WILDER (B.G.)

GAR-PIKES, OLD AND YOUNG.

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SOME readers of The Popular Science Monthly may never have seen gar-pikes, or even heard of them. The word does not occur in some of the dictionaries, and the animals themselves are found alive only in certain parts of the world. So, before telling what gar-pikes do, it is necessary to explain what they are.

Fig. 1.—The Short-nosed Gar-Pike (*Lepidosteus platystomus*).
Nearly adult, one-fourth natural length. *O*, the gill cover, or operculum. *P*, the pectoral, and *Ve*, the ventral, fin of the left side. *D* and *A*, the dorsal and anal fins. *DF* and *VF*, the "fulcra" which cover the dorsal and ventral borders of the root of the tail. *X* indicates the point where the section shown in Fig. 3 was made. The scales are shown in the next figure.

In the first place, the gar-pike is not a weapon, but a *vertebrated animal.* The vertebrates include all animals having a spine or back-bone made up of a series of segments or *vertebræ.* But this common definition is not wholly accurate. For the very young of man and monkeys, quadrupeds and birds, reptiles and fishes, have no skeleton at all; and some of the lowest fishes, the *Amphioxus* and the lamprey-eels, have no bones. So the vertebrates are now said to include all animals having a longitudinal axis or spine (whether membrane, cartilage, or bone) separating an upper or dorsal cavity, containing the spinal cord and brain, from a lower or ventral cavity, containing

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the stomach, intestine, heart, and other organs of vegetative life. This is shown in Fig. 3.

Let us now go one step further and learn what kind of a vertebrate is the gar-pike. At present the most natural primary subdivision of the branch seems to be into three great groups. The highest

FIG. 2.—PART OF THE SIDE OF THE BODY OF *Lepidosteus platystomus*, Natural size, showing the arrangement of the enameled scales. Below is an outline of a single scale; the point is covered by the scale in front.

is the Mammalia, comprising our common quadrupeds, also bats, monkeys and men, seals and whales. The females of all these bring forth their young alive, and nourish them with milk.

Next come the Sauropsida, including birds, turtles, crocodiles, lizards, and snakes. Lastly, the Ichthyopsida, embracing the Batrachians (frogs, toads, and salamanders), and all other vertebrates.

Evidently, our gar-pike is neither a mammal nor a bird, a turtle, a snake, nor a lizard. It does look a little like an alligator, but it has not only fins and scales, but also *gills*, which are not known to exist in any reptile; while all the Ichthyopsida have gills during at least a part of their lives. The gar-pike is neither a frog nor a toad; it has scales and fin-rays unlike salamanders. Why, then, not call it a *fish?*

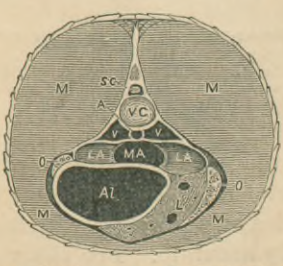


FIG. 3.—CROSS-SECTION (NATURAL SIZE) OF THE SHORT-NOSED GAR-PIKE (*Lepidosteus platystomus*),

Showing the general arrangement of the organs which is characteristic of vertebrates. The section is made in front of the ventral fins at the point indicated by *X* on Fig. 1. The cut surface is looked at from behind. Near the middle is the vertebral column or backbone (*VC*). Above it is the spinal cord (*SC*), surrounded by bony walls. Below are the abdominal viscera. *A* is the median aorta, *V V* the lateral veins. *MA* is the median channel of the air-bladder, and *LA*, *LA*, are its lateral chambers. The cavity of the stomach (*Al*) is on the left, and the liver (*L*), with two veins, on the right. *O*, *O* are the two ovaries, of which the left lies farther forward so that its section is smaller. The whole is surrounded by the muscular walls of the body (*M*, *M*, *M*, *M*), and this again is covered by the plates of the skin.

Because, unfortunately, we are not sure that there are any "fishes." The terms "beast, bird, and fish," notwithstanding common usage and the sanction of Scripture, are devoid of scientific accuracy. For "beast" includes turtles and alligators, and excludes the aquatic mammals, whales, porpoises, manatee, and dugong. "Bird" includes bats and pterodactyls, and excludes the ostriches and penguins, which cannot fly. So "fish" is not only held by some persons to embrace the aquatic mammals, but also, when employed in a stricter sense, it includes forms differing among themselves in many important points.

At any rate, the "fish-like vertebrates" present the following well-marked groups:

1. *Amphioxus lanceolatus;* the lancelet. A single genus with perhaps a single species, but so peculiar as to have received the following appellations: Branchiostoma, Cirrostomi, Pharyngobranchii, Leptocardia, Acrania, Entomocrania, Dermopteri.

2. Myzonts, or Marsipobranchii; the hag-fishes and lamprey-eels.

3. Plagiostomes, or Elasmobranchii; sharks and skates.

4. Holocephala; the *Chimæra* and *Callorhynchus*.

5. Ganoids; the sturgeons (*Acipenser* and *Scaphyrhynchus*); the spoonbill (*Polyodon*); the mud-fish (*Amia*); the gar-pike (*Lepidosteus*); and the *Polypterus* and *Calamoichthys* of Africa, with many fossil forms.

6. Dipnoans; the mud-fishes of Africa, South America, and Australia (*Protopterus*, *Lepidosiren*, and *Ceratodus*).

All of the above were formerly, and are now popularly, regarded as *fishes*.

But the fishes proper, or ordinary fishes, are now called:

7. Teleosts; the perch, salmon, cod, mackerel, and all others not included within the other six groups.

Some have included *Amphioxus* with the Myzonts; others the Plagiostomes with the Ganoids. The most natural combination seems to be that of the Ganoids with the Teleosts; and to this larger group the term Pisces has been applied. But for the present it is safer to recognize the distinctions, and to make our generalizations more exact.

What, then, is a gar-pike? Is it a Ganoid or a Teleost? Curiously enough, the prefix "gar" (signifying a dart or pointed weapon) is employed to designate two fishes, of which one (*Belone*) is a marine Teleost, and the other (*Lepidosteus*) is a fluviatile Ganoid. Both have long jaws with sharp teeth, but in other respects they are very unlike. It will be better to call *Belone* the "gar-*fish*" and *Lepidosteus* the gar-*pike*.[1]

The general appearance of the gar-pike is sufficiently indicated by

[1] These common names are very perplexing. Thus the true pike is *Esox*. The name dog-fish is popularly applied to *Menobranchus*, a batrachian; to *Amia*, a ganoid; and to *Acanthias*, a shark.

the figure. The body is an elongated cylinder covered with hard and shining scales closely joined, and leaving as vulnerable points only the throat and gills, the eyes, and the parts just under the pectoral fins. The tail is moderate in size and rounded, the longest rays a little above the middle, so that it is not quite symmetrical. Upon the hinder part of the back is the dorsal fin, and below the dorsal an anal fin, immediately in front of which is the vent or outlet of the alimentary canal. The paired fins, pectoral and ventral, occupy the places natural to them as representatives of the anterior and posterior limbs of salamanders and alligators.

