13). In the first stage, a fish of 9 mill. long, it is to be noted that the jaws are of equal length and both bear teeth; above the eye is a series of short bristles; from the back of the head project, above and below, long pointed spines. The dorsal fin is long and low, the pectoral fin large and truncated, whilst the ventral fins are represented only by tiny buds. In the next stage, a fish of 14 mill. long, the dorsal fin has increased enormously in size, whilst the spines projecting from the back of the head are relatively shorter; the bristles above the eye have vanished; the upper jaw has grown slightly longer than the lower; the ventral fins, represented previously by buds, have now increased to long slender filaments; the pectoral fin has changed its shape, and the pre-operculum or gill-cover has increased greatly in size. In the third stage, a fish of 14 mill. long, the dorsal fin has developed unequally, dividing the whole into two distinct parts, an anterior of great size and a smaller posterior; the upper jaw has increased so as to project considerably beyond the lower, whilst the teeth have disappeared; the long spines from the back of the head have almost vanished, whilst the ventral filamentous fins have become reduced in size. In the eye there is a conspicuous relative decrease in size from the earliest stage onward. The great size of the eye is a feature of all vertebrated animals, during the embryonic stages of their growth at any rate.

The young of the sun-fishes again present some very remarkable features—of which there is no indication in the adult forms—so much so that these young have been described as of distinct genera. The main features which characterise them at this period is a series of sharp spines projecting in all directions all over the body. The adults are either smooth-skinned or covered with minute prickles, according to the species. Similarly, the young of one of the flying-fishes (*Dactylopterus*), of the sea-perch (*Serranus*), the "rockling" (*Motella*), and some others have passed unrecognised, and have also been described as distinct genera, their identity being so completely masked.

The young of the ribbon-fish (*Trachypterus*) are remarkable for the very extraordinary development of the fin-rays, exceeding that of any other known fishes; sometimes their fin-rays are many times longer than the body; moreover, these fin-rays are provided with curious lappet or flangelike dilatations. The great length of these fin-rays shows that these fish are hatched far down in the depths of the sea, where absolute stillness prevails, the currents such as prevail at the surface would wreak ruin on such fragile structures at once.

A most remarkable trait in the life history of larval fishes is that exhibited by the young of the sand-smelts (*Atherina*), which, for some time after hatching, cling together in dense masses and in enormous numbers. It is said, by the way, that that peculiarly larval and archaic type, the *Amphioxus*, occasionally forms a swimming chain by uniting one with another by their mouths. This is the only other instance I can recall comparable to the masses of young fry of the sand-smelt.

CHAPTER XI.

MIGRATION AND HYBERNATION

THE migratory impulse seems to be as strongly developed in the fishes as in the birds. In no other vertebrates, indeed, save these two classes, do we find these periodic movements so well marked. This is probably due to the peculiar facilities offered either by air or water for extensive journeys under fairly uniform conditions. Barriers such as confront non-flying terrestrial animals being absent.

Migration with both bird and fish is generally associated with the provision for the next generation, but whilst in the former it seems to be due to the need of securing a certain and suitable food supply, in the latter it appears to be rather the need of securing a larger amount of protection for the offspring. In this solicitude, if we may call it so, for the preservation of the species, many fishes have succeeded in passing what proves an insuperable barrier to most—to wit, the passage from salt water to fresh, and *vice versâ.* Surface temperature, however, and climate present an additional barrier to many fresh water fishes, preventing their further movement even if they could survive the transition into salt water. That is to say, a fish which might survive this exchange of medium, would succumb to the effects of changed temperature. Salt water fishes do not appear to be so deeply affected in this matter.

In addition to this orderly and periodic migration, in which shoals of countless millions are involved, we have a form of what we may call sporadic migration—many marine fishes individually ascending rivers for hundreds of miles of their course, whilst many fresh water fishes similarly descend into the sea, though these are fewer in number. This passage from fresh to salt water is often very gradual, broken by a longer or shorter sojourn in brackish water, but in some cases (as in the common stickle-back) the transition may be quite sudden without producing any injurious results. Migration of this kind is not associated with any known cause. The exchange from a salt to a fresh water habitat may have been to avoid competition in the more crowded sea;

to this exchange we owe the preservation of some very interesting and archaic forms, such as the bony-pike (*Lepidosteus*), bichir (*Polypterus*), and barramunda (*Ceratodus*), for instance.

There can be no doubt but that fish life originally commenced in the sea, and spread thence to the brackish and fresh water by a series of sporadic migrations such as we have just instanced. Possibly this migration was due to pressure and competition amongst the species involved in this migration, just as amongst ourselves, overcrowded populations seek relief by emigration.

The causes of the migration of the mackerel seems to be an exception to the rule suggested—that migration in fishes is probably due to the desire to secure a safe harbourage for the young fry. Mackerel swim in shoals, and spawn in the open sea. Periodically, however, they appear off shore, apparently, as Dr Günther suggests, in pursuit of other fishes on which they feed. They prey upon the young and adults of the herring-tribe, the pilchard and sprat. These guide the movements of the mackerel.

The perils of the migrating adults of such species as the herring or sprat, for instance, are many, for not only are they subjected to an unceasing attack from hordes of their predaceous relatives, but toll is taken by numberless others besides, such as "schools" of porpoises, and countless flocks of birds, who seize them from above. Besides these we have to reckon the millions captured annually by our fishing-fleets. In spite of all this persecution, wonderful though it be, the herring, for instance, still holds its own.

In studying migratory movements many facts have to be kept in sight, and a close watch has to be placed on the migrants in order that we may discover, if possible, whether, there is any return of those fishes which move to some distant spot for the purpose of depositing their eggs, and what, if any, changes are undergone in the appearance of the pilgrims during their journeys to and fro. Some of the more interesting of the details of this aspect of the life history of fishes will be discussed now.

The migration of the salmon may fittingly come first under consideration, and illustrates the migration from salt into fresh water, of which we have already hinted. The efforts which the salmon makes to gain the upper waters of the rivers they ascend may often be truly described as Herculean. Rapids, even of six feet high, they surmount by leaping, trying again and again until successful (see frontispiece). In some of the Scotch rivers artificial stairs have been constructed in order to enable them to overcome some of the otherwise unsurmountable barriers. "Excelsior" seems to be the salmon motto. So violent are their exertions that they have perforce often to rest for days in some quiet pool, from whence they continue their struggle upwards. At last the Mecca of the pilgrimage is reached; but the journey and the nature of its termination tells sadly upon both males and females. "To such," writes Mr Rooper, "as have only seen the salmon in prime condition, the appearance of the fish when on the eve of spawning would come as a surprise. The female is then dark in colour, almost black, and her shape sadly altered for the worse from that which she presented when in condition. As for the male, he is about as hideous as can well be imagined, his general colour being a dirty red, blotched with orange and dark spots. His jaws are elongated, and the lower one furnished with a huge beak, as thick and nearly as long as a man's middle finger; while his teeth are sharp and numerous, and his head, from the shrinking of his shoulders, appears disproportionately large. His skin also is slimy and disagreeable to handle, and, in fact, scarcely a more repulsive creature in appearance exists. . . . After spawning, the fish speedily recover their colour, and, to a great extent, their condition; the baggit (as the female is called) at once losing her dark complexion, and the kipper discarding his hideous livery, his great beak being rapidly absorbed, his sides becoming silvery, and his back assuming a dark bluish tinge."

Salmon return year by year to the river in which they were hatched, just as swallows and many other birds return each spring to their own particular nesting-places. At least this is generally the case, but it would seem that some on leaving the river stray so far away that they are unable to find their way back. There seems, however, to be a yet deeper, may we say "instinctive," impulse behind these apparent tender associations and regard for the ancestral waters. Since year by year fish hover longingly at the mouths of the Thames and the Liffey, for instance, yet, at least in the former river, are compelled to relinquish their attempts to make their way up on account, to our discredit be it said, of the foulness of its waters. When these shall be once more free from pollution—and they are slowly approaching this blessed state, thanks to modern sanitation—we shall once more restore to these debarred ones their ancient home and shelter in Father Thames. With the Liffey it would appear things are not quite so bad, and, remarkable as it may seem, the fish apparently know that the polluted water is but local and of a limited area, for they have been remarked to charge this befouled region at full speed, and successfully emerging in pure water, to lie quiet for a few hours to recover from their exertions. How is it, we may ask here, that since no fish have been hatched in the Thames for many generations, an effort is still made, or at least contemplated, to gain the paradise of the quiet upper reaches which lay far from the busy turmoil at the river's mouth? Is there a tradition of golden days within the sanctuary of this grand old stream? or is this yearning to ascend to be regarded as a transmitted impulse?

The sturgeon is another denizen of the sea—though there are some fresh water species—that annually ascends the rivers to spawn. "In summer," writes Mr Lydekker, "regular fishing stations are established on the Russian rivers, where the approach of a shoal is heralded by a watchman. Upwards of fifteen thousand have been taken in a day at some of these stations;

and when the fishing is suspended for a short time, a river of nearly four hundred feet in width and five-and-twenty in depth has been known to be completely blocked by a solid mass of fish." Sturgeon fishing is prosecuted for the sake of the flesh, the ova, from which caviare is made, and the air-bladder, from the inner lining of which isinglass is prepared.

The sturgeon and the salmon afford us instances of a universal migration of adults from the sea into the rivers for the purposes of making provision for the future generation. But besides these armies of adults, the rivers are also invaded by hosts of young fishes hatched in the sea, but which complete their growth in the rivers. The common eel is one of the most interesting of these hosts. "In the course of the summer," writes Dr Günther, "young individuals from three to five inches long ascend rivers in incredible numbers, overcoming all obstacles, ascending vertical walls or flood-gates, entering every larger and smaller tributary, and making their way even over *terra firma* to waters shut off from all communication with rivers. Such immigrations have been long known by the name of *Eel-fairs*. The numbers participating in these migrations are so vast as to be almost incredible. Upwards of three tons of "elvers" —as these young eels are called — were despatched in one day from the Gloucester district in the spring of 1886, and it has been estimated that over fourteen thousand of these elvers go to make a pound weight. "In the previous year," writes Mr Lydekker, "the annual consumption of eels was estimated at a minimum of 1650 tons, with a total value of £130,000." It is believed that the adult eel does not return to the river, but dies soon after having deposited its eggs, or their equivalent.

