THE WORLD OF FISHES

Guide to the Fish Collections of The American Museum of Natural History

By WILLIAM KING GREGORY

and FRANCESCA LA MONTE

GUIDE LEAFLET SERIES No. 81

THE AMERICAN MUSEUM OF NATURAL HISTORY

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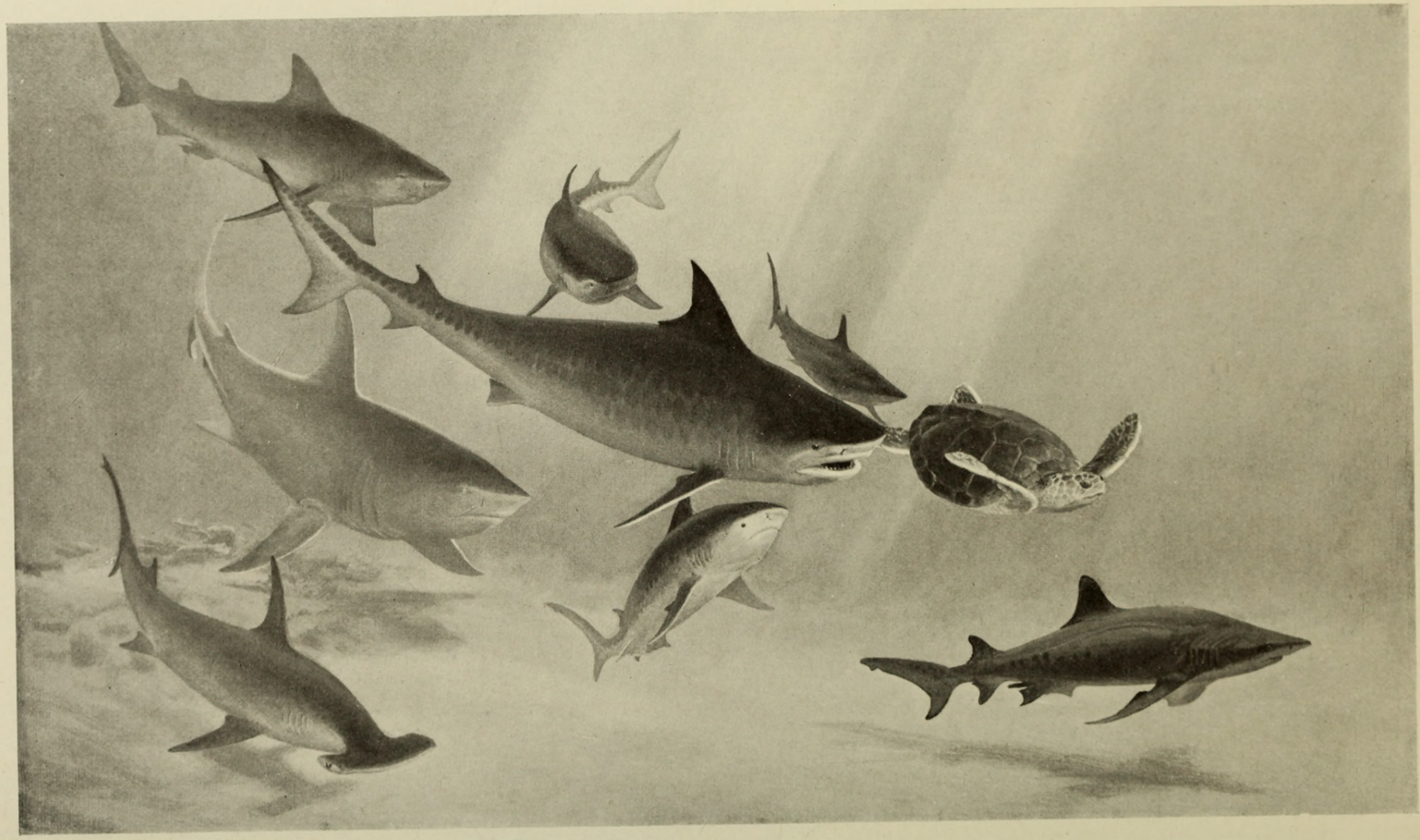

The Sea Rovers.

An undersea scene, showing a number of sharks attacking a sea turtle. In the lead is a twelve-foot Tiger Shark; on the left, a Hammerhead, and in the background, the White Shark or Man-Eater.