The length of the head varies in the different species, but, whether longer or shorter, the jaws are furnished with rows of very sharp and closely-set teeth. The apparent form of these teeth is a simple elongated cone; but it has been shown by Prof. Jeffries Wyman that their surface is really deeply folded, so that a cross-section resembles that of the teeth of the curious fossil Batrachians, called, for that reason, Labyrinthodonts. The eyes are of moderate size. As with ordinary fishes, the ears do not appear externally. The nostrils are two pair of small holes at the tip of the snout, communicating with an olfactory sac on each side; the lining of this sac presents one median longitudinal and many transverse folds.

The genus *Lepidosteus*, according to Huxley, has not been found earlier than the Tertiary rocks; although the family *Lepidosteidæ* is represented by more or less numerous genera as far back as the Carboniferous and perhaps (by *Cheirolepis*) in the Devonian.

True gar-pikes are not found in Europe, Asia, Africa, or Australia, or in South America; while in North America they seem to be nearly confined to the Mississippi River and its tributaries, and the Great Lakes.[1]

Prof. Poey has also recorded the existence of a gar-pike in Cuba, a fact which is interesting, not as an indication of "manifest destiny," but as a memorial of the supposed ancient connection between the West India Islands and our continent. None have been found in salt-water, and the writer has no knowledge as to how far they enter the mixed water at the mouth of the Mississippi; but their tenacity of life encourages the belief that they might possibly adapt themselves to the ocean. Their introduction into New England waters would afford to Eastern zoölogists the much-desired opportunity of studying their development, of which nothing whatever is known.

We must now inquire whether there are more than one species of *Lepidosteus*.

Unfortunately, this question involves several others. For the genus *Lepidosteus*, established by Lacepede for the single species

[1] A few examples have been taken in Cayuga Lake, in Central New York, having probably entered by the canal at its northern end; it is said to occur in the Susquehanna River, Pennsylvania. It is lately reported that a species has been found in China.

osseus, has since been subdivided by some authors into *Lepidosteus*, *Cylindrosteus*, and *Litholepis*, or *Atractosteus ;* and nearly forty specific names have been applied. One of these, *Sarchirus*, merely denotes the lobed state of the pectoral fin of the *young* gar (as will be shown further on), and most of the others seem to be based upon individual or geographical variations. Much more remains to be learned before the exact number of species can be ascertained; meantime, we may safely admit the three following:

L. osseus, the bony gar, having a long and narrow snout, and rarely attaining five feet in length; *L. platystomus*, the short-nosed gar, with a short and broad snout, as the name implies; and *L. adamantinus*, the alligator-gar or diamond-gar, with a short and wide snout, but attaining a greater size than the other two, and more common in the southern part of the Mississippi Valley. Probably the careful comparison of many individuals will oblige us to admit one or two additional species.

Notwithstanding, however, the peculiarities by which several of the species of *Lepidosteus* may be distinguished, so many and so obvious are the features which unite them together, and separate them from all other fishes, that they are recognized by all as belonging together, just as are the catfishes, the suckers, or the sturgeons.

Moreover, their internal structure, so far as it has been ascertained, presents a remarkable uniformity, whence we may infer that there is no important difference in their functions or habits, excepting in so far as may depend upon their circumstances, their food, etc. It is desirable to ascertain the extent of this variation, by accurate observation of carefully-determined examples, but on the present occasion we must be content, although unwillingly, with the assumption that what one gar has done another gar can do.[1]

Like most other New England zoölogists, the writer had been long obliged to content himself with dead gar-pikes, and with the somewhat unsatisfactory figures and descriptions which occur in a few zoölogical works. He had gained some more vivid impressions from the words and blackboard sketches of him who regarded "the establishment of the order of Ganoids as the most important advance which he had brought about in ichthyology."[2]

But even these privileges only increased the desire to behold the gar alive and active, and to realize the delight expressed by the great teacher when first enabled to observe them upon his journey to Lake Superior.

[1] Unwillingly, because all such assumptions are very undesirable. There have proved to be exceptions to nearly all general rules, whether of structure or of functions, as is shown in a paper by the writer, entitled "Is Nature inconsistent?"—(The *Galaxy*, April, 1876.)

[2] Although most other zoölogists have differed with Agassiz respecting the limits of the group, the name has been generally retained.

When, therefore, the writer found himself upon the Illinois River (at Peoria, Illinois), his steps almost instinctively sought the water, in the somewhat unreasonable expectation of being first greeted by a majestic "gar," rather than by some of the many kinds of ordinary fish so abundant in the Western rivers.

The first glance was disappointing. The river here widens into a basin known as Peoria Lake; and from the fishermen's pier, projecting some forty feet from the shore, could be seen no sign, near or remote, of the hoped-for mail-clad fish. The fishermen, who had not yet become acquainted with that unnatural perversity of naturalists which causes them to prize some things inversely as their beauty, their gentleness, and their commercial value, called attention to the "cats," "buffaloes," and other marketable fish swarming in the sunken pens, and promised to bring in some gars from their next haul; adding some emphatic statements as to the superabundance of these and of other such trash.

Just then, gliding slowly about very near the surface, and apparently undisturbed by the splashing of the bulky "cats" and "buffaloes," was seen a slender little fish less than three inches long. It was a young gar-pike. It might easily have escaped between the bars of the tanks, but instead remained within arm's-length of the edge of the open trap, moving gently to and fro as if courting observation.

A tin cup was anxiously brought: it was dipped into the water, slowly approached, and quickly lifted. The gar was there. But, floating as usual at the surface, a slight tilting of the cup spilt it back again into the water. To the astonishment of all, it soon reappeared in its former place, seeming actually to welcome death for the sake of (scientific) immortality.

By a second and more careful effort the young gar was secured, and soon transferred to the basin of water which was destined to be its home for three weeks.

During that time a part of each day was spent in observation of its form and its movements, and in comparing it with other gars, old and young.

Their Habits.—None of the young gars observed by the writer showed any disposition to attack each other or the small fishes placed with them; and the stomachs of the two adults examined with reference to this point contained only a few grasshoppers. But the many and sharp teeth are evidently well fitted for seizing living and active prey, and the fishermen accuse the gars of destroying large numbers of food-fishes. On this account, as also in revenge for the damage done by them when entangled in the nets, the fishermen are said to throw them out upon the bank to die, or to plunge them forcibly head first into the soft mud. More information is needed as to the food of the gar.