The young salmon on their way down to the sea are equally subjected to persecution, though only from their natural enemies. These young fish, it should be remarked, for the first year of their existence, at least, are known as "parr." At the end of this first year they take on the brilliant silveryness and characteristic marking of the adult form, and are known as "smolt." "Perhaps," says Mr Rooper, "with a wish to exhibit himself in his new and beautiful apparel, [he] evinces a daily increasing restlessness and desire to quit his home. With the first floods in May myriads of these lovely little fishes start on their downward journey toward the sea. It is a beautiful sight to watch their movements when descending; and for many days the river teems with them, not a square foot of water being without one where the stream is at all rapid. As fry the smolts were exposed to many dangers, but they were nothing to those which beset them as parrs, on their journey towards the sea. Their enemies are legion. Trout and pike devour them, gulls swoop down and swallow them wholesale, herons standing mid-leg deep in the water pick them out as they pass, and even their own kindred devour them without scruple. Unluckily, too, for them, a certain number of great hungry kelts (as the fish are called after spawning) having recovered to a great extent their condition, accompanying them on their seaward journey, and prey upon their young companions as they travel; and I believe that a hungry kelt will devour upwards of forty or fifty smolts in a day. Arrived at the sea, the little fish are met by a fresh array of enemies. The army of gulls is always with them, and these are reinforced by cormorants, divers, and other sea-birds, besides which shoals of ravenous fish await their arrival, and assist in thinning their ranks. It is wonderful that any should escape, and but for the extraordinary fecundity of the salmon they would speedily be annihilated; but such is their prolific nature that a remnant always survives to return to the spawning-beds and keep up the supply. . . . The food of the smolt during his sojourn in the sea is abundant, consisting chiefly of sand-eels, molluscs and marine insects. The smolts increase accordingly very rapidly in size, and in three or four months the fish that came down five or six ounces in weight returns to the river from whence he came, a grilse of from four to six pounds: the grilse being the fifth stage of the salmon's existence. Unless accidentally prevented, the grilse always returns to the river from whence it came, and after spending the autumn and winter at home, and providing for the continuance of the family by spawning, as already described, returns as a kelt to the sea in the following year, reappearing the next as a salmon of at least ten or twelve pounds' weight."

Our common stickle-back affords us an instance of that mysterious sporadic migration by vast numbers which occurs amongst all groups of animals not usually regarded as migration species. Thus Dr Günther records, on the authority of Pennant, "that at Spalding in Lincolnshire, there was once in seven years amazing shoals, which appear in the Willand, coming up the river in the form of a vast column. The quantity may, perhaps, be conceived from the fact that a man employed in collecting them, gained, for a considerable time, four shillings a-day by selling them at the rate of a halfpenny a bushel."

Similarly, the horse - mackerel sometimes appears off our coasts in incredible numbers. On one occasion, it is on record, as many as ten thousand were taken in Cornwall. In 1834 one of Yarrell's correspondents informed him huge shoals were seen on the Glamorganshire coast. "They were first observed in the evening, and the whole sea, as far as we could command it with the eye, seemed in a state of fermentation with their numbers. Those who stood on some projecting rock had only to dip their hand into the water, and with a sudden jerk they might throw up three or four. The bathers felt them come against their bodies, and the sea looked on from above, appeared one dark mass of fish. Every net was put in requisition; and those which did not give way from the weight, were drawn on shore laden with spoil. One of the party who had a herring-seive with a two-inch mesh was the most successful; every mesh held its fish, and formed a wall that swept on the beach all before it. The quantity is very inadequately expressed by numbers, they were caught by cart-loads. As these shoals were passing us for a week, with their heads directed up channel, we had the opportunity of noticing that feeding-time was morning and evening. They were pursuing the fry of the herring, and I found their stomachs constantly full of them."

Another form of sporadic migration, and less mysterious, is that of some of the South American cat-fishes, which appear to possess a remarkable power of anticipating disasters. For they have a "habit of travelling during the dry season, from a piece of water about to dry up, in quest of a pond of greater capacity. These journeys are occasionally of such length that the fish spends whole nights on the way, and the bands of scaly travellers are sometimes so large that the Indians who happen to meet them, fill many baskets of the prey thus placed in their hands. The Indians supposed that the fish carry a supply of water with them, but they have no special organs, and can only do so by closing the gill openings, or by retaining a little water between the plates of their bodies."

The Indian serpent-head (*Ophiocephalus*) can travel considerable distances over moist ground, progressing in a serpentine manner, by means of their pectoral and tail fins.

It sometimes happens that fish are forcibly translated from one place to another by floods, for instance, and manage to establish themselves in their new conditions and thrive. In this way many isolated pools and lakes may have been peopled; often with forms not naturally to have been expected to obtain there. The writer well remembers an extraordinarily high tide on the river Yare in Norfolk, which flooded the marshes some seven or eight miles from the sea. Some four months later, at about Easter-tide, codlings and whitings were being daily captured in the ditches which bounded the various marshes. The water here was almost fresh, yet these salt-water forms when captured were in fine condition, apparently having suffered neither from change of water nor their narrow surroundings.

The disappearance of an animal from its familiar haunts does not necessarily imply migration to some distant region. Indeed the older naturalists, both lay and professional, commonly overlooked the phenomena of migration altogether, and believed the sudden disappearance of this or that particular animal to be explained by its retirement to some sheltered nook or cranny. This disappearance was more particularly associated with the approach of winter. Many believed that the swallows, for instance, sought shelter from the rigours of this season in sheltered caves or other hiding-places, or even in the mud at the bottom of pools and streams; and there are most circumstantial accounts extant of eye-witnesses to this strange disappearance, which, needless to say, never happened. In justice, however, to these older observers, it must be remarked that many animals actually do seek retirement at the fall of the year, as witness the bat, squirrel, dormouse, bears, snakes, lizards, frogs, fish, and, in short, quite a host of animals. This periodical retirement we know as "hybernation." Extended observation has shown that extremes of heat are followed by a similar retirement on the part of many animals, so that we may discuss the facts herein concerned under two heads: (1) winter sleep and (2) summer sleep.

The winter sleep seems to be gradually induced by the reduction of the temperature, and to be sustained so long as the low temperature continues. The desire to sleep felt by ourselves on exposure to extreme cold is well known, as are the fatal effects which follow any yielding to this desire.

The carp amongst the fishes is one of the most familiar instances of winter-sleepers. In winter great numbers bury themselves in the mud amongst the roots of plants, where they remain torpid for many months. So, too, does the tench.

The facts concerning summer sleep are much less familiar. The drowsiness that overcomes us on a hot summer's day will naturally be recalled in this connection, and we may even proceed to connect this with the similar inclination to sleep under the influence of extreme cold. To suppose that in either case the temperature alone is the cause of this deep sleep—chill-coma and heat-coma—would be to fall into an error. This deep sleep is rather a way provided by Nature as an escape from famine. Excessive cold and excessive drought alike cut off the food supplies, and drought, in the case of many fishes even the element in which they live. The African mud-fish (*Protopterus*) will afford a case in point, illustrating the effects of prolonged drought (fig. 14). The rivers in which these fishes live for many weeks or months are absolutely drained, and their beds become baked by the burning sun. To escape an otherwise certain death the mud-fish burrows down into the mud, and there tarries till the clouds come again bringing the grateful rain. In burrowing, as soon as the fish has reached a sufficient depth it coils itself up into a half-circle, covering its mouth with its tail. The skin then secretes a quantity of slime, which forms a sort of inner coating to the mud-chamber in which it is now enclosed, and which serves to keep the walls moist. This chamber is known as a "cocoon" from its resemblance to the cocoons of beetles and moths, which, it will be remembered, are constructed variously of silk, wood-pulp, or earth. While enclosed in their self-made prison numbers are dug out and sent to this country. The writer well remembers assisting Dr H. O. Forbes to release a number of these fishes from their cocoons, at one of the evening conversaziones held during the last meeting of the British Association at Oxford. The clods of earth containing each fish, or sometimes two, were then more than *six months old*, and had to be broken up with a saw and chisels. When the bulk of the earth around the slimy case had been removed, the cocoon was placed in a tank of tepid water. This rapidly dissolved

Fig. 14.—Outline figure of the African Mud-fish (*Protopterus annecteus*).

the mud and set free the captives, who were soon swimming about as if in their native rivers. Some of these fish were kept alive for many months.

The Indian serpent-head (*Ophiocephalus*) likewise passes prolonged seasons of drought enclosed in mud, emerging therefrom only after the rains have filled the bed of the stream.

The climbing-perch (*Anabas*) of Ceylon also withdraws to a mud retreat, and is habitually unearthed with the shovel by natives.

A trout-like species of fish (*Neochanna*) of New Zealand is so far known only by specimens which have been obtained from mud-burrows at a distance from water. These burrows are excavated by the fish, but how, or under what conditions, appears yet to be a mystery!

CHAPTER XII.

TRANSFORMATIONS

THE stock-in-trade with which fishes start in life is a comparatively limited one, being no more, in fact, than is sufficient to complete the outfit necessary to meet immediate needs. Evolution, progressive or otherwise, is possible only by modifications of, and additions to, the original structures represented in the person of the founder of the house. Other chapters in this little book bear witness to the magnitude of the changes which have taken place during the development of the various organs of the body. The present will indicate a few of the changes of another kind, of which evidence is to be found in a study of the anatomy of fishes. These well show how the already elaborated structures and secretions may combine to form yet other structures. Often these arise in parts of the body which have been relieved of their original functions, and are therefore free to undertake such new duties as may be beneficial for the continuance of the species. This replacement of one organ by another is known as the *substitution of organs.* Instances of such substitutes we shall discuss here, together with cases wherein organs of long standing have become further adapted to perform new duties without undergoing any great changes in external appearance.

A simple instance of the substitution of organs is illustrated by certain members of the skate tribe. The skates are nothing more than highly specialised sharks. They have become skates, we may put it, by virtue of the fact that they have transferred the seat of locomotion from the tail to the pectoral fins. These have become enormously developed in consequence—a development accomplished at the expense of the tail, which has become greatly reduced in size, and functions only as a rudder. The changes in the general form of the body, consequent on this substitution of the pectoral fins for the tail, have become so marked that naturalists once separated all the animals so affected into a group by themselves—the skates. The release of the tail from its original function of propelling has been followed in some cases by its degeneration, and in others by its transformation into an organ of prehension and weapon of offence. Thus in some of the eagle-rays of the genus *Ælobates*, it has assumed the form of a long trailing and very slender whip-lash armed with spines, the whole forming a very formidable weapon indeed, as will be seen presently. In the genus *Urolophus* the tail is short, and armed with but a single spine. Eagle-rays appear occasionally off the coast of Scotland. "They frequently arrive suddenly in oyster-beds, to the dismay of the owners, where they remain so long as any of the molluscs are obtainable." Mr Day, in describing the spine-tailed rays, says "they lie concealed in the sand, and are reputed to be able to suddenly encircle fish, or other prey swimming above them, with their long whip-like tails, and wound them with their serrated tail spines."