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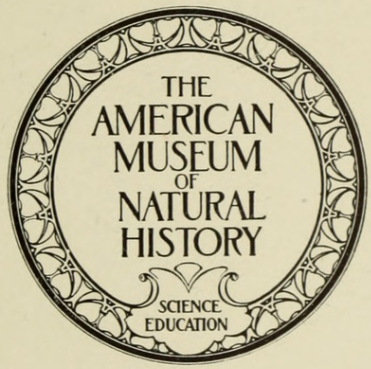

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TABLE OF CONTENTS

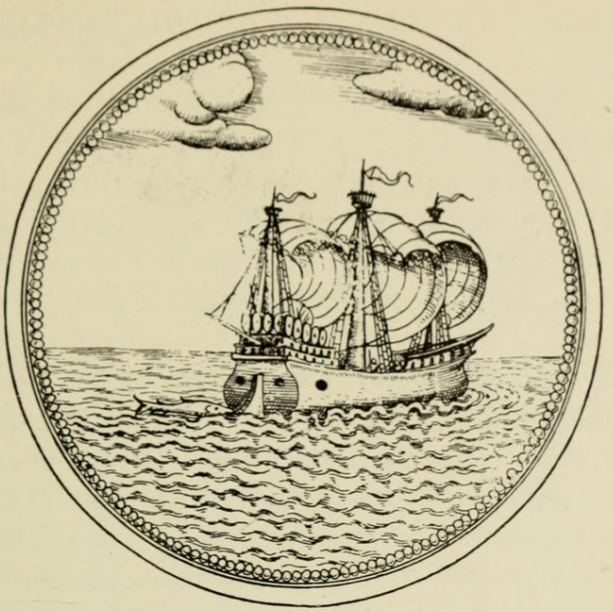

Fig. 2. Remora, the Shipholder. (After Camerarius, 1654).

INTRODUCTION

"FISH stories" have been cheerfully told by romancers of all ages, and a public that loves to be humbugged has greedily believed them.

The mermaid, the sea-serpent, and the giant "devil fish" that threw its slimy tentacles around a Chinese junk are among the more famous narratives of marine life, but there are others equally ancient and astonishing.

The myth of the Shipholder, for instance, lasted from Aristotle's time to the end of the Middle Ages. This slender, smallish fish with an adhesive disc on top of its flattened head, according to Pliny "bridles the impetuous violence of the deep" and stops large vessels in their course merely by fastening itself to them. To this fish, the Remora, prominent roles in ancient naval encounters have been assigned by credulous authors who should have known better.

In the same delightful manner, a learned gentleman named Conrad Wolffhart rose in the sixteenth century to announce a "downpouring from heaven" of little fishes, illustrating his story with a woodcut of the fishes dropping as a gentle rain from heaven upon a village in Saxony.

Man's small imaginative efforts have, however, been put to shame by nature's own inventions. No sixteenth century collection of zoological yarns could rival the contents of nature's unique collection. For here are fishes with bifocal spectacles, or four eyes—two for looking above water and two for seeing below the water line; fishes fully equipped with

rod, line, hooks and dangling bait; fishes that can shoot—water—with deadly aim; fishes carrying electric batteries on their backs or tails; fishes that drown if prevented from rising to the surface for atmospheric air; fishes that hop about on land. "Believe it or not," there is a species of black, deep-sea Anglers in which the female is sometimes a thousand times heavier than the male, who dangles like a pendant from the cheek of his huge mate.

Our object, however, is not to lay undue emphasis on the numerous freaks and oddities of nature's Cabinet of Curiosities, but to exhibit fish life in its more truly representative phases. The Hall of Fishes of the World contains representatives of only a very small fraction of the twenty thousand already known species of fishes. It aims, however, to present a selection of the better known families, classified and arranged according to their natural blood relationships with each other.

Under Biology of Fishes, we consider the fish as a natural mechanism. Here our object is to look below the surface and see the wheels go round,—to see how the fish lives, moves, eats, etc.

The collection of Game Fishes appeals not only to the student, but to everyone who loves fishing as a sport. It contains several of the biggest fish ever caught on rod and reel, according to available records. The Sailfish Group and the gigantic Marlins caught by Dr. Zane Grey form the chief features of this exhibit.

In general, the arrangement of this guide follows that of the Hall.

