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Fishery Leaflet 132

STRUCTURE AND SENSES OF FISHES

By Ralph Hile
Fishery Research Biologist

THE "TYPICAL" FISH

If one here required to "describe a bird," he doubtless would be distressed at the necessity of covering in a single account the tiny hummingbird the soaring eagle, and the bulky, perpetually grounded ostrich. Even it assigned a such smaller group of animals, such as the dog, he would give no little thought to the range from the Mexican hairless to the sheep dog or from the bulldog to the whippet. In either situation the final description unquestionably would be couched in vague but commendable generalities.

Affairs are no different with the description of "a fish." If anything, fishes offer an even thornier problem than do birds or dogs. In the first place, they are an extremely numerous group and accordingly one with great latitude for variation. Indeed, more than half of all species of vertebrates (animals with backbones) are fishes. Furthermore, fishes have adapted themselves to an enormous- variety of environments. On the one hand they are to be found in the icy waters of the polar regions, while on the other, they can exist miraculously uncooked in hot desert pools up to temperatures well- above 100. F. They may roam widely over the vast expanses of the open sea or spend their entire existence in the cramped, underground quarters of an artesian well. They thrice in high mountain lakes and in the abyssal depths of the ocean. They may even desert temporarily the aquatic habitat to scamper over mud flats or climb small trees in search of food. If pools dry up, they may bury themselves in the mud and spend the dry season breathing air. only the most extreme conditions-as the briny waters of the Great Salt or the foully polluted areas that man has created—can defy them. On the whole, it can be said that where there is water, there are fishes—and three-fourths of the earth's surface is covered with water.

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The diversity of size and structure of fishes is much as would be expected in a group adapted to live under such a wide range of conditions. Sizes run the full gamut from certain Philippine gobies that may be only a half-inch or less in length when fully grown to the whale shark which certainly attains a length of 40 or 50 feet and possibly may reach 70 feet. Shapes are equally variable. As extreme examples we may cite: the elongate eel with its snake-like body that so often gives rise to erroneous suspicion of reptilian affinty; the skates and rays which look like they have been flattened by a roller; the ocean sunfish with a body as deep as it is long; the gloular puffer; the flounders and soles with both eyes on the same side of the head; and the ever-popular sea horse, which at first glance would hardly be detected as a fish. The preceding are merely selected illustrations of the extraordinary extremes in the size and shape of fishes, not a few of which approach the monstrous.

Yet, for all their variability, a bird is still a bird, adog is still a dog, and a fish is still a fish. Furthermore, the fullest realization of the existence of wide variations and unusual extremes does not preclude the information of reasonably definite concepts of "typical" or "average" animals. These concepts, to be sure, are likely to be colored somewhat by percsonal experience. On the whole, however, they are fully valid since almost all of them will bear close resemblance to the kinds of birds, dogs, and fishes most commonly encountered.

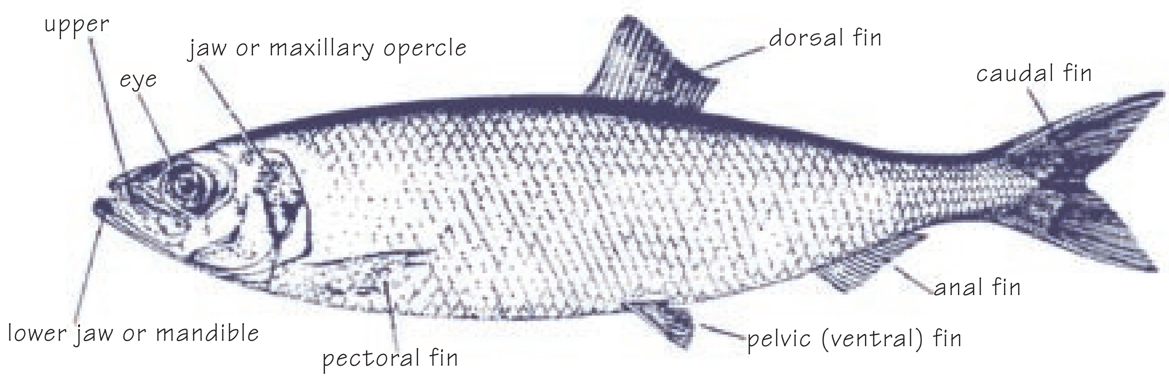

Figure 1 External structure of herring (<u>Clupea harengus</u>).