The possession oi spines is common to many fishes. Their earliest appearance is in the form of supports to the fins. But, as we have just seen, their original function may be lost, and the spine by a very natural transition becomes a weapon of offence. In its new rôle, however, the spine undergoes further modification, and adds to its dread powers the sting of poison. The evolution of this poison organ is, we shall see, as gradual as is the rise and development of all other organs

The spines in the tail of *Ælobates* may be five in number, and are seated on the upper surface of the tail; all are barbed, and in consequence inflict a very dangerous wound. "Although," says Dr Günther, "they lack a special organ secreting poison, or a canal in or on the spine by which the venomous fluid is conducted, the symptoms caused by a wound from the spine of a sting-ray are such as cannot be accounted for merely by the mechanical laceration, the pain being intense, and the subsequent inflammation and swelling of the wounded part terminating not rarely in gangrene. The mucus secreted from the surface of the fish, and inoculated by the jagged spine, evidently possesses venomous properties." The common weaver-fish (*Trachinus*) will be a familiar form to many of my readers, for it is so frequently shaken out of the nets of "long-shore" fishermen at the seaside during the summer months. In this fish the spine of the dorsal fin, and of the plate covering the gills on either side of the head, are very venomous. Unlike those of the sting-ray just described, the spines of the weaver are deeply grooved, for the passage of a violently poisonous mucus. The genus *Synanceia,* of the Indo-Pacific, is represented by two species, justly feared on account of their poisonous properties. They are as hideous in appearance as they are dangerous in fact. The poison organ is more perfectly developed than in the weavers, each dorsal spine having its terminal half provided with a deep groove on each side, at the lower end of which lies a pear-shaped bag containing a milky poison. This bag is prolonged into a duct lying in the groove of the spine, and open at the point of this. The native fishermen, knowing the dangerous properties of these fish, give them a wide berth; but people walking in the sea with bare feet often step upon this fish, and the poison is injected into the wound by the pressure of the foot on the poison bags. So virulent is the action of this poison that death is not infrequently the result.

But the most perfect poison organs yet discovered are those of a genus of frog-fishes (*Thalassophryne*) of Central America. Here, as in the weaver of our own shores, the poison spines are those of the operculum or gill-plate, and of the dorsal fin. These spines are hollow, and resemble the poison fangs of the snake. They are perforated at the base and tip. The base of the spine is embedded in a poison sac filled by the secretion of a fluid from its inner walls. As these sacs are not provided with muscular tissue, it is supposed that they must discharge their contents down the hollow spine as a result of the pressure of the spine when it enters the body of the victim.

In many cat-fishes there is found a very remarkable apparatus, which it is believed represents a poison organ. "Some of these fishes," observes Dr Günther, "are armed with powerful pectoral spines, and justly feared on account of the dangerous wounds they inflict; not a few of them possess, in addition to the pectoral spines, a sac with a more or less wide opening in the axil of the pectoral fin, and it does not seem improbable that it contains a fluid which may be introduced into a wound by means of the pectoral spine, which would be covered with it, like the barbed arrow-head of an Indian. However, whether this secretion is equally poisonous in all the species provided with that axillary sac, or whether it has poisonous qualities at all, is a question which can be decided by experiments only made with the living fishes."

With some fishes, by the way, it would seem the flesh is more or less permeated with poison, either at certain seasons or at all times of the year. "When eaten," says Dr Günther, "it causes symptoms of more or less intense irritation of the stomach and intestines, inflammation of the mucous membranes, and not rarely death. The fishes, the flesh of which appears always to have poisonous properties, are *Clupea thrissa*, *Clupea venenosa* (West Indian herrings), and some species of *Scarus* (parrot-wrasses), *Tetrodon* and *Diodon* (globe-fishes). There are many others which have occasionally or frequently caused symptoms of poisoning. Poey enumerates not less than seventy-two different kinds from Cuba; and various species of *Sphyrœna* (barracuda), *Balistes* (file-fish), *Ostracion* (coffer-fish), *Caranax* (horse-mackerel) . . . have been found to be poisonous in all seas between the tropics. All or nearly all these fishes acquire their poisonous properties from their food, which consists of poisonous medusæ, corals, or decomposing substances. Frequently the fishes are found to be eatable if the head and intestines be removed immediately after their capture. In the West Indies it has been ascertained that all the fishes living and feeding on certain coral banks are poisonous. In other fishes the poisonous properties are developed at certain seasons of the year only, especially the season of propagation, as the barbel, pike and burbot, whose roe causes violent diarrhœas when eaten during the season of spawning."

It is probable, however, that the presence of poison in the cases just related is an accidental character, and such fishes are, therefore, to be distinguished from those which secrete poison at certain restricted areas of the body and in connection with spines, for the purpose of causing punctures for the admission of the venom.

More remarkable than the poisonous are the electrical properties of fishes. No less than fifty species of electrical fishes are known to science, though only a few, some five or six, species have been carefully studied. These are *Gymnotus*, the electric eel of the rivers and lagoons of Brazil and the Guianas; *Malapterurus*, the räāsh or thunderer fish of the Arabs, found in the Nile, Niger, and other African rivers; the torpedo or electric skate of the Mediterranean and Adriatic, and various species of British skates.

It will be noticed from the above list that the electrical fishes are by no means always closely related, neither are they confined either to fresh or salt water.

The electrical powers are most strongly developed in gymnotus, the South American eel; next in order of strength comes the malapterurus; then the torpedo. The electric organs, or batteries, are seated in different parts of the body in these three fish. In the torpedo they form a broad mass lying on either side of the head, and extending backwards on either side to terminate at the level, and to the outer side of the hindmost gill-slit. In the gymnotus they lie in the ventral region of the tail, which is enormously elongated, displacing the ventral postures of the powerful lateral muscles. In the malapterurus the electric organ invests the body like a mantle, lying between the skin and the muscles of the body.

In the British species of skate, various species of *Mormyrus* and *Gymnarchus* (African beaked-fish), the electric organs lie on either side of the end of the tail. These fishes were formerly described as pseudo-electric, the shock which they give being comparatively feeble. Recently, however, the possession of an electric organ has been fully demonstrated, lying, as we have indicated, in the tail.

The electrical organ is to be regarded as modified muscle-tissue. Dr Günther has thus graphically described those of the torpedo. "The electric organs with which these fishes are armed are large, flat, uniform bodies, lying one on each side of the head, bounded behind by the scapular arch, and laterally by the anterior crescentric tips of the pectoral fins. They consist of an assemblage of vertical hexagonal prisms, whose ends are in contact with the integuments above and below; each prism is sub-divided by delicate transverse septa, forming cells, filled with a clear, trembling jelly-like fluid, and lined within by an epithelium of nucleated corpuscles. Between this epithelium and the transverse septa and walls of the prism there is a layer of tissue in which the terminations of the nerves and vessels ramify. Hunter counted 470 prisms in each battery of *Torpedo marmorata*. . . . The fish gives the electric shock voluntarily when it is excited to do so in self-defence, or intends to stun or kill its prey; but to receive the shock the object must complete the galvanic circuit by communicating with the fish at two distinct points, either directly or through the medium of some conducting body. . . . It is said that a painful sensation may be produced by a discharge conveyed through the medium of a stream of water. The electric currents created in these fishes exercise all the other known powers of electricity; they render the needle magnetic, decompose chemical compounds, and emit the spark. The dorsal surface of the electric organ is positive, the ventral surface is negative." A correspondent in *Land and Water*, in reply to Frank Buckland, contributes some very interesting information concerning two torpedos taken in the estuary of the Tees. He says: "I was curious enough to see what those I caught were living upon, so I put my knife into one and took from him an eel 2 lbs. in weight, and a flounder nearly 1 lb. The next one I opened also, and was more astonished to find in him a salmon between 4 and 5 lbs. in weight; and what I was more astonished at was that none of the fish had a blemish of any description, showing that your idea of the fish killing his prey with his electrical force is quite correct."

The nerves of the electric organ in the torpedo arise from the brain; in all the other electric fishes from the spinal cord. In gymnotus over two hundred of these nerves pass to the electric organ. Malapterurus is remarkable in that the electric nerves arise from a single, enormous lens-shaped nerve-cell, lying in the neighbourhood of the head, to wit, near the origin of the second spinal nerve; it is continued into a large primitive fibre, which passes backwards, giving off branches as it goes, to the end of the tail.

The use to which these organs are put is probably chiefly for the capture of food. The shock given by *Gymnotus* is very considerable, quite sufficient to kill other fish, or small mammalia. Humboldt related a story to the effect that the Indians, who wished to procure these eels, drove horses into the water, which caused the eels to discharge so much electricity into the water as to exhaust themselves by their efforts, when they fell an easy prey. The poor horses, it was said, were often killed by the violence of these discharges. There is, however, no confirmation of this story by recent travellers. Bates, in his "Naturalist on the Amazons," tells how he amused the Indians, with whom he was travelling, "by showing them how the electric shock from the eels could pass from one person to another. We joined hands in a line, whilst I touched the biggest and freshest of the animals on the head with the point of my hunting-knife. We found that this experiment did not succeed more than three times with the same eel when out of the water, for the fourth time the shock was barely perceptible." This experiment was made upon fishes which had just been taken out of the water. They had been captured, it is interesting to note, from "little ponds" made by the eels in which to pass the season of drought. These ponds, it seems, abound with other fishes. It would be interesting to know if these live in peace and amity with the eels, or are gradually devoured when other food supplies fail.

We have yet a third very remarkable transformation. This concerns the change which certain gland-cells of the body in fishes undergo, converting them into *phosphorescent* organs. It is a well known fact that the slime secreted by the skin glands of certain sharks is highly phosphorescent, and in this we have the foundation for natural selection to work upon. If we pass in review all the known species of phosphorescent fishes, we shall find numerous gradations of increasing perfection, leading up to exceedingly complicated and powerful light-producing organs.

Two kinds of phosphorescent organs are distinguishable. One of these takes the form of peculiar eye-like, or lens-like bodies, arranged in one or more rows down the sides of the fish's body, forming, as Professor Hickson remarks, "a series of miniature bull's-eye lanterns to illuminate the surrounding sea"; the other, to quote the same authority, is constituted by a series of "glandular organs, that may be situated at the extremity of the barbels (the filamentous organs of touch round the mouth), or in broad patches behind the eyes, or in other prominent places in the head and shoulders." The light given off by these organs, in some species, is said to shine with a reddish lustre.