The following brief account of their manner of feeding is from a

report of some remarks of Prof. Agassiz on young, living gar-pikes from Lake Ontario, before the Boston Society of Natural History, in 1856:

"The manner of feeding also is unlike that of other fishes, and resembles that of reptiles. Other fishes take their food and swallow it at once, with open mouth. But this one (the young gar) approaches its prey (in this case small minnows) slyly, sidewise, and, suddenly seizing it, holds it in its jaws until, by a series of movements, it succeeds in getting it into a proper position for swallowing, as is the habit with lizards and alligators."

Before attaching much importance to the reptilian analogies here suggested, it should be ascertained whether the mode of swallowing above described is not followed by certain long-billed Teleosts (as *Belone*, etc.), and, on the other hand, discarded by the short-headed gar, whose jaws have nearly the form of the pickerel. Upon the whole, the gars and other typical Ganoids seem to have affinities with Batrachians rather than with scaly reptiles.

The flesh of the gar is soft, and speedily decays. In Wood's "Natural History," it is stated that "the flesh of the bony pike is said to be good;" and Prof. W. S. Barnard informs me that the gars, especially the young, are not infrequently used as food by whites in Wisconsin, and by both whites and negroes in Mississippi. Still, there is no reason for believing that the flesh is particularly desirable.

In this connection, it is worth noting that little use as food is made by man of the representatives of the Ganoids and the Plagiostomes, which, as shown by fossil remains, were created before the ordinary fishes. Some kinds of skates are eaten on the French coast, and sturgeons are known as "Albany beef," but no comparison can be made between them and the salmon, the cod, or the mackerel.

While watching the living gar, whether old or young, one of the first things noted is that it not only remains usually near the surface, but, at short intervals, actually protrudes the head from the water. In so doing, it turns partly over upon one side, emits a large bubble of air, executes a slight gulping movement of the jaws and throat, and sinks again below the surface; immediately afterward a few smaller bubbles escape from the gill-slit on each side of the neck. The foregoing is a very bald and inadequate description of a curious and, when first observed, astonishing operation. The movements are very rapid, and almost convulsive, as if the fish were suddenly oppressed by something, and hastened to remove it. The little gar first obtained almost invariably turned upon the left side, the air escaping from the right; this uniformity was not observed with the others. Occasionally they would open the jaws widely, as if gaping; and at other times the sides of the mouth were spread laterally.

With reference to the young gars from Lake Ontario already mentioned, Prof. Agassiz is reported as follows: "This fish is re-

markable for the large quantity of air which escapes from its mouth. The source of this air he has not been able to determine. At certain times it approaches the surface of the water, and seems to take in air, but he could not think that so large a quantity as is seen adhering in the form of bubbles to the sides of the gills could have been swallowed, nor could he suppose that it could be secreted by the gills themselves."

Since the exhalation of air from any source is evidently as easily performed below the surface, the periodical ascent of the gars goes far to show that there is likewise an inhalation. But as it was not easy to determine this, on account of the small size of the young gars and the difficulty of handling the older ones, the writer experimented upon another Western Ganoid, the *Amia*, or "mud-fish," or "dog-fish."

When placed in a tank the *Amia* kept near the bottom, and seemed to prefer the darker portions. But it came to the surface at pretty regular intervals, emitting one or two large bubbles from the mouth, and, on descending, several smaller ones from the opercular orifice.

The fish was gradually accustomed to having the body gently embraced by the hand about the middle.

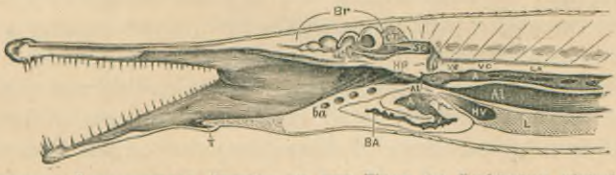


FIG. 4.—VERTICAL LONGITUDINAL SECTION OF THE HEAD OF *Lepidosteus platystomus*, ONE-HALF NATURAL DIAMETER.

Br, the brain cut on the median line so as to show the ventricles of the two hinder lobes, the cerebellum and optic lobes. *SC*, the spinal cord passing backward into the canal of the vertebral column (*VC*). *CT*, a mass of connective tissue filling the hinder part of the brain-cavity. *HP*, the right hypopharyngeal bone, just in front of the passage (*CH*) from the throat (*Al*) upward and backward into the air-bladder (*A*). *Ve* is a valve which seems to guard the opening from within; a corresponding valve is on the left side. *LA* is one of the openings from the median channel of the air-bladder into a lateral chamber. *L* is the liver, which terminates forward in a large blood-vessel, *HV*. *A* and *V* are the auricle and ventricle of the heart; *BA*, the branchial artery; and *ba*, the cut ends of the smaller arteries to the gills on the right side. *T* is the tongue.

Having been thus prepared, the fish was permitted to swim to and fro in the tank, but prevented from rising. It soon became uneasy, and, after a few not very violent efforts to disengage itself, emitted a large bubble of air.

Now, if this emission were all that was necessary we may suppose that it would have remained quiet for another period. On the contrary, after a second or two of repose (perhaps resulting from the habit of being satisfied after the respiratory act), the fish became more and more uneasy, moved rapidly to and fro, turned and twisted and lashed with its tail, and finally, by a violent effort, escaped from the hand. It rose to the surface, and, *without emitting any bubble, opened*

its jaws widely and apparently gulped in a large volume of air. It then descended and remained quiet for the usual interval.

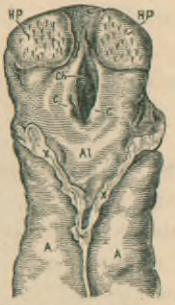


FIG. 5.—VIEW FROM BELOW OF THE UPPER OR DORSAL WALL OF THE THROAT OF THE LONG-NOSED GAR (*Lepidosteus osseus*), ONE-HALF NATURAL DIAMETER.

The œsophagus is removed excepting that part of the dorsal wall (*Al*) which is closely attached to the air-bladder (*A*). Its cut edges are indicated by *x x*. *Ch* is the opening or "chink" leading into the air-bladder, and *C C* indicate projecting points at the sides of the chink. *HP*, hypopharyngeal bones armed with teeth.

The escaping air should be chemically examined. But, so far as the experiments go, it seems probable that, with both *Amia* and *Lepidosteus*, there occurs an inhalation as well as exhalation of air at pretty regular intervals, the whole process resembling that of the *Menobranchus* and other salamanders, and the tadpoles, which, as the gills shrink and the lungs increase, come more frequently to the surface for air.