SECTION I

ARCHAIC FISHES

(Sharks, Rays, Lampreys, Lungfishes)

[Cases, 7, 11, 5, 3, 1; groups; inner room]

SHARKS

The Sharks of the present are the survivors and descendants of sharks that lived many millions of years ago in the Devonian age of the earth's history. [*See* Fossil Fishes]. They differ from ordinary fishes especially in the gristly or cartilaginous state of the skeleton, which is not strengthened by bony tissue, but by deposits of calcium carbonate and calcium phosphate. The skeleton as a whole is in a primitive or generalized state as compared with that of higher vertebrates and the same is true of the brain, blood vessels, digestive system, etc. Hence a study of the anatomy of the shark forms an excellent introduction to the anatomy of higher vertebrates, including man.

The diagram in Case 11 attempts to visualize the evolution of the body forms of the higher sharks from some ancient central stock which is most nearly typified by the existing Sand Shark (fig. 1 of diagram). Each figure stands for a family or group of related forms, and the branching of the lines indicates the relationships.

The whole surface of the shark's body is covered, not by scales, but by denticles or little teeth, or plates, called "shagreen." Because of its roughness and durability, the skin of the shark has been considerably used in place of sandpaper for polishing wood and ivory, as well as for ornamental purposes. The commercial leather known as "galuchat" is shark skin. Around the mouth of the shark, these denticles become enlarged and give rise to the teeth.

The swifter sharks, like the Mackerel Shark (Case 11), pursue and devour live fish, but the more sluggish ones, like the Nurse Shark are content with offal. Some with blunt teeth, like the Port Jackson Shark (Case 7), crush shellfish, while some with very large mouths and reduced teeth, such as the Whale Shark (*see* separate case) and the Basking Shark, (above Case 11), feed like whales on small copepods and other floating, shrimp-like forms.

Reproduction: Sharks produce but a few eggs at a time, in contrast to the hundreds of thousands produced by a single Codfish; hence they can afford, so to speak, to invest a large amount of capital in each egg, that is, to endow the young with a very large yolk. This nourishes the young for a long time, so that they are well equipped to take care of themselves when they are hatched. In some sharks, however, the eggs