These phosphorescent organs, it should be noticed, are found either in fishes which inhabit the open sea, but which come to the surface only by night, passing the day in depths so great that light is almost excluded: or in fishes which live at still greater depths, from which there is no escape save by death; so deep that absolute darkness always prevails—it is the region of eternal night. In consequence we find that the eyes of the fishy prisoners of these dark waterways are either of enormous size, very small, or wanting. But as the eyes decrease so the luminous organs increase, till in some of the totally blind fish those of the head have reached a size which has been described as colossal. Thus the eyes become replaced by lantern-like phosphorescent organs. The reason for this remarkable luminosity is at first sight not quite clear. Reflection suggests, however, that being blind, or nearly so, the capture of food becomes impossible, unless the food can be induced to come to the fish. A sort of realisation of the very obdurate mountain being induced to go to Mahomet at last. In the luminous organs we have, strangely enough, the necessary wonder-working charm. These, it would seem, are used as a lure to draw the more fortunate sight-possessing brethren to destruction. Just as salmon poachers decoy salmon within spear-reach by means of a lantern whilst the world sleeps. But it may be objected that this same lure will serve equally well as a beacon to draw down upon itself larger and equally hungry fish, as pirates might be guided by the light of a ship riding at anchor! So that this specious benefactor standing in dark places diffusing light and gobbling up all who attempt to profit thereby, is in hourly danger of being hoist by his own petard! Possibly this occasionally does happen. As a rule, however, it is probable a catastrophe of this kind is avoided by the fact that together with these luminous organs has grown up a wonderfully delicate sense of touch and approaching danger. This new safeguard has been formed, either by exceedingly long and delicate filaments produced by the excessive development of the fin-rays, and which act like the vibrissæ of the cat: or as "beards" and "barbules" developed round the mouth. In addition it is not improbable that these fishes have developed a sense of size by which they may judge the measure of approaching animals, just as we ourselves can tell when in the dark that we are approaching some larger body before we actually touch it. Should danger be at hand the lights would be dulled, or even extinguished, and in a few moments escape would have been effected.

This replacement of the eye by luminous organs is another instance of the "Substitution of Organs."

The enormous eyes of the fishes which see are the result of selection and adaptation to the requirements of the new light—the light given off by the numerous phosphorescent animals. A large proportion of the worms, polyps and star-fish, for instance, are also phosphorescent, some of them highly so. Thus Professor Wyville Thomson remarks of a phosphorescent brittle-star (one of the Echinoderma), that the light was of a brilliant green, corruscating from the centre of the disc, now along one arm, now along another, and sometimes vividly illuminating the whole outline.

Mention may fittingly be made in this chapter of transformations in the shape of the body as a whole, selecting from the very numerous instances two of the most striking.

Of these the most familiar will be that of the sea-horse (*Hippocampus*). The change in shape here is not perhaps very considerable, but it is quite unique. The fish in swimming moves in a *vertical* position, and is driven along by rapid vibrations of the dorsal fin. The tail-fin has disappeared, and the tail has become transformed into an organ of prehension. The external scaly armour has developed exceedingly, and at the expense of the internal skeleton. It forms a delicate bony framework, which may be likened to filagree work. Further modifications which the fishes of this genus may undergo may be studied in the "Story of Life in the Seas," where a picture will be found showing the extraordinary mimetic resemblance to seaweed, which some species develop for protective purposes.

Our second example of transformation of the external form is furnished by the wonderful sun-fish (*Orthagoriscus*). This fish has the appearance of having undergone the amputation of the hinder end of the body, just behind the dorsal fins. One is naturally puzzled to account for such an extraordinary modification, but it seems to be associated with, and has, perhaps, resulted from its peculiar diving habits. It is the ogre which haunts the night of the deep seas, and preys upon the larval eels, *Leptocephali* (p. 132), which at certain seasons abound there. This we know, because large numbers of these once mysterious fish have been taken from the stomachs of stranded sun-fish. When at the surface the sun-fish swims by vibratile motions of the curiously shortened tail-fin, which acts precisely like the dorsal fin of the sea-horse described above. On diving the dorsal-fin is brought into requisition, and apparently by a sort of sculling motion affects the desired descent, and perhaps the ascent.

These two modifications are sufficient to call attention to the importance of a careful study of the external form as a whole, as well as of the individual parts, of fishes.

CHAPTER XIII.

PEDIGREES.

THE pedigrees of most of us are like our worldly possessions, small in compass. The proverbial "mists of antiquity"—the limbo to which all obscure things are assigned—begin with them at about the third generation, if they carry us back so far. Occasionally some one or other of us, for various reasons, desires to know more of his descent, and in such cases calls in the aid of the trained specialist, who, like some other specialists, fills in from his imagination the "missing links," and in the end furnishes the desired and much treasured "genealogical trees."

The interest to the world at large attached to the pedigree of an individual of our own species, however distinguished or popular he may be at any particular moment, is never very deep or widespread, and but rarely of any very great importance or value save to the individual concerned. But with the lower animals this is not so. Whatever we can gather of the life history of an animal, of its ancestors and its relations to other forms, is knowledge of universal interest and profit received with gladness by men of all tongues. Indeed the piecing together of the pedigrees of animals is now one of the most important considerations of men of science.

The present and succeeding chapters of this little book will be devoted to a brief presentation of the main facts which have been discovered concerning the ancestry of that very ancient house of cold-blooded vertebrates—the fishes, and the nature of the consequent grouping together of the various forms which has resulted therefrom.

For the sake of clearness we shall begin not with the most primitive of all known fishes, nor with forms undoubtedly primitive and of great antiquity, but concerning whose affinities there is much dispute. For concerning these last some hold that they bear the stamp of so lowly a character .that they are probably to be regarded as forms yet lower in the scale than the fishes themselves. Rather we shall choose as a starting-point the more specialised descendants of these which represent some of the most lowly of the living fishes, and about the primitive nature of which all are agreed. These constitute the sharks, dog-fishes and rays of the present day. But how do we know, some one may ask, that these fishes are more primitive than, say, the salmon tribe? Because, we should answer: comparison of the anatomy of these two types (shark and salmon) shows that the shark in every respect is simpler in structure than the salmon. What is the evidence for this? Well, in the first place, it is an established fact that the earliest vertebrates have the skeleton or supporting framework of the body made up not of bony but of fibrous and cartilaginous tissue. The skeleton of the shark is cartilaginous. Again, in the shark, the upper and lower jaws are made up of simple bars of cartilage; in the salmon they are formed of numerous separate bony elements. In the shark the teeth differ but little in form and structure from the scales covering the body, from which we know they have been derived, whilst in the salmon the difference between teeth and scales is so great that it seems impossible that the one could ever be associated with the other. The adult shark does not differ very much structurally from the young one—the adult salmon differs greatly, the young having a cartilaginous and the adult a bony skeleton. And so we might go on, each new character bringing out the fact that the salmon in the course of its development from young to adult increases in complexity, whilst the adult shark differs but little from its early stages. There is abundant evidence, in short, that the adult salmon has made a distinct advance in the direction of complexity and perfection, whilst the adult shark has not far outstretched the condition of its babyhood. This advance from the simple to the complex, which takes place in the course of the life history of the salmon, is illustrated again in the life history of the development of the race of fishes, the simpler forms, such as the shark tribe, appearing earlier in the world's history than the more complex bony fishes, of which we have taken the salmon as a type. The gradual advance in complexity of structure and variety of form which has taken place since the appearance of the early fishes, we call their evolution.

One word more; we shall discuss fossil and recent forms indiscriminately, both in the following and all other orders of fishes, for, as Dr Traquair pertinently remarks, "Does an animal cease to be an animal because it is preserved in stone instead of spirits? Is a skeleton any the less a skeleton because it has been excavated from the rock instead of prepared in a macerating trough? And I may now add, Do animals, because they have been extinct for it may be millions of years, thereby give up their place in the great chain of organic beings, or do they cease to be of any importance to the evolutionist because their soft tissues, now no longer existing, cannot be embedded in parafin and cut with a Cambridge microtome."

The sharks and rays, though belonging to an ancient and lowly organised group, are of that group exceedingly specialised forms. The evidence of specialisation here is found in the changes which have taken place in different regions of the body, changes which show a gradual advance in structure, as a consequence of more perfect adaptation to their environment. The structure of the pectoral fins, the equivalent of the fore-limbs of higher animals, is much more complex, for instance, than is the case with the similar fins in the older sharks, about which we shall speak in the next chapter. So too with the main axis of the body, which we call in ourselves the backbone or vertebral column. In the sharks this is made up of a series of separate hard bodies or vertebræ, each of them shaped roughly, like a dice-box, when seen in section. In the living animal they are joined one to another by their ends to form a long jointed support — the vertebral column. Immediately above this column runs a tube, formed by a series of Λ-shaped arches, one to each separate vertebra. Through this tube runs the spinal marrow. Besides, the vertebræ also bear processes for the support of ribs and for the protection of blood-vessels, details of which must be sought for in more technical works. This vertebral column we call a specialised structure, because in the very young or embryo dog-shark it was preceded by a much simpler structure, inherited from its ancient and more lowly forbears. The transformation of this into the complex vertebral column then is another piece of evidence of specialisation. This simpler type of vertebral column took the form of a continuous, or as we say, unsegmented, gelatinous rod, called the *notochord.* Such a notochord always precedes the more complex types of vertebral column or backbone. In many living fishes, and a large number of fossil forms, the "backbone" is represented only by this unsegmented gelatinous rod, around which are arranged the Λ-shaped "neural arches" for the spinal marrow, and the elements for the support of ribs and protection of blood-vessels. In many fossils we find these separate elements preserved and arranged evenly around a space. This indicates that the space was filled by the very perishable gelatinous "notochord," and tells us that the vertebral column retained permanently the unsegmented and unhardened condition such as we find in the embryos of to-day.