But the reader may say: "These fishes have gills, of course; but have they also lungs?" To this the answer is both yes and no; for there are at least two different ways of interpreting certain facts; and some definitions are not as yet wholly agreed upon.

FIG. 6.—CROSS-SECTION OF THE AIR-BLADDER OF *L osseus*, ONE-HALF NATURAL DIAMETER.

The central open space is the median channel; on each side is seen one of the numerous subdivisions of the lateral portions of the air-bladder. Above are the median aorta and the two lateral veins, as in Fig. 3.

The facts are as follows: the *Lepidosteus* and *Amia*, like many other fishes, have an *air-bladder*—a sac lying under the spine and above the alimentary canal, and communicating by a slit-like orifice with the upper side of the throat. With sturgeons and catfishes and most common fishes, the sac is nearly or quite simple, and the communication with the throat may be very narrow or even closed. Such fishes are not known to swallow air, and there is need of further information as to the composition and source of the contained gas. But the air-bladder of *Amia* and *Lepidosteus* is divided into many cells,

so as to resemble a frog's lungs; and the walls and partitions of these cells have many blood-vessels. These air-bladders are, in fact, more cellular and more vascular than the lungs of *Menobranchus*, or the hinder and larger portion of the lungs of serpents. And, in the light of the observations already recorded, there seems good reason for believing that pure air is inhaled and vitiated air exhaled whenever the fish rises to the surface.

It is worth noting, also, that both *Amia* and *Lepidosteus* are very tenacious of life, and endure removal from the water for a time much better than do the sturgeons, whose air-bladders are neither cellular nor vascular. The latter, also, are bottom-feeders, while the gars seem to keep near the surface of the water.

Why, then, are not these air-bladders lungs?

The most obvious objection is, that their openings are into the upper or dorsal side of the throat, while the glottis of batrachians, reptiles, birds, quadrupeds, and ourselves, communicates with the lower or ventral side.

This objection may be met in two ways. In the first place, if allowed, we should have to admit that all the so-called air-breathing vertebrates have organs (the lungs) which have no representative in the fishes, and that most of the latter have an organ (the air-bladder) which has no representative in the former.

It is true that some fishes have no air-bladder; but with some, as *Amphioxus*, the lamprey-eels, the sharks,[1] and the skates, we may infer that it has not yet become developed; while with others, as the flat fishes, the air-bladder may have been lost through what may be called a local retrograde metamorphosis.

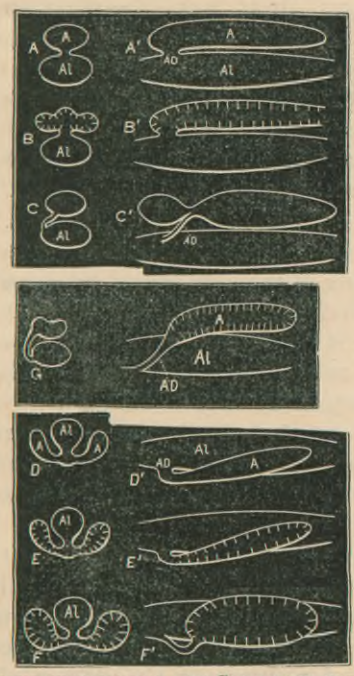
It is important to note, also, that an air-bladder and lungs have never been found in one and the same animal; and since arms, front-legs, flippers, and wings, are all regarded as modifications of the same organs, anterior limbs; and since, in many other cases, organs of very different size, form, complexity, and function, are considered as homologous, we shall be following precedent in admitting a willingness to regard air-bladders and lungs as modifications of the same organ.

But the true argument against the objection is derived from the existence of transition forms, or links, between air-bladders and lungs, as to the position of the organs themselves, and their communications with the alimentary canal.

With *Amia* and *Lepidosteus* the air-bladder and the opening of the duct are both dorsal. With the Brazilian fish called *Erythrinus* (as first stated by Johannes Müller, and lately verified by the writer), the duct opens upon one *side* of the throat. In the lately-discovered *Ceratodus* of Australia, as described by Günther, the sac and duct are single, but the former is vascular, and the latter enters at the left

[1] Maclay has figured a rudimentary air-bladder in certain shark-embryos.

of the ventral surface. With two African Ganoids, *Polypterus* and *Calamoichthys* (as also stated by Müller, and verified by the writer as to the latter genus) the sac is double, and communicates with the ventral side in the median line; but it is slightly cellular, as in *Menobranchus*.



A. Sturgeons and many Teleosts.

B. *Amia* and *Lepidosteus*.

C. *Erythrinus*.

G. *Ceratodus*.

D. *Polypterus*, *Calamoichthys*.

E. *Lepidosiren*, *Protopterus*.

F. Reptiles, birds, mammals.

FIG. 7.—DIAGRAMS REPRESENTING THE CONNECTION BETWEEN THE AIR-BLADDER OR LUNG AND THE ALIMENTARY CANAL IN CERTAIN VERTEBRATES.

Al, the alimentary canal. *A*, the air-bladder. *AD*, the air-duct.

The figures at the right show the alimentary canal and air-bladder from the left side; those at the left represent cross-sections more or less foreshortened in some cases.

A A' represent the simple condition-connections of the air-bladder in the sturgeons (*Acipenser*) and in most Teleosts where the air duct remains open. *B B'* represent the arrangement in *Amia* and *Lepidosteus*, where the duct opens upon the dorsal side of the throat, but the bladder is more or less cellular. The hinder end of the bladder is left open to indicate its great length in *Lepidosteus*. In *C C'* is shown the arrangement in *Erythrinus*. The bladder is still upon the dorsal side, but the front part is separated from the hinder two-thirds by a constriction, and the long duct passes forward from just behind the constriction to enter the left side of the throat. There are fibrous partitions in part of the bladder, but I do not know that they are vascular. The condition in *Ceratodus* is shown at *G*; the bladder is single but vascular, and the duct opens on the ventral side, but not in the middle line.

In the remaining figures the air-duct opens on the lower or ventral surface of the throat, and the air-bladder is in two parts, which unite at the duct, but separate backward and lie upon the sides of the stomach, or even to some extent upon its dorsal surface next the backbone. In the side-views only the left sac is seen; in the cross-sections the whole is foreshortened so as to bring it into one plane. In *Polypterus* and *Calamoichthys* the inner surface of the sacs is nearly smooth, but in *Lepidosiren*, as in the salamanders, it is more or less folded and vascular, and is also connected with the heart by special vessels. In the reptiles, birds, and mammals, the duct or trachea soon divides into the two bronchial tubes.