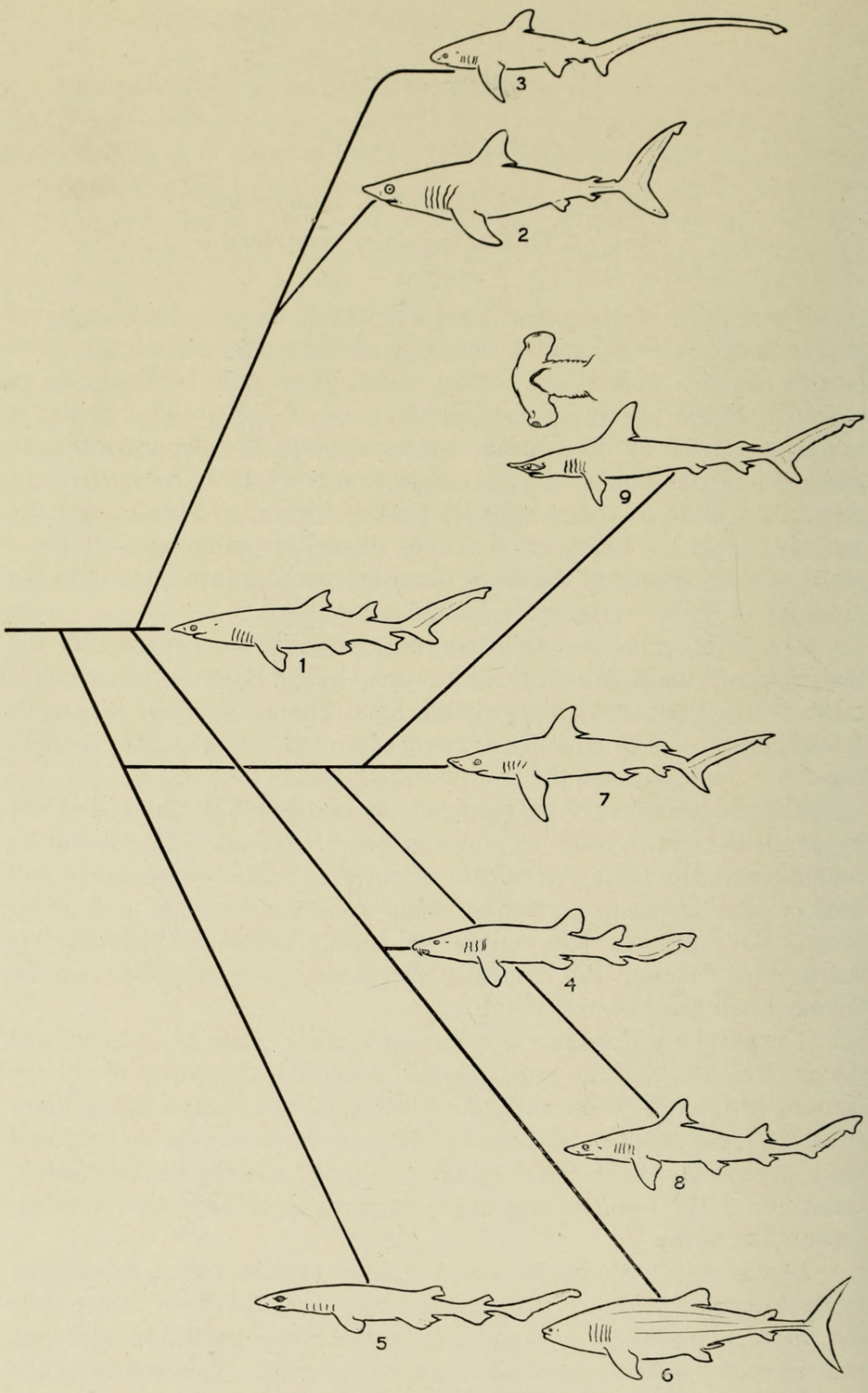

Fig. 3. Evolution of the Body Form of Sharks.

develop within the oviducts or egg ducts, and the young draw nourishment from the mother by means of root-like outgrowths from the region of their gills.

The Port Jackson Sharks (Heterodontidæ). [Case 7]: During and before that ancient period of the earth's history in which the vast swamps and forests of Pennsylvania were accumulating their stores of coal-forming vegetation, the shallow seas of the world swarmed with ancient sharks, many of which bore curved spikes on the front margins of their fins. The more specialized forms of these early sharks became extinct, but one family survives,—the Port Jackson Sharks—which are still found living in the Pacific Ocean. These retain the stout fin spines and whorl-like crushing teeth of their vastly distant ancestors. They lay eggs which are enclosed in a spirally twisted egg case.

The Spined Dogfishes or Squaloid Sharks (Squalidæ). [Case 7]: These sharks are far removed from the higher sharks and appear to be related to the ancestral stock of the Rays. They have lost the anal fin; the teeth are usually closely packed and more or less uniform. Some of the deep-sea members of the family are only a few inches long, while the Greenland Shark is said to reach a length of twenty-four feet. In the common Spiny Dogfish, the eggs are surrounded by a horny shell, but they are not laid; the egg shells break down within the egg duct in which the young are retained until fully developed.

The Notidanoid Group. [Case 11]: This group includes the long-bodied, deep sea Frilled Shark (*Chlamydoselache*), the Cow Sharks, and their allies. The Frilled Shark has trident-shaped teeth, but in the Cow Sharks and their allies the lower teeth are saw-like. Very large yolked eggs are laid. There are not less than six large gill clefts, and but one dorsal fin.

The True Dogfishes or Cat Sharks. [Case 7]: These sharks are variously called Scylliidæ, Scilliorhinidæ, and Catulidæ. As in all the higher sharks, there are two dorsal fins without spines. These are displaced backward, and the lower lobe of the caudal fin is not much produced. Their teeth are many-pointed. The egg cases are elongate and quadrangular with the corners produced into long, curling filaments. This family dates from the Jurassic period. The common "Dogfish" (*Mustelus*) does not belong to this family but is related to the Requiem Shark group. (*See* below).

The Sand Sharks (Odontaspidæ, Carchariidæ). [Case 11]: These are perhaps the most central or generalized of the higher sharks. The body is perfectly normal or shark-like, with none of the fins reduced or displaced. The teeth have needle-sharp points with small accessory cusps on either side of the yoke-like base. The gill slits are of ample

size and lie entirely in front of the pectoral fin. The checker-like centra of the backbone are of the asterospondyl or star type, with four uncalcified streaks radiating outward from the center. The family of the Sand Sharks dates from the Cretaceous. A deep sea member of it, *Scapanorhynchus*, has an elongate, depressed snout.