The modern type of shark made its first definite appearance so far back in the world's history as the period known as the Lias. We may distinguish two groups of sharks, the one embracing the sharks and dog-fish which have an "anal fin" (pp. 12, 61), the other certain dog-fish and the rays in which the anal fin is wanting. If my readers will forgive the introduction of apparently long-winded names, he will find it useful to remember that these two groups are known respectively as the Asterospondyli and Tectospondyli, in allusion to the characters of the vertebræ. In the Tectospondyli (covered vertebræ) the vertebræ are strengthened by concentric layers of hardened tissue: in the Asterospondyli the strengthening tissue is mainly arranged in the form of lines radiating from a common centre, hence the name Asterospondyli (star-vertebræ). The sub-order Asterospondyli, or sharks and dog-fishes with an anal fin, contains several forms of considerable interest. One of the most remarkable of these is the formidable hammer-headed shark and the curious angel or monk-fish, very closely approaching the form of the rays in consequence of its similar habits. These are the two most profoundly modified in external form. The largest member of the sub-order is the *Charcharodon*, and is at the same time the most dreaded, attaining a length of some forty feet. Teeth of a gigantic species, only recently extinct, are occasionally dredged up between Polynesia and the West Coast of America, some of these teeth being as large as those of a fossil species found in the Crag, and measuring five inches in length and four inches wide at the base. The seven-gilled shark of the genus *Notidanus* and the Port Jackson shark (*Cestracion*) are of great interest, on account of certain very primitive characters of the skeleton and the teeth. These last bear a close resemblance to certain fossil forms. Those of the seven-gilled shark are interesting on account of the fact that they are provided with numerous cusps, giving the free edge of the tooth a saw-like appearance resembling similar teeth found in the Red Crag of Suffolk, and as far back in time as the Jurassic period. Whole skeletons of *Notidanus* occur in the Solenlufen slates of Bavaria. The Port Jackson shark of to-day, occurring from Australia to Japan, the Galapagos Islands and California, carries us back into the remote past to the Carboniferous period; teeth differing but little from those of the living *Cestracion* occurring in the rocks of this age. These teeth it will be remembered we discussed on p. 39. They are remarkable as well for their beauty—seen *in situ*—as for the evidence of adaptation to function which they have undergone, resulting in crushing teeth of a very perfect description. The Cestracionts reached the hey-day of their development during the Mesozoic period. The living species is but an isolated member of his kind. Another very remarkable and ancient type of shark, living at the present day in the sea around Japan, is the Japanese frill-gilled shark (*Chlamydoselache*). Amongst its most striking features are its teeth, resembling those of the living *Notidanus*, to which it is related, and certain fossil forms occurring as far back as the Jurassic epoch.

The *Tectospondyli* contains those dog-fishes which have no anal fin, and the rays and devil-fishes. Earlier naturalists, impressed by the superficial characters only, grouped all the shark-like fishes together, leaving the ray-like forms together to form a separate sub-order. Recent investigation has shown how dangerous are conclusions based on external appearances. We now realise that adaptation to similar physical conditions may result in the transformation of animals not nearly related to an extraordinary external likeness. This is exemplified in the case just mentioned. More deep-seated characters show that the spiny dog-fishes agree rather with the rays than the sharks. It is significant that many of the very oldest known rays apparently differ but little from species now living.

So much for the shark-tribe, the Elasmobranchii of the scientific text-books (p. 192). We will turn now, not to a consideration of the still higher groups of fishes descended from the sharks, but to some other shark-like forms—the chimeras. In spite of their superficial resemblance to the sharks, they are held to be distinct therefrom. Their points of resemblance are probably derived from an ancestor common to both. One species of chimera, *Chimæra monstrosa*, is found occasionally in the Atlantic and Mediterranean. It occurs sporadically. Another, *Chimæra affinis*, is occasionally to be seen, according to Mr Bashford Dean, in Lisbon market, "where, from its low price, it evidently ranks with the sharks as a food-fish." Another species, *Chimæra antarctica*, is common in the Straits of Magellan. Yet another is abundant in the shallow waters of Vancouver, where it is known as the "rat-fish," and "may often be seen in the neighbourhood of the docks swimming slowly at the surface." The last of the chimeras to be discovered has been placed in separate genus, *Harrotia*. It is the most primitive and most shark-like of all.

The chimeras are divided into four families, three of which are now extinct. The family to which the living chimeras belong attained the zenith of its development in the Cretaceous and Eocene periods. The surviving members are to be regarded as the degenerate descendants of those days, for they never exceed five feet in length, whilst *Edaphodon*, one of the fossil members of the family, attained gigantic proportions.

There is nothing very exciting to relate about Chimæroids. They are very ugly fish. Their claim, however, to attention is a strong one, for there seems to be no doubt that they form a connecting link with the dipnoi. The backbone is not divided into separate bony segments, but is represented by that more primitive structure, the forerunner of the typical backbone, known as the notochord (p. 170). There is but a single gill opening, as in the dipnoi (lung-fishes). But there are two particulars which lift the chimeras out of the ranks of the commonplace. The first of these concerns the teeth. These are somewhat plate-like structures, bearing hard-ended areas known as "tritors." There are two pairs of these in the upper jaw, and they bear a resemblance, on the one hand, to the teeth of the lung-fishes, and on the other to those of certain extinct sharks known as Cochliodonts. The resemblance to these latter is significant, suggesting that they may have had a similar origin — the fusion of separate smaller teeth. The second of the chimeras' notable characters is represented in a remarkable movable spine in the head, of unknown function, the free end of which is covered with recurved spines, and is received into a pit in the forehead. In some of the fossil members of this group this spine was represented by a sword or spike-like structure.

About the life history of Chimæroids we know next to nothing, about the embryology and larval development nothing at all.

We must turn now to the discussion of that higher group of fishes, the descendants of the ancient sharks. These are represented by the modern bony fishes—the Teleostomi of science. By many of the older naturalists this group was sub-divided into two portions, known respectively as the Ganoid and Teleostean groups. This division is not followed now.

The Teleostomi are distinguished from the sharks, their ancestral kindred, by the fact that both the upper and lower jaws are ensheathed in bone, which in turn supports the teeth; that the skeleton is more or less well ossified; and that the gill-clefts open into a large chamber with a single aperture. The outer covering of this gill-chamber is constituted by a bony shield known as the operculum. The outer covering of the body, instead of the placoid scales of the Elasmobranchii (shark-tribe), is made up of a bony mosaic or of delicate horny lamellæ, which form the characteristic "fish-scales." These are the principal characters of the sub-class Teleostomi.

The Teleostomi are divided by modern naturalists into two groups or "orders": (1) the Crossopterygii or fringe-finned fishes, and (2) the Actinopterygii or ray-finned fishes. The differences between these two and the more interesting members contained in each order we will now proceed to discuss.

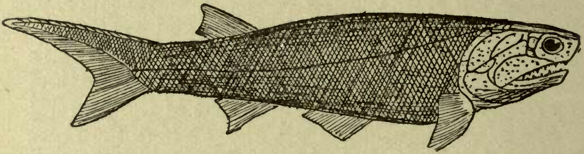
The fringe-finned fishes are regarded as the more ancient type. Their oldest fossil remains are extremely ancient, carrying us back to the Devonian period. The epithet "fringe-finned" is bestowed on account of the fact that in the paired fins there may be distinguished two distinct parts, a lobe-shaped central and basal portion, surrounded by a marginal or fringed portion. The former is constituted by the muscles covering the axial portion of the skeleton, and the latter by delicate fin-rays connected with the central or axial portion.

Of the fringe-finned fishes, as Dr Smith Woodward points out, there are two distinct types, distinguishable by the form of the pectoral fins (fore-limbs). In all the extinct members these fins are attached to what corresponds with the shoulder girdles of the higher vertebrate by a single support, whilst in the other type these fins are attached to the girdle by means of three separate elements placed side by side. A reference to the accompanying figures (fig. 7, p. 66), should make this clear. The latter type of fin is called a tribasal, the former a unibasal fin. The tribasal fin is found only in living forms.

In some respects these fringe-finned fishes resemble the lung-fishes, but whether this resemblance is due to adaptation to similar physical conditions or to actual affinity, is a matter for debate. The evolution of the group is accompanied by specialisation in many directions, details of which will be found in more profound works.

The remains of these fishes, which we dig up to-day as fossils, are but samples of the denizens of the ancient lakes and inland seas, whose dried basins form the rocks known as the old red sandstone. The most characteristic feature of these remains is the nature of the form of the scales. These, in the majority of the fossils preserved to us, take the form of very large and thick overlapping scales, coated externally with an enamel-like substance known as "ganoine"

A



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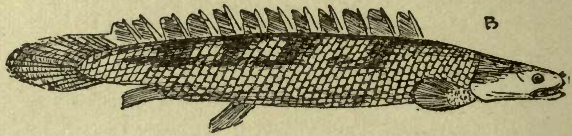

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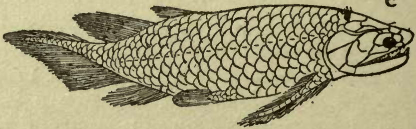

FIG. 15.—*A.* Restoration of a primitive Sturgeon—*Cheirolepis*, after Traquair. *B.* The African "bichir," *Polypterus bichir*, living in the Nile at the present day. Note the heavy armour of rhomboid scales. *C.* Restoration of the extinct lung-fish, *Holoptychius*, after Traquair.

(hence the old name "ganoid" fishes). In addition these scales were also more or less elaborately sculptured. The head was encased in hard, closely-fitting plates.

Other forms of this period have rhomboid scales, very thick and closely set, forming a kind of pavement or mosaic; that is to say, they did not overlap.

The accompanying beautiful restoration, by Dr R. H. Traquair, of the form known as *Holoptychius*, shows the nature of the overlapping scales. The mosaic arrangement can be studied (fig. 15 *B*).

Cœlacanthus, *Diplurus*, *Undina* and *Macropoma* are four noteworthy genera, for they are all highly specialised forms, having arrived at this distinction chiefly by degeneration. Furthermore, "these have," says Dr Smith Woodward, "perhaps the most remarkable range of all known extinct fishes, occurring almost unchanged throughout the whole series of formations from the lower Carboniferous to the upper Chalk." Amongst other things, they are remarkable for the fact that the air-bladder was ossified.

Diplurus seems to have threatened to forestall the Cheshire cat, for its body has become excessively shortened, so that the head is relatively enormous in size. It is further remarkable for the fact that it, together with its cousin *Undina*, was blessed with two tails, one behind the other (see p. 56).

Strangely enough, a few of these crossopterygian or fringe-finned fishes have survived to the present day, in the "bichir," *Polypterus bichir* of the Nile (fig. 15 *B*), the reed-fish (*Calamoichthys malabaricus*) of Old Calabar. These are, furthermore, remarkable in that they differ from the fossil forms described above in the form of the skeletal elements of the pectoral fin, which have the tribasal arrangement which we referred to on p. 177, fig. 7, p. 66. This tribasal form of fin presents a close resemblance to the basal cartilages of the modern sharks, a fact of great interest and significance. The scales of these fishes are very thick and dense; quadrangular in form, therefore not overlapping, and coated with "ganoine." Very little is known of the breeding habits of these wonderful mail-clad fishes. The young have very large and well-developed external gills (fig. 3).