Finally, in the "mud-fishes" of Africa and South America (*Protopterus* and *Lepidosiren*) the duct is ventral, and the air-bladder is a double and lung-like sac with stiff walls.

This series seems to connect the air-bladder of the fishes with the lungs of the true aërial vertebrates, and to remove the objection

based upon the different position of the communication between them and the alimentary canal.[1]

But another and perhaps more weighty objection has been urged by Prof. Huxley. He says: "But such air-sacs are air-bladders and not lungs, because they receive their blood from the adjacent arteries of the body, and not direct from the heart, while their efferent vessels are connected only with the veins of the general circulation."

According to this view, therefore, the Dipnoans (*Protopterus* and *Lepidosiren*) have lungs, because the blood goes to the air-sacs by a pulmonary artery, and returns by a pulmonary vein into a left auricle; while the cellular and vascular air-bladders of *Amia* and *Lepidosteus* are not lungs, because such an arrangement does not exist.

Yet Prof. Huxley applies the name *placenta* to the vascular interdigitations by which the young of some sharks are connected with the mother, although they are developed from the yolk and not, as in mammals, from the chorion. It would be interesting to know whether the *nerves* of the air-bladder are the same as those of the lungs.

The best test of the naturalness of the definition would be furnished by the discovery of some form having the pulmonary vessels connected with an air-bladder lying upon the dorsal side of the alimentary canal. Meantime, since all are agreed upon the facts, the question concerns interpretations and definitions.

Whether or not the air-bladder of the gar-pike is entitled to the name of lung, we may admit that it corresponds with a lung in its essential connection with the alimentary canal, and apparently in its function as an organ for aiding the oxygenation of the blood.

The writer's opportunities for observing the motions of the adult gar were too brief to enable him to describe them accurately. It is to be hoped that this fish may soon be placed in some public aquarium. But the motions of several young gars were carefully watched daily during three weeks.

The movements of the little gars, even the smallest, were very unlike those of the common little fishes, minnows or catfishes, which were placed with them. These latter seemed agitated, and splashed about in an indeterminate way. But the little gars, though they went like arrows when disturbed, usually remained almost at rest, or moved slowly about with a dignified, almost solemn air, as if conscious of very ancient and honorable lineage. They also have, as was remarked by Prof. Agassiz, the power of moving the head upon the neck; and occasionally the whole body was thrown into two or three undulations, resembling those of a short serpent; and so impressive is the air of supercilious self-possession that one might almost imagine them shrugging their shoulders at other creatures, including the bipeds of recent creation, who study their movements.

To sounds in general they paid no attention. But a tap upon the side of the vessel usually caused them to start and open the mouth, sometimes two or three times in succession.

It has already been said that the little gar first taken was recognized as such; yet the resemblance to the adult was mostly in the general elongated form of the body, and in several other respects there were marked differences. First, in *color*. The old gar is a bluish ash-color, or light gray; darker above, and lighter below, but with no distinct patches. All of the young gars presented a distinct though irregular dark stripe along the side of the body and head, crossing the eye. The belly, too, was almost white, and strongly contrasted with the darker regions.

Second, the smallest ones had *no scales* at all; but with one, 108 millimetres (about four and a quarter inches) long, the hinder half of the body showed outlines of the scales in process of formation, and the larger ones had the armor more or less fully developed. At about the same time the upper and lower borders of the tail become protected by several pair of pointed plates, the *fulcra*.

The third and most striking peculiarity of the young gars consisted in the existence of *two tails*, an upper and a lower. These are shown in Fig. 8, *B*.

The formation of these two tails, and their significance, will be considered further on; for the present, we are concerned with their structure, their relative position, and their uses. The lower tail was evidently the caudal fin. It had several rays, and a rounded hinder border. But it was smaller in proportion than in the adult gar, and the middle rays were directed obliquely downward, instead of horizontally backward.

The upper tail is best described as a single fleshy filament, flattened from side to side, and tapering to a fine extremity. In the smallest gars it was longer than the fin below, in the older it was shorter, while in the adults no trace of it appears.

These two tails have very different movements. The lower, corresponding to the caudal fin of the ordinary fish, is used in three ways. When the little gar is in a gentle current, and wishes not to be carried downward, the fin is made to execute a series of undulatory movements, such as have been described by Prof. Agassiz respecting the dorsal fins of young pipe-fishes, etc., and such as the writer has observed with the long dorsal fin of *Amia*.

This tail is also strongly flexed to one side, as with ordinary fishes, in order to change the course. And it is rapidly moved from side to side for all sudden and rapid locomotion, as when frightened.

The movements of the filament were first described by Prof. Agassiz, and he called attention to them upon several occasions. But his descriptions are very brief, and, upon one point, seem to require modification.

The filament is in almost constant vibration. Occasionally, when the gar is at rest, and perhaps also when it is turning, or rapidly swimming, the filament is not used. But usually the vibrations are so rapid that the tip of the filament is invisible, excepting as an indistinct blur. Generally, it is directed backward and slightly up-

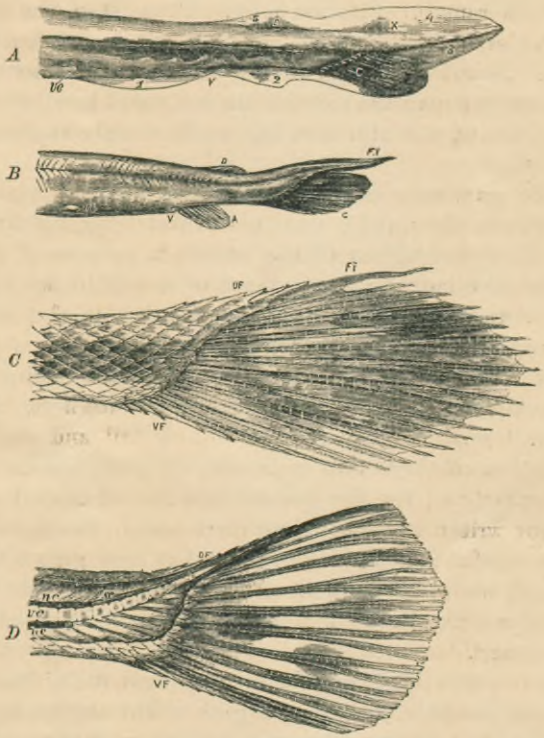


FIG. 8.—FOUR FIGURES OF THE TAILS OF *Lepidosteus* AT DIFFERENT STAGES.