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The establishment of the property of discussion in terms of a typical animal is vital to the present argument, for it would be futile to attempt within a space of a few pages a description of structure and special senses that would hold even approximately for all fishes. The Sections that follow accordingly were written largely with a single species, the North Atlantic herring, in mind. Supplementary comments are introduced, however, to bring out certain of the more striking specializations.

There is much to recommend the herring (Clupea harengus) for selection as our typical fish. First, it is one of the abundant food fishes in the world. Second, it is an inhabitant of the open ocean, an area in which a high percentage of all species of fish live. Finally, the herring is relatively unspecialized and consequently exhibits no extremes in size, form, or structure.

EXTERNAL STRUCTURE AND PRINCIPAL ORGAN SYSTEMS EXCLUSIVE OF SPECIAL SENSE ORGANS

External Features

The external structure of the herring (fig. 1) is admirably designed to offer a minimum of resistance to movement through the water and hence to insure the maximum speed and efficiency in swimming. In outline the body is spindle-shaped although somewhat heavier toward the front than toward the rear; the cross-section is elliptical. The head is integral with the body—that is, a neck is lacking. So effective is this natural streamlining that man-made objects constructed to move with a minimum of resistance as, for example, the submarine, invariably take on a similar shape. Nor is the body form the only provision for free movement through the water. The body surface is generally free from projections that might offer resistance. The eyes are smooth and do not extend beyond the contours of the head; the gill opening is covered with a smooth flap (operculum); and the scales lie closely against the body surface. Resistance is lessened still further by an over-all coating of slime.

Only the fins extend beyond the body, and they have been demonstrated by means of experiments with objects constructed to resemble the body of a fish to be essential; to stability in the water. During rapid swimming the fins may be depressed or folded along the body so as to minimize resistance. Erect, they serve well as brakes.

Fins are of two general types—paired and unpaired or median. The paired pectoral and pelvic (known also as ventral) fins which are attached to the girdles bearing the same names correspond to the fore- and hind-limbs of terrestrial vertebrates. The relative positions of the paired fins vary considerably among fishes, and in some (as the eels) the pelvics or even the pectorals may be entirely lacking. The unpaired fins are dorsal (on the back), caudal (the tail), and anal (on the belly). Fishes never have more than two pairs of paired fins, but the number of dorsal and anal fins is variable.

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In the herring the fins are supported by soft "rays," but in many species (as the yellow perch) the front part of the dorsal and anal fins and the outer parts of the paired fins are supported by bony spines. These spines give the fins greater rigidity and also provide organs of offense and defense.

Fins of fishes exhibit numerous remarkable modifications, a description of which would require many pages. Among the most interesting may be mentioned the enormously developed pectorals of the flying fish which enable that animal to "fly" or more properly to glide through the air over distances of several hundred yards. Possibly the most fantastic modification of a fin is found in the anglerfish in which the first spiny ray of the dorsal fin, greatly elongated, highly flexible, and with a flap-like structure at the tip is located on the snout in such a position as to serve as a line and bait to attract unwary fish into the angler's capacious mouth. In some species the "bait" at the end of the line consists of a bulb that can be made luminous as desired and in one this bulb is further equipped with a series of horny hooks!

The streamlined structure of the herring that was emphasized at the beginning of this section is characteristic of the pelagic inhabitants of the ocean and of other fishes that depend on speed of movement to capture or to avoid becoming food. Any substantial deviation from this streamlining inevitably detracts from swimming efficiency and requires a way of life in which speed and agility are not fundamental to survival.

Skin

The streamlining of fishes is carried over to the skin, which in all probability fits more closely than the skins of other vertebrates. Fishes need have no fear of developing bagginess and wrinkles with advancing age.

A primary function of the skin is the provision of a relatively impervious, tough, and elastic protective covering. The effectiveness of this protection is increased greatly in most fishes by the presence of scales. Scales may be considered characteristic of fishes; their absence (as in many catfishes) or reduction to insignificant size (common eel) represents special development. In structure, scales range from the tooth-like scale of the shark (indeed, the teeth of the shark are nothing more than modified scales) and the heavy, bony plates of the sturgeon to the more common types to be found on such "teleost" or "bony" fishes as the herring, brook trout, or sunfish. The scales of the teleost fishes are imbricated-that they overlap more or less in the manner of shingles. A feature of the scale structure of many fishes that is particularly valuable to scientists is the "annulus" or ear-mark which permits the determination of age.