The "ray-finned fishes," the *Actinopterygii*, embrace the whole of the remaining forms to be discussed in this chapter. For the fishes belonging to this order we may adopt Mr Lydekker's name of "fan-finned," since the rays or bony supports of the fin spring from a common base, fan-wise, instead of being distributed so as to form a fringe to a more or less extensive scale-covered lobe. There are, of course, other additional characters peculiar to the fan-finned fishes, but these need not concern us here.

It is a remarkable fact, but nevertheless true, that the fan-finned are as old as the oldest of the fringe-finned fishes, occurring as far back as the Devonian period. And, furthermore, it seems to be equally true that we have in the modern sturgeons the highly specialised descendants of the earliest forms of the fan-finned group. For this we have the authority, so often quoted here, of Dr Smith Woodward.

These ancestral sturgeons differ much from their modern descendants. The latter have in the course of ages undergone great specialisation, accompanied by degeneration. The oldest of the ancestral forms belongs to the genus *Cheirolepis*, and occurs in the Old Red Sandstone (fig. 15 *A*). One of the most striking features of this fish was its covering of scales. These were exceedingly small, and closely fitting, but they did not overlap. The head was enveloped in bony plates, and the mouth was large, at the front of the head, instead of on the under surface after the fashion of modern sharks, and armed with teeth. These characters stand in strong contrast with the typical modern sturgeon, wherein the body is covered, not with closely-fitting scales, but with rows of isolated bony bosses arranged, one along the back, one along each side, and one along each side of the under surface. Again, in the living sturgeon the mouth has shifted to the under surface of the head, and the jaws have lost the teeth, the mouth now being suctorial. But it is interesting to note that in the embryo sturgeon the jaws bear teeth.

But there are other sturgeons which serve as links in the chain which we hope will one day be complete enough to carry us back by easy transitions from the toothless and curiously armoured form, which we have just discussed, to the toothed and scaly members of the genus *Cheirolepis*. These links are, however, it must be admitted, somewhat slender.

The most interesting are the living shovel-beaked sturgeons of the genus *Polyodon*. In many respects they are, like their more familiar cousins, the sturgeons of the genus *Acipenser*, both highly specialised and degenerate. They are highly specialised in that the anterior end of the head is produced forward into a broad shovel-like process, used, it is supposed, as an organ of touch: and degenerate in that, the eyes are so extremely small as to render them of but little use. This degeneration of the eyes, and the compensatory organ of touch, seems to have been induced by the turbidity of the rivers in which they lived, which is so great as to render eyes almost useless. Another degenerate feature is seen in the scales, which are very minute and star-shaped. Teeth are retained throughout life. From the living *Polyodon* we are carried geologically back to the fossil genus *Chondrosteus* of the Lias formation, which, like *Polyodon*, had, amongst other things, developed a tactile paddle.

In studying the animal life of the globe, from its earliest dawn till to-day, we shall find evidence of a gradually increasing complexity therein. Furthermore, if we select any particular group of animals for review, we shall not fail to be struck with the fact that that group exhibits a series of characteristic forms, the rising, waxing, and waning of which may extend through one or more geological periods, and then suddenly die out; or it may persist under greatly modified aspects till to-day, either in the form of an isolated survivor of an ancient race, or as a congeries of forms in the hey-day of development.

In the history of the house from which the sturgeons derive their origin, we may find some instructive instances of this rise and decline. The earliest representatives of this house, we have already remarked, were armoured fishes, which increased in wealth of form till they reached the climax of their evolution in the Carboniferous and Permian periods. By this time they had flowered out into a very numerous company, in which we may distinguish two types —an elongated, and a deep-bodied. Above the Permian, remains of the deep-bodied form gradually dies out, finally disappearing towards the end of the Jurassic period. Although these deep-bodied fishes held their own for an enormous period of time, they yet have a shorter record than the parent stock. This, during the lower Carboniferous period, produced a very remarkable scaleless form, known as *Phanerosteon*; and during the Jurassic an equally remarkable type, characterised by deeply overlapping scales, ornamented with tubercles of the glistening ganoine. Finally, as we have already remarked, we may reckon as descendants of the earliest forms our modern sturgeons, which again afford us valuable material for our evolutionary studies in the highly specialised shovel-beaked, and the more typical sturgeon, which we can trace back to the Lias, in the form of *Chondrosteus*.

From the sturgeons we must pass to the consideration of a fish which, until recently, was a stumbling-block to many. This is an American fish (*Amia calva*), commonly known as the bowfin, but also as the mud-fish, lawyer-fish, and Joseph Grindle. For a long while this fish was believed to be closely allied to the herrings, it was only after a closer acquaintance of its anatomy was made that its real affinities became known, and with this knowledge came a revelation as to its great importance from a pedigree-making point of view. The bow-fin is a carnivorous fish. The streams in which it lives frequently become very foul; on such occasions it comes to the surface to breathe air, taking in large mouthfuls at the surface without making a single bubble. It is said that when near to the surface the bow-fin often gives vent to a bell-like note, which is explained as probably due to the passage of air from the air-bladder. This last is cellular in structure, and hence adapted for breathing purposes.

Once upon a time the distribution of the bow-fin over the earth's surface was much wider than at present, for its fossil remains have been found in the Upper Eocene of Hampshire and the Isle of Wight, and of Paris. But we can trace it much further back than this, for under another generic name—*Megalurus*—it occurs as far back as the Kimmeridgian formations of Bavaria, that is to say, it is a Jurassic fish, and that is a long while ago! But we can trace them yet further back, for the *Amiidæ*, the family to which the bow-fin belongs, were preceded by, and descended from, a group of fishes known scientifically as the *Eugnathidæ*, occurring in the Lias formations at the bottom of the Jurassic series. One of the chief points of difference between these and the modern bow-fin was the possession of a coat of armour in the shape of a heavy pavement-like scale.

A branch of the bow-fin family, which ranges throughout the Jurassic and Cretaceous periods, is distinguished by the remarkable resemblance which it bears to the modern sword-fish, with which it cannot possibly be related. In *Protosphyrænea* of the upper Cretaceous period, the sword—which has been gradually increasing in length in different genera, beginning with a form known as *Pachycormus* (thick hide) of the Upper Lias, and passing through *Hypsocormus* of the Kimmeridgian—was as formidable a weapon as in the living sword-fish. This curious resemblance is another instance of parallelism (pp. 13, 173).

It will be sufficient to show the importance of the bow-fin family to remark that this is regarded as probably the group from which the majority of the modern fishes may be traced.

Of uncertain relationships are the American bony-pikes, or gar-pikes, *Lepidosteus*, and their fossil kindred. The living Lepidosteus—of which genus there are three species—like the bow-fin, is at present confined to the fresh waters of North America; but, like the bow-fin, once enjoyed a much wider distribution, its remains occurring with great frequency in Europe—in the Eocene and Lower Miocene periods. The living gar-pike in many respects resemble the fringe-finned Polypterus (p. 178), being similarly clad in heavy armour. *Polypterus, Amia* and *Lepidosteus* are each alike interesting as the isolated survivors of different branches of extinct groups. The living gar-pike, or bony-pike, sometimes attains a length of six feet. They are carnivorous. In South Carolina Mr Bashford Dean tells us he has known it to occur in such numbers as to fill the shad-nets, and thus render that fishery impracticable for many days. In the formation of the vertebral column Lepidosteus is unique, being the only fish in which the vertebræ are connected by cup and ball articulations.

Concerning the actual descent of the more modern fishes, we have much yet to learn. But the general model upon which the most familiar of our existing forms was shaped appears as far back in time as the Upper Triassic formations. Some of the fishes of this period, Dr Woodward tells us, differ only from such groups as the herring tribe in the more primitive form of the backbone, which was only imperfectly ossified, in the presence of peculiarly shaped scales at the base of the fins, known as "fulcra," characteristic of the older so-called "ganoids" such as the sturgeons, and in the possession of the thick enamel-coated scales known as "ganoid." These are the models which time and evolution have changed into the herrings, salmon, pike and perch, and so on, of to-day.

The tropical and sub-tropical *Elops* is one of the most ancient of living fishes of the modern type. Like the sharks, and many other primitive forms, its intestine is provided with a spiral valve—to be quite correct, in elops there is a vestige of this valve. Furthermore, it bears another badge of lowly origin in the shape of a bony plate beneath its jaws—the gular plate; in this respect it resembles the bow-fin and its allies.

The herrings form another group of ancient lineage. They may be traced back as far as the Cretaceous period. Other relatives of the herrings—the sardine tribe—are also to be traced back to the cretaceous. The sardines are a numerous family. In addition to our familiar little friend of the breakfast table, there are numerous deep sea phosphorescent forms, with which we cannot deal here for lack of space. The herring-like elops, the true herrings and sardines, are the living representatives of a much larger and ancestral stock. The extinct forms all bear a very striking resemblance to modern herrings. To discuss these in cold print were profitless; but those who have the good fortune to live near great collections of fossil-fishes, such as that of the British Museum, can glean for themselves some very striking lessons in the pedigree of the herring and its kindred. All these forms are grouped together to form one family, the *Isospondyli.*

As allies of the herrings, we turn now to the eels—a tribe with which we are all more or less familiar, at least with some members. Three well-marked forms are included in this group—the common fresh water and conger eel, the muræenas, and the electric eel. The muræenas are probably but little known to most people. They differ from all the other forms with which they are associated in their remarkable colouration, which is very brilliant and generally mottled in pattern. The feature which makes the electric eel celebrated we have already discussed (p. 158). The eels serve as admirable object lessons in the effect of adaptation to a peculiar mode of life burrowing in the mud for the purposes of concealment. To this adaptation is due the peculiar and familiar elongated form. This change in shape has been followed by the loss of the pelvic fin in all, and both the pectoral and pelvic fins in the muræнas, whilst the scales have been reduced to mere vestiges embedded in the skin. Moreover, the primitive condition of a continuous median fin fold, from the middle of the back to the middle of the belly, has once again been introduced, or secondarily acquired, as it is scientifically expressed. Reasoning from experience, some scientific specialists in the natural history of fishes, have been led to suspect that the supposed common descent of these three forms of eels may prove to have no foundation in fact. In other words, that originally unlike and unrelated forms have become moulded by adaptation into a common resemblance.