The Nurse Sharks (Orectolobidæ). [Case 11]: The Nurse Sharks are related to the Sand Sharks but are specialized for a more sluggish life. The head is typically broad and more or less depressed; the teeth closely packed, flattened, or not needle-like; the dorsal fins more or less displaced backward. There are one or more flaps or projections of skin around the mouth. The eggs of the Nurse Shark are about as large as goose eggs, with a delicate, horny shell. It is believed that these eggs are retained in the body during the entire incubation period and free young released as in the Requiem or Carcharinid sharks. In this respect the Nurse Sharks are intermediate between the true Dogfishes (Scyllidæ) which are oviparous or egg-laying, and the Requiem Sharks which are viviparous (producing living young). Fossil representatives of the Nurse Shark family date from the Eocene.

The Mackerel Sharks (Isuridæ). [Case 11]: represent a swift-swimming adaptation from some ancient relative of the Sand Sharks. The contour of the body recalls that of the swift-swimming Bonitos [Case 32]. The upper lobe of the tail-fin is turned sharply upward; its lower lobe is produced downward so that the tail as a whole is more or less lunate. Its base is supported by lateral keels. The second dorsal and anal fins are much reduced. The teeth range from simple bodkin points in the Cretaceous *Orthacodus* [*see* Fossil Fishes] to the broad, serrate triangles of the Whale Shark and the far larger teeth of the gigantic extinct *Carcharodon* shown at the entrance of the Fossil Fish Exhibit. The gill slits are very large, wholly in front of the pectoral fins. The White Shark, or Man-Eater, is a gigantic member of this family. The whale-like Basking Shark [above Case 11] is another giant, with the gill rakers prolonged into a sieve for straining from the water multitudes of minute floating crustaceans.

The Thresher Sharks (Alopiidæ). [Case 11, also above elevator]: These are heavy-bodied derivatives of the Mackerel Shark group, in which the enormous tail is used for rounding up the schools of fish upon which the Thresher feeds.

The Requiem Sharks (Carcharinidæ). [Case 7]: The most numerous and dominant group of the present day, these sharks arose later than most of the other families, their fossil teeth dating back at most to the Eocene epoch. They have advanced beyond the lower sharks (such as the true Dogfishes) by retaining the eggs within the egg-tube until the

young are well developed; the young are, therefore, born alive. The Requiem Sharks may be distinguished from the Sand Sharks (*Carcharias*) by the fact that the last one or two of the rather small gill slits lie above the base of the pectoral fin. The base of the tail is notched above and below; the upper lobe of the tail is turned partly upward and the lower lobe is more or less produced. The body form is long and slender in the Blue Shark (*Prionace glauca*). A group at the southwest end of the hall shows a Blue Shark surrounded by its new-born young, swimming about under Sargasso weed and among the wreckage which drifts into the comparatively currentless ocean area known as the Sargasso Sea.

In the New York Ground Shark (*Carcharinus milbertii*) [Case 7], the body is stout, with a massive snout.

The Smooth Dogfish (*Galeorhinus* or *Mustelus*) somewhat resembles the true Dogfishes (Scylliidæ), but differs from them in the more normal position of the first dorsal fin which is not displaced backward. The teeth also are flattened and the fish feeds on crabs, squid and many other creatures. The type represents a bottom-living adaptation of the free-swimming Carcharinid stock.

The strange Hammerhead Sharks (*Sphyrna zygæna*) appear to have derived from some more normal member of the Requiem Shark or Carcharinid group, in which the snout was broad and shovel-like. The Bonnet Shark (*Sphyrna tiburo*) shows an intermediate stage in the widening of the head. The Hammerhead is a swift swimmer and makes sharp turns with great agility, apparently using the flattened head as a "bow rudder."

The Japanese Sawfishes (Pristiophoridæ) [Case 7], like the true Sawfishes (*Pristis pectinatus*) [above Case 7], have their nose produced into a very long, flat rostrum, armed on each side with a row of teeth. But a comparative study of the skeleton and internal anatomy of these forms shows that the Japanese Sawfish is more nearly related to the spiny-finned sharks, while the true Sawfish is closely related to the Guitar Fishes [Case 5]. In other words, the saw-like rostrum has been acquired independently in two distantly related groups.

The Whale Shark (*Rhineodon typus*): In a case near the entrance to the Hall of Ocean Life stands a scale model of the Whale Shark, the largest living fish. This fish has been measured up to 45 feet in length, and is estimated to reach 70 feet. It resembles a whale in manner of feeding as well as in size. Its teeth, about $\frac{3}{16}$ of an inch in height and 5000 in number in each jaw, are set in many card-like rows, but are useless for biting. Its food consists of small organisms filtered out of the water by its sieve-like gill rakers. Despite its huge size, this fish is harmless. It occurs in warm waters of the ocean.