Also located in the skin are certain sense organs (which will be mentioned again later), numerous glands (including the mucous glands and the unusual light-producing organs of deep-sea fishes), and the color cells that are responsible for the intricate and occasionally gaudy patterns to be found in some fishes. The skin serves further as the depository for a waste product known as guanin, which has the power of reflecting light and thus can produce white, silvery, or on occasion iridescent effects.

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Skeletal System

The skeleton of a fish may consist of actual bones, as is true with the marine herring in which ossification is nearly complete, or it may be cartilaginous as in the sharks and rays. The major divisions of the skeleton may be listed as: the central vertebral column or backbone with its associated structures, the ribs, the median or unpaired fins, and the terminal tail; the girdles (pectoral and pelvic) and the attached paired fins; the skull , including the supporting structure of the operculum or gill cover. So numerous are the bones and so complicated is the skeletal structure that a detailed description here is entirely out of the question. This point is well illustrated by figure 2 in which the principal bones of the small mouth bass are named.

The usefulness of the skeleton does not end with its service as a scaffold supporting the body. It functions also in a protective capacity (witness the protection afforded the brain by the cranium and the spinal cord by the vertebrae), offers surfaces for the attachment of muscles, and provides leverage for movements. Because of the supporting effect of the water the two last-named functions are of notably less significance among fishes than among terrestrial vertebrates. Water offers sufficient resistance to sinking that locomotion can be accomplished readily by lateral strokes of the tail. The fish has no need for the intricate system of levers represented by the legs and wings of the higher vertebrates.

Musculature

The absence of such complicated appendages as the legs and wings of the terrestrial vertebrates makes it possible for fishes to maintain to a large extent the primitive condition in which the muscles of the body are arranged regularly down each side in a series of definite and similar segments. In most fishes these vertical segments are divided into dorsal (upper) and ventral (lower) sections by the lateral line. Fishes also have numerous specialized muscles such as those concerned with the movement of the jaws, operculum, and fins. Mention should be made also of the "smooth" muscles that are essentially parts of certain organs (as, for example, the wall of the digestive tract) and of cardiac muscles of the heart and certain major blood vessels.

A most interesting specialization of muscle tissue is found in the electric organs of certain eels and rays, which are capable of imparting a shock sufficiently strong to knock done a full-grown man.

Respiration

In most fishes respiration takes place entirely by means of gills. (Figure 3 shows the gills and various internal organs of the green sunfish.) Each of the gill filaments, which are Attached to the outer curve of the gill arches, is richly supplied with blood vessels. As water passes over the gills, carbon dioxide and other wastes are discharged from the blood and oxygen dissolved in the water is absorbed into the blood stream through the delicate membrane of the filaments.

The swim-bladder which is believed by students of evolution to have been developed originally as an organ of respiration still retains that function in certain relatively primitive fishes such as the lungfish, gar pike, and bowfin. The swim-bladder in most fishes (it is not present in all species) serves principally, however, as an organ for the maintenance of hydrostatic equilibrium between the fish and its environment.