Fossil eels occur in the upper cretaceous rocks of Mount Lebanon. The eels form a sub-order by themselves at present—the *Apodes.*

Near here we encounter a host of familiar forms, constituting the sub-order, *Plectospondyli*, of Dr Smith Woodward. This sub-order embraces the carps, breams, roach, chubb, barbel, gudgeon, tench and loaches.

These are forms with which we are all more or less familiar: a comparatively modern group of fishes, carrying us back but a very little way into the past, geologically speaking.

So it is with the cat-fishes, which are generally regarded as a tribe which may claim kinship with the above. In the record of the rocks we do not find them until comparatively near the end.

Similarly, it is not till we get to the closing chapters, so to speak, of the ancient history of the world that we find any record of the pikes and toothed-carps, the flat-fish—such as the sole, turbot, and so on—and the cod-fish and haddock tribe. Of the ancestral forms of these, as yet we know absolutely nothing.

The pedigree of the perch tribe, which embraces the blennies, gobies, millers-thumbs, angler-fishes, mackerels, sea-breams, coral-fishes, and perches, is of more interest. Not so much, however, on account of what it reveals concerning remote ancestors, which show us the lines along which the living forms have gradually developed, as on account of records of troublous times and days of horror, with which the chapters of the past are occasionally punctuated.

In the collection of fossil fishes in the British Museum of Natural History, there can be seen a slab of rock containing the fossil remains of a shoal of fishes of the genus *Holopteryx*, a near ally of the living perches. These remains are in the most extraordinary state of preservation, and seem to show that this shoal was suddenly overwhelmed in some great catastrophe. And this because the fishes are lying one upon another in all kinds of contorted positions, with gaping mouths and gills and erected fins, suggesting suffocation by the escape of volcanic gases at the bottom of the sea. And further, they must have been rapidly interred by the settling of vast quantities of suddenly raised sediment before decomposition could set in, or before they could fall a prey to the scavengers of the sea, in the shape of other fishes of vulture-like habits, or of crustacea, and other carrion-feeding animals of the lower orders. Such a catastrophe recalls the great earthquake of Lisbon, or the overwhelming of Pompeii by Vesuvius, whereby hundreds of people were as suddenly entombed as these fishes. But the fate which befel these ancient perches was by no means an isolated case. Far back in the world's history—as far back as the time when the old red sandstone was accumulating—there is proof of just such another calamity, as is shown by a portion of a slab containing the remains of some of the ancient fringe-finned fishes (*Holoptychius*). Yet again we have a third instance, this time indelibly stamped upon a slab of cretaceous rock from Mount Lebanon, in which are embedded the bodies of hundreds upon hundreds of young herrings. These, however, all lie flat, suggesting less violence in the manner of their death.

Of fishes whose origin remains at present a mystery are the pipe-fishes and sea-horses, and the bizarre globe-fishes, coffer-fishes, and sunfishes. Of the last mentioned species, a distinguished professor of comparative anatomy at Oxford once remarked, that they should be called cherub-fishes, "because they are cut off behind"! Connecting links, or "annectant forms," as Professor Huxley called them, in the chain of evolution through which these have passed, would be valuable indeed. *Hippocampus*, the sea-horse, comes nearest to the realisation of this, inasmuch as a fossil species from the Eocene of Monte Bolea possesses a caudal fin, which may be said to have since gone out of fashion.

The present chapter may be summarised briefly as follows:—

The fishes of the present day may be divided into two great groups according to the structure of the skeleton of the head. In one group we have the ancient sharks and rays, and the modern bony fishes represented by the salmon, perch, and cod-fish, for instance. In the other we have the curious chimeras, which will be described presently, and the lung-fishes, which we have discussed from some aspects (pp. 25, 67).

The shark-tribe and the modern bony-fishes are bracketed together because the upper jaw is but loosely attached to the skull—a type of skull known as the *hyostylic* — whilst in the chimeras and lung-fishes the upper jaw is indistinguishably welded to form one piece with the skull, and on this account forms a second type of skull, the autostylic.

The hyostylic group of fishes are divided into two sub-classes—the *Elasmobranchii* and the *Teleostomi.*

The sharks and rays constitute the Elasmobranchii—a name given in allusion to the strap or band-like bars that divide the gill-slits. They are distinguished from the Teleostomi by the fact that the body is covered with "placoid" scales (p. 34), and that the gill openings are numerous and exposed.

The modern bony fishes form the Teleostomi, or fishes with the mouth parts composed of separate bony elements. The *Teleostomi* have the body clothed with symmetrical plates or scales, and a single gill opening covered with a shield-shaped plate.

The autostylic group of fishes are similarly divided into two sub-classes—the *holocephali*, or whole-headed, in allusion to the autostylic skull and the dipnoi, or lung-fishes.

The *holocephali* are represented by the chimeras. These bear a great resemblance to the sharks, having the body covered with placoid scales. But there is but a single gill-opening covered by a fold of skin.

The dipnoi are the lung-fishes. Herein the body is covered with overlapping scales, resembling those of the Teleostomi, and the gill-opening is protected by a bony shield.

We may express these relationships briefly as follows :—

CLASS PISCES.

Branch A.

Hyostylic.

Sub-class I. Elasmobranchii.

„ II. Teleostomi.

Branch B.

Autostylic.

Sub-class III. Holocephali

„ IV. Dipnoi.

This is the classification of Dr A. S. Woodward, one of our greatest authorities on this subject.

This sub-division of the fishes is the result of a careful analysis of all the characteristics of the class, and has brought us not only somewhere near the extreme base of the piscine branch of the great vertebrate tribe, but it has also marked out the lines along which our investigation into the descent of the various smaller groups must proceed, if we would know more of the evolution of fishes.

CHAPTER XIV.

PUZZLES AND PATRIARCHS.

MOST of Nature's children are, so to speak, " earmarked," so that those who will take the trouble to learn the nature of these marks may tell thereby to what great branch of the animal kingdom any particular individual belongs. Those who are skilled in the interpretation of these marks can go further, they can tell not only to what tribe it belongs, but what position it holds in that tribe.

Sometimes just one mark alone is of sufficient importance to enable us to dispense with all others. Birds afford us an admirable instance of this. We can distinguish a bird at once from all other known animals by the fact that it possesses feathers. Feathers form the external covering of the bird, and are absolutely unique structures, being produced by no other animal under the sun. Now fishes are by no means so distinctly and decidedly marked. Generally speaking we are right in our determination that this or that particular creature is a fish. But there are many pitfalls, for not a few animals, not even remotely related, are from their general contour classed by the uninitiated as "fish." Those who are on their guard and are familiar with the credentials of fishhood, when suspicion is aroused look for the characteristic scales, fins and gill-openings. Generally all these will be found, but scales may be wanting, so also may the paired fins, but the median fins and gills, never. And so it would seem then that it is easy after all to determine what is a fish. By no means, for the early tadpole stages of the common frog are practically fish, whilst the greatest experts of the year of grace 1901 differ among themselves as to the claims to fishhood which have been put forward on behalf of certain living and fossil forms which we shall now describe.

Let us take the living forms first. These are represented by the somewhat unfamiliar eel-like lampreys and hag-fishes. In a number of characters these differ markedly from the forms hitherto discussed. There are no movable jaws; there is but a single nostril placed in the middle of the snout; the mouth is a circular cup-shaped cavity armed with numerous horny teeth; there are no limbs, no ribs, no gill-arches. The skeleton of the head is cartilaginous; the vertebral column is represented by an elastic and fibrous rod. The gills are of a quite peculiar pouch-like form, hence the scientific name of the group—*Marsipobranchii.* The skin in the region of the gills is supported by a delicate cartilaginous basket-work called the branchical basket, and representing the jointed, cartilaginous gulars of the sharks and the similar bony bars of the higher fishes. The body is naked, and eel-like in form.

Lampreys are marine inhabitants which ascend the rivers to spawn. Years ago they ascended English rivers in vast hordes, nearly four thousand having been taken at Newark in a single night; they were captured as bait for cod and similar fish. More fish were caught in the Severn than in any other of our rivers.

Lampreys are carnivorous in their habits, and are, on this account, the more interesting, for whilst other fishes have become, so to speak, quickened by their carnivorous desires, the lampreys have become degraded. The sharks and the mackerel, for instance, to select familiar examples, have developed extraordinary activity and general physical perfection to enable them to overtake and destroy their prey. The lampreys, on the other hand, have degenerated, as we have just remarked. How far this degradation has gone is a moot point, to which we will return presently. But it is significant that the species of *Petromyzon* fasten themselves by their sucker-like mouths to other fishes, and scrape off the flesh therefrom with their teeth. "Whilst thus engaged," Dr Günther tells us, "they are carried about by their victim. Salmon have been captured in the middle course of the Rhine with the marine lamprey attached to them." This apparent doggedness of purpose is really their undoing. For the members of another genus, *Myxine*, have acquired the habit of boring into the victim's body and feeding thereon till death puts an end to the long-drawn tragedy. On account of this ghoulish practice this species has been christened the hag-fish. Now the lampreys are, as we have already hinted, regarded by some as degenerate, a contention which the living forms amply support. For we can see how, by a very natural transition, a predatory form has become degenerate by adopting the method of the leech instead of the vigorous attack of the shark, and how this leech-like method has led to further degradation, ending in the parasitism of the hag-fish. The evidence for degeneration lies mainly in the absence of jaws and paired fins. These may well have been lost in consequence of the habit above described. The loss of hardened scales or skin armour of any kind, and the absence of bony matter in the skeleton, may be further consequences of their evil ways. There is certainly much to be said for the degenerate theory, for dissection of the lamprey in its early stages of development reveals traces of a hardened skeleton. By way of additional evidence in favour of this hypothesis that the skeleton of the modern lamprey is degenerate we may adduce the fact, that in the most ancient known members of this tribe, the remains of which occur in the old red sandstone of Caithness, there was a well-defined vertebral column or backbone, made up of calcified or hardened bone-like vertebræ. This fossil was discovered and has been described by Dr Traquair, and named by him *Palæospondylus gunni.* It is a very small fish and, it should be noted, shows no trace either of jaws or limbs, so that if these have been lost it must have been at some infinitely remote period. But there is another side to this question, for many and very eminent authorities hold that the evidence of degeneration is more imaginary than real, and that we are to regard the lamprey as an exceedingly primitive type.