A, from a specimen twenty-two millimetres or seven-eighths inch long, enlarged four diameters. The ventral fin (*Ve*) is just appearing. The median fin is being absorbed between the four spots referred to in Fig. 9. The tip of the tail is inclined upward, and the infra-caudal lobe is larger. In *B* the primordial fin has almost disappeared; the dorsal (*D*) and the anal (*A*) fins are quite large. The infra-caudal lobe is nearly as long as the tip of the original tail, which has been reduced to a slender vibratile filament. This specimen is forty-four millimetres or one and three-fourths inch long, and the tail is enlarged two diameters. *C* shows the tail of a specimen three hundred millimetres or nearly twelve inches long, of natural size. The filament is still further reduced, and the rays of the infra-caudal lobe form the end of the tail In *D* the tail is that of an adult, one-half natural diameter. The filament, the original end of the body, has wholly disappeared, and the infra-caudal lobe forms the tail. But dissection shows the spinal axis extending along the dorsal border to a point corresponding with the previous attachment of the filament. (Further description and discussion of these changes, with references to authors, may be found in a paper by the author, entitled "Notes on the North American Ganoids," "Proceedings of the American Association for the Advancement of Science," 1875, pp. 151-193.)

ward, but at times it is bent to one side, or elevated to nearly a right angle with the body, the tip all the while in constant vibration. Those who have watched the tail of an irritated rattlesnake, or even of a common striped snake, under strong excitement, may form a pretty correct idea of the nature of this movement. It was charac-

terized by Prof. Agassiz as "involuntary;" and so it may be regarded, since its rapidity is such as to preclude the idea of a separate volition for each movement. But the gar, evidently, has entire control of the vibrations; for they are more or less rapid at different times, and are occasionally intermitted; the position of the whole filament is changed at will; finally, the muscular bands upon each side of the cartilaginous rod, which runs through the filament, consist of the striped variety of muscular fibre, as are the other voluntary muscles.

This is all the writer has seen of living young gar-pikes. But the explanation of the peculiar double tail is furnished by some still younger specimens, the smallest of which is shown, enlarged, in Fig. 9.

These little gars were scooped out of the Red River, near Shreveport, Louisiana, in the spring of 1871, by a lad only ten years old, who had heard the writer say that he wished for very *small* fishes. At that point these young gars were then as abundant as minnows, as easy to catch, and commercially as worthless. All of them are less than two inches long, and among them are two about three-fourths of an inch in length. These last are not only much smaller than any previously examined by naturalists (so far as known to the writer), but they also furnish the clew to the double tail, and suggest some important paleontological considerations.

While earnestly expressing his appreciation of the value of these little gars, the writer finds himself compelled to exemplify the proverbially ungrateful and dissatisfied nature of zoölogists by regretting that there were not more of them, and that some were not very much smaller, or even still within the egg.

In this connection one is reminded that now, as a rule, the smallest rather than the largest are desired by naturalists. The giants are curiosities, and interesting as showing the capacity for *growth;* but the mysteries of development, the relations of apparently diverse forms, and the order of geological succession, are best revealed by the apparently most insignificant.

A good illustration of this inverse ratio between size and value is contained in the following passage from Prof. and Mrs. Agassiz's "Journey in Brazil:"

> "Mr. Agassiz has a corps of little boys engaged in catching the tiniest fishes, so insignificant in size that the regular fishermen, who can never be made to understand that a fish which is not good to eat can serve any useful purpose, always throw them away. Nevertheless, these are among the most instructive specimens for the ichthyologist, because they often reveal the relations not only between parent and offspring, but wider relations between groups."

Of the two smallest gars, one is nearly colorless, while the other is marked very much as are the older ones. They are 18 millimetres (a little less than three-fourths of an inch) in length. The head is

short and flattened, with slight indications of teeth on the edges of the jaws. With one of them the ventral fins have not appeared; with the other they are represented by minute white elevations. Each pectoral consists of a fleshy lobe, surrounded by a thin fringe or border.

FIG. 9.—SMALLEST GAR-PIKE YET OBTAINED (EIGHTEEN MILLIMETRES OR ABOUT THREE-FOURTH INCH LONG, ENLARGED FIVE DIAMETERS).

The actual length is indicated by the line above the figure. There are no scales. The head is short. The pectoral fin (*P*) consists of a fleshy lobe (*L*), with a thin fringe or border (*F*). The ventral fins have not appeared. A median fin extends along the hinder third of the body above and the hinder half below. It is interrupted by the vent (*V*), and presents four darker and more or less differentiated spots. The anterior pair are evidently the beginnings of the dorsal (*D*) and anal fins. The signification of the hinder dorsal spot is uncertain. But the hinder spot below (*C*) presents rays, and is the commencement of the infra-caudal lobe.

The hinder end of the body tapers to a point, as with *Amphioxus*, the extremity being slightly bent downward. At the junction of the middle with the hinder third of the body commences a delicate median fin, colorless, and without rays for the most part, and extending around the tip of the tail forward to the vent, thence forward to about the middle of the body. Such a primordial median fin exists in the young of all fishes whose development has been studied. The permanent fins seem to result from the formation of cartilaginous or bony rays either throughout most or the whole of its length, as with lampreys and common eels; or at several points, as with the mackerel and *Polypterus*; or at three, or two, or only one, as with the cod, the blue-fish, and the pickerel. The intervening portions disappear. The hinder part of the primordial fin of the smallest gars presents four points of darker coloration, two above and two below. The posterior upper spot presents no rays, and later seems to disappear.[1] The other three are evidently the beginnings of fins. The anterior above and that below occupy the positions of the future dorsal and anal fins. The destiny of the hinder lower spot is better seen by comparison with larger examples.

The series given in Figs. 8 and 9 shows that, as the gar increases in length, the primordial fin disappears, the dorsal and anal increase, and the end of the tail becomes more slender and pointed. But the most striking change consists in the enlargement of the hinder lower spot into what may be called the infra-caudal lobe. The rays of this become longer and more numerous. They project beyond the margin of the primordial fin, so as to leave a decided notch, as in Fig. 8, *A*.

In Fig. 8, *B*, the end of the body merits the name of filament, and the relative size of it and the lobe is reversed. Afterward, partly by more rapid increase of the lobe, and partly by absorption of the fila-

[1] It may have a morphological significance, as suggested further on respecting the fossil *Glyptolæmus*.

ment, the latter seems smaller and smaller, and at last disappears; so that the lobe, from having been at first an outgrowth from the filament, finally becomes the whole of the tail or caudal fin.