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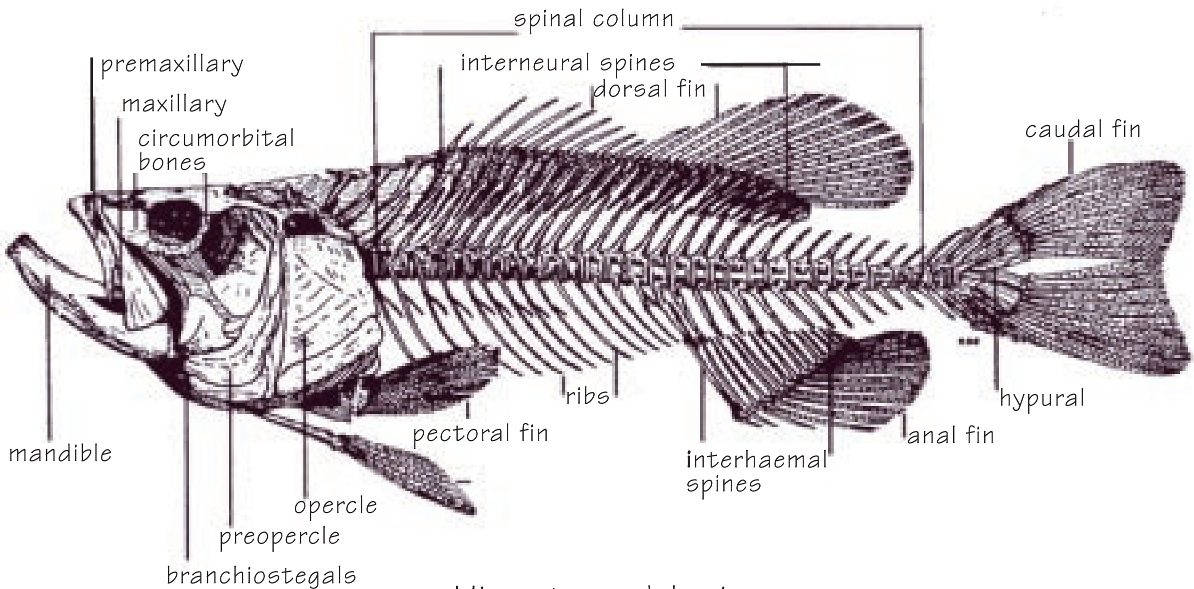
Fig. 2. Skeleton of smallmouth black bass.



Micropterus dolomieu

skeleton drawn by Mrs. Ann S. Green

Nervous System

In comparison with the higher vertebrates the nervous system of the fish must be considered poorly developed. The brain is extremely small in relation to the size of the body—too small indeed even to fill the tiny cranial cavity allotted to it. The lack of "gray matter" is especially appalling in the bony fishes (of which the herring is one), for in that group the cerebrum, traditional center of thought and reason, is almost totally by lacking. Poor development extends also to the nerves which are relatively few.

Circulation

In the higher vertebrates two chambers of the heart (one auricle and one ventricle) are concerned with pumping the blood from the heart to the lungs and two with the distribution of oxygenated blood to various parts of the body. Since the fish's blood undertakes no "side trips," these animals are able to get along with a single auricle and a single ventricle.

The blood of a fish is pumped forward from the heart to the base of the gills, passes through the capillaries of the gill filaments, and is then distributed to the body tissues through arteries and capillaries. Blood collected by other capillaries returns to the heart through veins, directly or by way of the renal, (kidney) or hepatic (liver) porta system.

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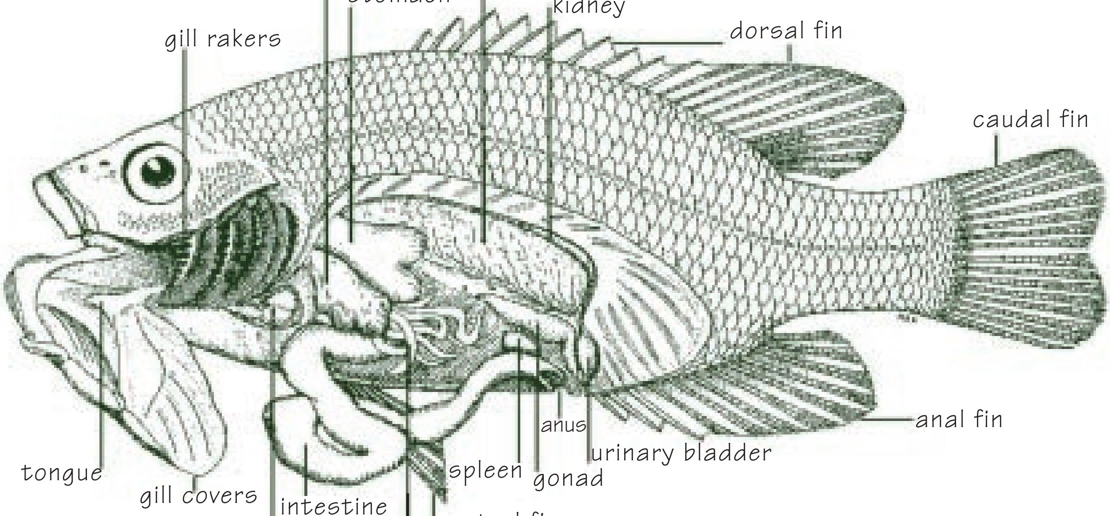
Fig. 3. Dissection of the green sunfish showing internal organs.