This indecision as to the true nature of the lamprey necessarily leaves the question of the pedigree still a matter for debate. Many of those who hold the lamprey to be a degenerate fish consider that it is possibly closely akin to the recent bony fishes. Whilst those who deny its claim to rank as a fish at all, regard it as the representative of the ancestral stock from which the fishes took their origin.

With the fossil forms, to which attention must now be turned, there is the same indecision, the same interpretation of facts, so as to demonstrate opposite conclusions. The forms in dispute are relics of a past exceedingly remote, dating back in fact to the old Silurian epoch, and representing the earliest record we have of vertebrate life on the earth. Whether they are closely related or not is uncertain. The feature that would impress the observer most on seeing one of these fossils for the first time, would be the remarkable development of the external skeleton, which formed a more or less complete coat of mail. Further examination would lead to the discovery that in some there were no paired fins or limbs; whilst in others only the front pair were present, and these differed fundamentally from those of all other vertebrates. Traces of eyes, nostrils and gill apertures would only be discoverable after careful search. There is reason to believe that there were numerous gill-slits, but that they opened, not directly on to the surface, but into a common chamber below the head shield, and that the water escaped from thence by a pair of openings at the hinder end of this shield.

There are three well marked types of these ancient creatures distinguished by the structure and form of the great shield enveloping the head and upper part of the back, and hence called the dorsal shield. All three types are generally included in one common group, or sub-class, known as the *Ostracodermi*, or shell-skinned animals, but this grouping together is rather for the purposes of convenience than to suggest any close relationship.

Those who would study these remains for themselves in museum collections would find these three groups arranged under three heads: the *Heterostraci* (anomalous shells), *Osteostraci* (bony shells), and the *Antiarcha*.

The *Heterostraci* represent the simplest and possibly the oldest of these groups. The head shield, which may be seen in our illustration (fig. 16 *A*), is made up of no less than seven pieces marked by numerous concentric lines. Each of the separate plates are believed to have been caused by fusion of minute shagreen tubercles. A section through the shield shows it to consist of three layers—an inner, called the "nacreous" layer, on account of its resemblance to the pearly layer of the oyster and other similar shells; an outer very dense layer, in structure resembling teeth, and a middle layer of polygonal chambers. The dorsal spine seen in the figure doubtless served the purpose of a

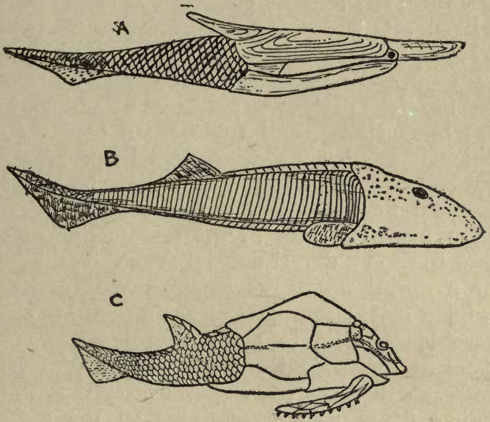

Fig. 16.—Three extinct ancestral forms of fishes. *A*. Pteraspis rostrata, one of the Heterostraci. *B*. *Cephalaspis* lyelli. *C*. Pterichthys, after Traquair.

dorsal fin, as a balancing organ. The tail was covered with a closely-fitting armature of scales. About the structure of the fin we know very little. The typical representatives of this order belong to the genus *Pteraspis*, of which one species, *Pteraspis rostrata*, is figured here (fig. 16 *A*).

The Osteostraci are practically confined to the Upper Silurian and Lower Devonian rocks. The characteristic genus is *Cephalaspis*, the finest known specimens of which have been found in Forfarshire and Herefordshire. This fossil presents many features of peculiar interest. One of the most important concerns its general form, which is curiously like that of the old trilobites, the ancient crustacea amongst which it lived, and which for some inexplicable reason it seems to have mimicked. As will be seen in fig. 16 *B*, the head-shield is of considerable size, and in some species was produced backwards into two bony spines, and these again bore spines, which it is surmised were used in progression. The body was ensheathed in numerous hard plates, disposed in bands round the body. Some of these plates rise up in the middle line of the back to form a dorsal fin. By the way, the need for a dorsal fin seems to be a very real one, judging by the totally different structures which have been made to serve this purpose. The spine in Pteraspis, the arched scales of Cephalaspis, cartilaginous, horny and bony rays in the higher fishes, and fatty tissue in the aquatic mammals—the whales, the porpoises, and the dolphins. A further interesting feature of Cephalaspis is the possession of a pair of flap-like structures behind the head-shield, which it has been suggested, represent not fins but gills.

The Antiarcha represent the most highly specialised of these ancient puzzles. The genus *Pterichthys* contains the typical species. The armour-plating of the head and trunk was very complex and perfect, the separate plates overlapped one another (fig. 16 *C*). Another feature of these plates is the series of shallow grooves by which they are traversed. These it is supposed represent sense-organs. Behind the head, it will be noted, are a pair of jointed appendages, whose origin is problematical. They probably served the purpose of fins, but they do not seem to have been derived in the same way. These fin-like structures are further remarkable on account of the fact that they were hollow, thus recalling the tubular limbs of invertebrates, with which, however, they of course have nothing to do.

How long these forms will remain "bones of contention" we of course cannot say, but there are signs that the veil is lifting. Dr Traquair is of opinion that both the Heterostraci and Osteostraci are rightly to be regarded as forming one sub-class—Ostracodermi. Furthermore, recent researches of his have succeeded in establishing a connection between these and certain exceedingly interesting and puzzling forms known as the *Cœlolepidæ.*

The Cœlolepidæ are extremely ancient shark-like fishes of the Devonian age. The name they bear is bestowed on account of the fact the scales are hollow. These hollow scales or rather spines, were shagreen-like in general form, but were open below, and without the basal plate seen in the typical shagreen-forming scale. The form of the tail was shark-like. But as yet no traces of jaws, teeth, eyes, gill-slits or internal skeleton have been discovered. The peculiar nature of the external covering leads Dr Traquair to believe that these curious and ancient creatures derive their origin from the same stock as that which gave rise to the sharks. The study of the Cœlolepidæ has thrown a flood of light upon some otherwise unintelligible fish remains found in the old red sandstone, in the form of skin-plates. These skin-plates prove to be made up by the fusion of shagreen denticles resembling those of the Cœlacanths. This discovery is one of great importance, for it establishes a connecting-link between the creatures who wore this ancient armour-plate, and who have been christened by the generic name of *Psammosteus*, and the Cœlolepidæ on the one hand, and the enigmatical Heterostraci, on the other. For by a precisely similar fusion of denticles the head-armour of these curious forms was probably derived. Indeed it is believed that traces of this fusion are obvious in the concentric lines which mark the separate elements making up the armour, which we have already described (p. 198).

The Cœlolepidæ may be included both as puzzles and patriarchs. So also may the remarkable fossil-forms known as the *Arthrodira*. The fishes of this group attained enormous size. The head and anterior end of the body were heavily armoured with bony plates. Between the head-shield and the dorsal-shield of the trunk immediately behind, a very perfect and elaborate joint was formed—hence the name Arthrodira—joint-necked. This is a feature unique among fishes. One of the largest of the group was the *Dinichthys* of the Upper Devonian, Ohio, U.S.A. The Arthrodira are generally held to be ancient lung-fish. No trace has yet been found of pectoral fins, but there are vestiges of the pelvic series.

The goodly fellowship of the patriarchs includes several forms of deep interest and importance. One of the oldest of these is

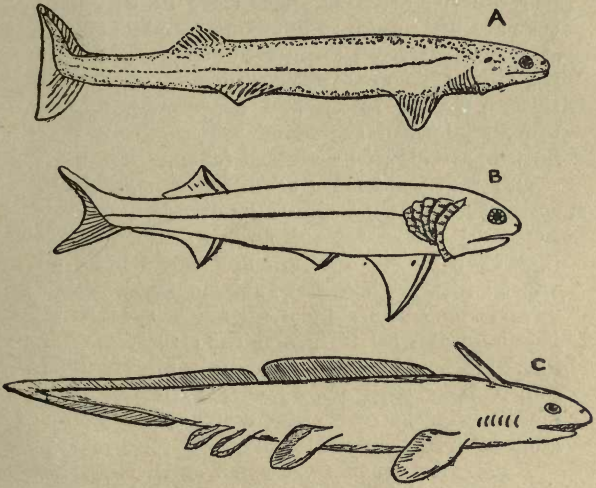

FIG. 17.—Three primitive sharks. *A*. Cladoselache tyleri. *B*. Acanthodes. *C*. Pleuracanthus.

known under the name of *Cladoselache* and lived during the Devonian period, in the seas of that far away age, which have long ceased to be; where they swirled and foamed now stands the flourishing State of Ohio.

The name Cladoselache, being interpreted, means the branch-toothed shark, from the saw-like or comb-like shape of its teeth. The ancient creature upon whom this name has been imposed is one of the very ancient and primitive sharks. Its discovery has done much to enlighten us on the vexed question of the evolution of paired limbs. These appendages in this early type are little more than triangular folds of skin strengthened from within by supports in the shape of rods of cartilage (fig. 17 *A*). How these rods, by fusion and other modifications, probably formed the foundation of the modern fin we have already discussed (chap. vi., p. 67).

Of a somewhat more advanced type, and of a somewhat later date—the Carboniferous and lower Permian—is the form known as *Pleuracanthus* (fig. 17 *C*). The fins are now much more advanced in type, but like those of Cladoselache, have formed the subject of much speculation. From its general form and the structure of its fins, this fish looks as though it might, as Dr Smith Woodward points out, with very little modification, become either a shark, lung-fish, or one of the fringe-finned fishes.

No less remarkable are some small shark-like fish, also of the Carboniferous period, known as Acanthodii—the spiny ones (fig. 17, *B*.). Their claim to special notice is a strong one, inasmuch as the fins are of a type that is quite unique. They appear to have been derived by specialisation of the type seen in Cladoselache, which has resulted in a fusion of certain of the cartilaginous rays to form a single support at the front of the fin, the rest of the fin was formed by skin only stretched between this support and the body. As in Pleuracanthus, the shagreen denticles of the head had become fused so as to form a number of separate bony plates for the protection of the skull. The denticles of the body had become modified to form a closely fitting mosaic of diamond-shaped pavement-like scales. The teeth were few in number and degenerate in type. The peculiar type of fin, not only as a whole, but also on account of the disappearance of distinct supporting rays, must also be regarded as degenerate in form. This early specialisation led to their speedy extinction, without leaving direct descendants.

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