It appears, then, that the hinder end of the body undergoes considerable change before reaching the adult condition. Aside from the partial disappearance of the primordial median fin and the gradual development of the ventrals, the dorsals, and the anal, the caudal-fin assumes at least three distinct forms. The first is lance-shaped and simple, like that of *Amphioxus*, the eel, the lamprey, salamanders, and tadpoles. The second is compound, with a slender filament above and a broader fin below, as with some sturgeons and sharks. The third consists entirely of the lower fin, which is enlarged and brought into a direct line with the body, the longest rays being a little above the middle. Its upper and lower borders are now thicker and stronger than the intermediate portions; whereas in the first stage the cartilage and muscle are in the centre, the upper and lower borders being very thin.

In short, the tail of the gar-pike undergoes a decided *transformation*. And one naturally inquires, "What is the occasion for it?"

It is so recently that all structural differences and changes were supposed to be readily explicable upon the doctrine of final causes, that we naturally turn first in that direction. Some transformations certainly seem to relate very distinctly to the welfare of the individual, as when the caterpillar becomes a butterfly, and when the aquatic larvæ of mosquito and dragon-fly change their forms with their habits and modes of life. So, among the vertebrates, it is obvious that the tadpole is by no means adapted to the necessities of the frog and the toad; and the intermediate stages, resulting from the gradual loss of the tail and the acquisition of legs, while perhaps not particularly suited to either aquatic or terrestrial locomotion, seem to be required in order to permit the development of the lungs and the accompanying disappearance of the gills.

But can the transformations of the gar-pike's tail be thus accounted for? According to present knowledge and justifiable inference, the *Lepidosteus* not only passes the whole of its life in the water, but is also, from first to last, an active, predaceous fish, requiring all possible advantages of form and fin in order to overtake its prey.

Since no marked change occurs in the general form of the body, we may perhaps assume that it is perfectly well adapted to the fish's needs; although this suggests the general inquiry as to the *cui bono* of the almost infinite variations from the ideal form supposed to be best suited to aquatic locomotion.

But do we know, or can we easily infer, any differences in the necessities or the manner of life of the *Lepidosteus* at different ages, which may account for its having a tail first like a lamprey's, then like a sturgeon's, and, finally, like that of *Amia?*

It may be suggested that the rapid and, at most, invisible vibrations of the filament enable the young gar to glide stealthily upon its prey. But the very young would seem to be even more in need of such precaution, and with them the tail is relatively as large as in the adult, although differently shaped. Finally, even if we conclude that the three distinct stages of the tail are perfectly adapted to certain hypothetically unlike necessities, what shall be said of the intermediate conditions? While growing, the infra-caudal lobe must be rather a hinderance than a help to the movements of the primitive tail; and while disappearing, the filament, being useless, must be, if anything, an incumbrance.

Shall we, then, conclude that these changes in the appearance of a single individual are for the sake of *variety*—as some would explain the great diversity of specific form and coloration among animals and plants?

At the present day, neither of the explanations above given is likely to wholly satisfy the large class of thinkers who, whether or not they accept any particular evolution doctrine, are inclined to believe that there is, in many cases, a more or less exact parallelism between the changes which occur in the development of an individual, the successive forms of geological times, and the series of living forms, lower and higher, or more generalized and more specialized.

In the smallest gar here described, and presumably in still younger examples, the axis of the body, represented by the notochord or primitive vertebral column, is nearly horizontal, about midway between the upper and the lower borders of the tail. This is likewise the case with the lowest known vertebrate, *Amphioxus;* with the forms next above, the hag-fishes (*Myxine* and *Bdellostoma*) and lamprey-eels (*Petromyzon*); with the larvæ (tadpoles) of frogs and toads; and with the adults of the aquatic and tadpole-like salamanders, *Menopoma* and *Menobranchus.*

Finally, such a tail exists in the Dipnoans, or mud-fishes, of Africa, South America, and Australia (*Protopterus*, *Lepidosiren*, and *Ceratodus*), which have some striking affinities with Batrachians, but are usually regarded as fishes, and are, perhaps, the best illustration of *generalized* forms.

To this variety of tail, Cope has applied the name *isocercal;* Huxley calls it *diphycercal*, and gives as an example *Polypterus*, where, however (as in *Calamoichthys*), the "end of the notochord is hardly at all bent up." Wyman, finding this kind of tail in the embryo of a skate, called it *protocercal*, and, on some accounts, this seems the more suitable name.

As the gars grow older, the relative length of the filament and the infra-caudal lobe constantly changes. At first the former is the longer; in a specimen 108 millimetres long, their tips coincide; in one 142 millimetres long, the lobe projects beyond the filament; and in a

third, 300 millimetres long, the filament is much the shorter, is ragged and attenuated, and during life was rarely employed. This second stage, or rather series of stages, has several counterparts among living Selachians and Ganoids. The most accurate resemblance is presented by the shovel-nosed sturgeon of the Mississippi River (*Scaphyrhynchus*). The filament is excessively elongated in *Chimera*, and exaggerated as to both length and breadth in the thrashing-shark (*Alopias*). But, with many sharks, the common sturgeons, and the spoonbill (*Polyodon*), the size of the infra-caudal lobe is so nearly that of the filament as to give the whole tail a nearly symmetrical outline, and lead zoölogists to speak of the "upper lobe," whereas it is really the bent-up end of the body. This kind of tail is called *heterocercal.*

The gars above mentioned are supposed to be the young of the *Lepidosteus osseus.* Just at what size the filament wholly disappears in that species is not known. But with the smaller and proportionally shorter species, *L. platystomus*, there is no sign of the filament when eighteen inches in length. The tail might then be thought, at first sight, to be symmetrical. But the longest rays are a little above the middle, and dissection shows that the spinal axis is continued backward and upward as a cartilaginous rod,[1] terminating at the upper border, just under the hinder pair of *fulcra*, and at the point where the filament was attached. The rays are all attached to the lower border of the spine; and there is only a lower lobe of the tail.

A similar structure exists in the tail of *Amia*, which Prof. Huxley gives as an example of *heterocercal* tail. It seems better, however, to discriminate between it and the previous stage, where the upper lobe (filament) exists, and it may, therefore, provisionally be called the *masked heterocercal*, or perhaps the pseudo-homocercal.

Prof. Huxley has more recently given figures and descriptions of the tail of embryo Teleosts (*Gasterosteus*), in which the structure is nearly identical with that of the adult *Amia* and *Lepidosteus.*[2]

The same author concludes that in many adult Teleosts the posterior end of the spine is more or less strongly bent up, although the tail is outwardly nearly or quite symmetrical.