Lepomis cyanellus

Modified drawing after Kellogg by Mrs. Ann S. Green

Digestive Tract

The digestive system consists of major organs as in the higher vertebrates, namely, the mouth, gullet, stomach, intestines, pancreas, and liver.

The size and position of the mouth vary widely with the feeding habits of the fish. In bottom-feeding forms (as the suckers) the mouth may be turned downward. When the principal foods are found in the open water (as with the herring), the mouth usually is terminal. The structure and distribution of the teeth also vary with feeding habits. Predatory fishes ordinarily are equipped with numerous strong, sharp teeth on the jaws and in other parts of the mouth and pharynx as well. In other species teeth may be shaped for crushing or grinding or may be lacking altogether.

The collection of food is assisted in some species by the gill rakers (attached to the inside curve of the gill arches), which are so modified as to constitute a comb-like structure that strains small particles from the water.

The remainder of the alimentary tract offers few features that call for comment here. Mention should be made, however, of the pyloric caeca, tube-like sacs attached to the stomach near its exit. Their exact function la not known. These structures may be lacking entirely in some fishes (for example, the northern pike) or may number nearly two hundred (mackerel).

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Excretory System

With respect both to position in the evolutionary sequence of vertebrates and to general complexity of structure, the kidneys of fishes may be termed intermediate. Anatomically, they appear as a pair of dark red elongate organs situated immediately below the vertebral column. The internal structure is such that numerous minute tubules are in sufficiently close contact with the blood to permit the extraction of waste products. These tubules empty into paired excretory ducts which run along the entire length of the kidneys and then join to form a common avenue of drainage. Enlargements of the urinary ducts near their hinder end form bladders of various shapes.

The fish's kidney is not a perfectly efficient organ, for, as we have seen, waste materials are deposited in the sk in quantities large enough to have a profound effect on the color.

Reproduction

The ovaries (one or more commonly two) of female fishes lie in the upper part of the body cavity, more or less parallel to the kidneys. In most fishes the eggs are first discharged into a hollow central cavity of the ovary and then passed to the exterior through special ducts. Among certain fishes in which the young are born alive (many sharks), the terminal portion of these ducts may be expanded to supply accommodations for the developing offspring. In other viviparous fishes (as the mosquito fish) development of the young take place within the ovary itself.

The number and size of eggs vary enormously according to the nature of reproductive habitats. Egg production is highest among pelagic fishes that spawn in the open sea; an extreme example of high fecundity is provided by a ling that was found to contain more than 28 million eggs. The herring, although itself a pelagic spawner, produces eggs on a much less pretentious scale—usually within the range of 21-47 thousand. Nest builders as a rule produce substantially fewer eggs than do "wild spawners," and in viviparous species the number may be extremely small (only 4 to 14 eggs per speason in one of the rays). Eggs of pelagic fishes are of necessity minute, but in some sharks they may be larger even than ostrich eggs.

The testes of male fishes occupy a position in the body comparable to that of the ovaries of the females and like them are provided with special ducts to lead the sex products from the body. Males of viviparous species are equipped with special organs (developed from the pelvic or anal fins) to facilitate internal fertilization of the eggs.

The size of the reproductive glands exhibits a tremendous increase as spawning approaches (especially the ovaries which in extreme cases can make up 25 to 30 percent of the body weight). At other periods, however, the ovarian and testes may be so small as to make determination of sex impossible without microscopic examination.

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Anatomical Miscellany

It should be emphasized again that the apace available here offers scant opportunity for delving into the minutiae of piscine architecture. The descriptive accounts of the preceding pages have been unavoidably more or less perfunctory. only here and there has it been possible to indicate the enormous range of variation of anatomical structure or to detail one of the myriad fascinating specializations. Furthermore, certain organs and organ systems have been neglected in tote. Nothing was said, for example, of the lymphatic system with its lymphatic hearts and "glandular" spleen. Disregarded too have been other organs with which the fish could not well dispense -the red gland of the swim bladder, the thyroid, the thymus, the suprarenal bodies,....

To a certain degree the deficiencies of these pages are alleviated by the three figures illustrating certain features of the external and internal anatomy. Those who may desire more detailed information should consult the references given at the end of this leaflet.

SPECIAL SENSES OF

Smell

The olfactory organs consist of deep pits lined with special sensitive tissue. The size and the position of these organs on the head vary rather widely. In some fishes the sense of smell, is extremely acute. Sharks, for example, are attracted from great distances by the smell of blood or of decaying flesh. The extent to which the olfactory sense is employed for the location of food varies not only with species but also with circumstances. Experiments conducted in England showed, for example, that pollock which were not very hungry regularly smelled food before taking it, but that when they were ravenous they readily bolted down clams soaked in such obnoxious substances as turpentine or chloroform.

Sight

The general structure of the fish's eye is similar to that of other vertebrates. There are, however, certain modifications for seeing under water. The outer wall of the eye is flatter in fishes than in land vertebrates. The lens, on the contrary, is much more rounded (in fact, is almost spherical) in fishes. Fishes focus their eyes, not by changing the shape of the lens as do terrestrial Vertebrates , but rather by shifting its position. There is good evidence that fishes are relatively nearsighted. Experiments have proved also that they are capable of distinguishing colors. Eyes tend to be small and inefficient in species that live regularly in turbid water, and may be entirely lacking in fishes that inhabit underground waters.

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Hearing

In fishes as in other vertebrates, the ear is an organ both of equilibrium and of hearing. An important difference, however, lies in the fact that fishes lack the external and middle ear of higher forms. The sense of balance is located in the three semicircular canals. That portion of the ear concerned with hearing lacks the intricate internal structure to be found in higher vertebrates. This fact, together with experimental evidence, has given rise to doubt as to whether fishes hear at all in the ordinary sense. It seems probable that their "hearing" consists of little if anything more than the detection of vibrations in the water.

In many fishes the ear is connected with the swim-bladder by a tube-like outgrowth from the latter organ or by a series of small bones. It is considered possible that this arrangement intensifies the impulses from vibrations in the water.

Yet another structure that may "assist' the ear is the lateral line organ which on the basis of experimentation is believed capable of detecting low-frequency vibrations (in the neighborhood of six per second).

Taste

Almost nothing is known about the sense of taste in fishes. In fact, there is considerable question—for most species, at least-as to whether this sense actually is present. Many of the functions of taste are performed by special organs distributed over the body or on barbels. (See next section.)

Touch

This is probably the most highly developed sense of fishes. Sense organs in the form of buds or small pits and in contact with nerves are distributed over the entire body. They are especially numerous, however, in such strategic locations as the surface of barbels and feelers. In many bottom-dwelling forms the highly sensitive barbels perform

The question as to the extent to which fishes feel pain has long been a subject for debate. Although we shall never know exactly how a fish feels when it is hooked, there is ample evidence that the experience is not sufficiently upsetting to cause even a halt to feeding activities. It is not at all uncommon for fishes that have escaped before being landed or have been released upon capture to take the hook again immediately afterwards.

Name

SOURCES OF INFORMATION ON THE STRUCTURE AND SENSES OF

No listing of technical publications on the anatomy and senses of fishes will be attempted here.Those interested can secure considerable information from such college textbooks as B. E. Walter's Biology of the Vertebrates (The Macmillan Company), or L. A. Adams' An Introduction to the Vertebrates (John Wiley and Sons, Inc.).

J. R. Norman's A History of Fishes (A. A. Wyn, New York, 1948) is a veritable storehouse of facts on fishes. Less pretentious in scope than Norman's volume but most entertainingly written is Brian Curtis' The Life Story of the Fish, His Morals and Manners (Jonathan Cope, London, 1949). Two other books that are recommended are The

Ways of Fishes by L. P. Schultz and E. M. Stern (D. Van Nostrand Co., Inc., 1948), and Chapman Pincher 'a A Study of Fish (Duell , Sloan and Pearc, Inc., 1948).

A recent publication that contains a wealth of information on both the anatomy and senses of fishes is the 2-volume work, The Physiology of Fishes, edited by Margaret E. Brown (Academic Press, New York, 1957).

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