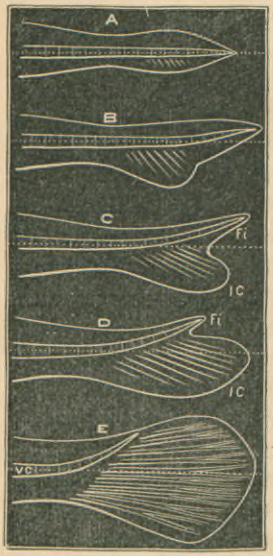
But when, as in the majority of species, the hinder border is emarginate, so as to form an upper and a lower lobe, the former is never known to contain any extension of the spine; although some South American Goniodonts have the upper ray prolonged into a sort of filament, yet in other forms the lower ray is similarly elongated, and

[1] This rod consists of the notochord, and a slender prolongation of the spinal cord, surrounded by a cartilaginous sheath.

[2] The writer has found the same condition in newly-hatched catfishes (*Amiurus*), and it has been observed in the embryo of a species of *Cottus*, by Mr. S. H. Gage, a student of natural history at Cornell University.

neither can be compared with the true filament of the young gar or the upper lobe of sturgeons and sharks.

It may not be possible to draw a sharp line between the tail of most adult Teleosts, and that of *Amia* and *Lepidosteus*, but perhaps the old term *homocercal* can be employed for the former.



A. Protocercal. First stage of *Lepidosteus*. Permanent in *Amphioxus*, *Petromyzon*, *Lepidosiren*, *Polypterus*. Also in some ancient Ganoids, as *Glyptolæmus*.

B and *C*. Heterocercal. In the sturgeons, and most sharks, and many mesozoic fossils.

D. Not represented, so far as I know, among recent or fossil forms.

E. Masked heterocercal. In adult *Amia* and *Lepidosteus*. In the embryo of many Teleosts. In *Megalurus* and some other fossils of Mesozoic and more recent epochs.

FIG. 10.—DIAGRAMS INTENDED TO ILLUSTRATE THE CORRESPONDENCE OF THE SUCCESSIVE STAGES OF TRANSFORMATION OF THE TAIL OF *Lepidosteus*, WITH THE TAILS OF CERTAIN LIVING FORMS MORE AND LESS GENERALIZED, AND OF CERTAIN FOSSILS MORE AND LESS ANCIENT.

A, the first or *protocercal* stage, where the end of the vertebral column (*Vc*) is horizontal and divides the tail into upper and lower lobes nearly equal in size. *B* and *C*, the heterocercal stage, where the original tail is more or less elevated by the lower or infra caudal lobe (*IC*), and becomes the filament (*Fi*), usually called the "upper lobe." In *D* the infra-caudal lobe is longer than the filament, and in *E* the latter has wholly disappeared, and the tail assumes the last or "masked heterocercal" condition.

Upon the whole, it would appear that the tail of the youngest *Lepidosteus* is protocercal like those of the lowest vertebrates and the generalized forms called Dipnoans; that the second or obviously heterocercal stage is comparable with the tails of sharks and sturgeons, while the last stage seems to correspond quite closely with that of the teleostean embryo. And, as the Teleosts are almost universally regarded as the most specialized group of fishes, there appears to be a pretty close agreement between the successive stages of *Lepidosteus* and the rank of the forms or groups with which comparison has here been made.

The corresponding geological series is less complete and satisfactory. No forms resembling *Amphioxus* or the hag-fishes and lampreys have yet been found fossil, although all, excepting the former, have horny teeth, of which, it would seem, some traces might well be preserved.

But among the oldest fishes are some described by Huxley whose tails are apparently protocercal. The resemblance to the earliest stage of *Lepidosteus* is emphasized also by the existence of two dorsals and two anals.

Fossil species of *Amia* and *Lepidosteus* have recently been discovered by Prof. Marsh in the Tertiaries of Western America. The *Megalurus* of the European rocks had a tail strongly resembling that of *Amia*, but this kind of tail is not known among the palæozoic rocks, and Teleosts are first found in the Cretaceous, becoming more and more numerous up to the present time.

But among the earliest known fossil fishes are some in which the end of the spine is not at all bent up; the tail is protocercal. And, with two genera (*Glyptolæmus* and *Gyroptychius*) described by Prof. Huxley, it may be possible to determine the correspondence between the two dorsals and anals and the two pair of differentiated spots upon the primordial median fin of the youngest *Lepidosteus*.

So far as the writer is able to ascertain, the protocercal tail is less frequent in later geological epochs, while the obviously heterocercal form, as with *Palæoniscus*, etc., becomes more and more abundant.

Apparently, therefore, the order of succession of the three or four kinds of tails coincides, in the main, with the series seen in the growing *Lepidosteus*; and the geological, the zoölogical, and the embryological series, upon the whole, have a recognizable correspondence.

So far, the writer has endeavored to give an outline of the natural history of the gar-pike as a peculiar American fish, concerning which little has hitherto been published even in strictly scientific works, and almost nothing in a form generally accessible.

In so doing he has purposely avoided the presentation of controversial points, or, in reference to the nomenclature of the air-bladder and of the tail, has presented opposing views, with an abstract of the evidence, so far as known to him; admitting his inability, as yet, to form a definite conclusion.

But there is another and, in some respects, most interesting and important light in which the gar-pike may be considered, namely, as to its relations with other fish-like forms.

Is *Lepidosteus* merely a somewhat peculiar fish? Or may it, with *Polypterus* and some fossils, be separated as a distinct group? Or should there be added to this group *Amia* and the sturgeons? Or should the catfishes and their kindred, with the pipe-fishes, globe-fishes, and others, be likewise included?

Upon what grounds may this group be defined? What is its grade, class, sub-class, or order? And how may it be subdivided?

Attempts have been made to find answers to these questions by the study of the scales, the skeleton, the limbs, the gills, and various internal organs. The embryology of the sturgeons is not fully known,

while nothing whatever has been observed of the earlier stages of the so-called typical Ganoids.

It is probably within the truth to say that, from the time of Cuvier down, no two authors upon fishes agree upon all the points, while any contemporary discussion, whether verbal or in print, is almost certain to be attended with a degree of heat quite incompatible with the apparent importance of the subject.

The fact is, however, that the so-called Ganoids occupy a very peculiar position. None of them can be touched without affecting the entire series of fish-like forms. Ichthyology is in a state of instability, and every important new fact, every decided expression of opinion by high authority respecting the Ganoids is liable to require a revision of all our ideas.

To present even an outline of the many views, and of the facts and considerations upon which they are based, would require an entire article, with many figures and some anatomical description.

To the reader who has become interested by the foregoing imperfect sketch of the gar-pike, and who has the good fortune to live within reach of it, of *Amia*, and of the sturgeons, the writer would earnestly recommend a careful and systematic investigation of their habits and their structure—especially that of the brain—and of their development, as likely to furnish the most reliable basis for their classification.