The specimen of which this is a model (1/6 scale) was 32 feet long. It was captured near Long Key, Florida, June 9, 1923.

Recent investigations indicate that the Whale Shark represents a peculiar family which is a specialized derivative of the Mackerel Shark group.

SKATES AND RAYS

"Winged Sharks"

[Case 5 and Inner Room]

The strange looking Skates and Rays of the present time may be regarded as transformed Sharks, in which the body became greatly

Fig. 4. Russell J. Coles harpooning a Devilfish.

flattened and the pectoral fins enlarged and widened into "wings" which finally became the principal organs of locomotion. The tail is reduced to a long, trailing rudder. The gill slits have been displaced onto the lower side and the water for the gills is pumped in and out through the large spiracles behind the eyes.

Several still existing forms show some of the stages by which this transformation has been brought about. The Monkfish (*Rhina squatina*) is, in fact, more or less intermediate between the Spiny Dogfishes and the Rays. Its pectoral fins are enlarged, but are still separated from the head by the gill slits, which remain lateral in position. The skull and jaws also are of the primitive shark-like type. In the Guitarfishes

(*Rhinobatus*) the front part of the enlarged pectoral fins is fastened to the side of the head and the gill slits are on the lower surface.

The true Sawfishes (Pristidæ) are essentially *Rhinobatus*-like forms in which the greatly prolonged snout has acquired a row of "teeth" on either side. These, like the teeth in the mouth of sharks, have been evolved out of the tooth-like denticles on the surface of the skin.

In the Electric Rays or Torpedoes [case 5 and Inner Room], part of the enlarged muscles of the breast fins have been transformed into electric batteries which consist of layers of alternating tissues of different electric potential, like the plates of a voltaic pile. These fishes are capable of giving a powerful electric shock.

In certain Eagle Rays [Case 5 and Inner Room], the front ends of the breast fins begin to project beyond the mouth, and in the Manta or Devil Fish these forward projections give rise to movable flaps or "horns" which appear to assist the fish in scooping into the broad mouth the small floating creatures upon which it feeds. The large central fish of the Inner Room is the model of a Manta taken off the west coast of Florida in 1915. It measures 17 feet across the outstretched wings. Also in this room, against the wall, is a Sting Ray, its whip tail bearing at the base a strong saw-edged spine which can inflict a severe and irritating, but not specifically poisonous, wound.

The Skates lay eggs enclosed in tough, horny coverings, the four corners of which are prolonged into filaments. These egg cases are frequently washed up on northern beaches. In the Sting Rays and Eagle Rays the young are developed in the egg duct and the embryos draw their nourishment from the mother by means of filaments that extend from their gill openings.

CHIMAEROIDS

Silver Sharks

[Case 3]

The existing Chimaeroids, or Silver Sharks, nearly all deep-sea forms, are the descendants of certain specialized sharks of the Jurassic period. [*See* Fossil Exhibit, case 6]. The living *Rhinochimæra*, for instance, with its long rostrum and tapering tail, strongly recalls this ancient stock, while *Harriotta*, a black fish from the great depths of the Atlantic and Pacific, is a caricature of *Rhinochimæra*.

The Chimæroids progress chiefly by means of their wing-like pectoral fins. Their teeth and powerful jaws are adapted for biting and crushing. In external appearance, as well as in their cartilaginous skeleton and general anatomy, they are clearly allied with the sharks although in

certain other features they parallel the higher fishes. Their mode of development is shark-like. Their eggs are enclosed in tough, horny egg cases which probably lie on the sea bottom. When the young are ready to escape, the egg case opens along hinge-like folds.[1]

CYCLOSTOMATA

Lampreys and Hags

[Case 3 and group]

This class includes the two groups of fishes known as the Hags and the Lampreys, eel-like forms with jawless, sucking mouths. With these mouths they fasten themselves on larger fishes and feed upon them until nothing is left of their prey but an empty skin.

The Hagfishes are the vampires of the ocean, a career for which their sucking mouth and their tongues armed with rasping teeth well fit them. The body of the Hagfish is heavily covered with mucous which it also exudes in quantity as a defense when caught, giving it the popular name of "Slime Eel."

These fishes appear to be the highly modified and degraded descendants of the Ostracoderms, the oldest known forerunners of the backboned animals; the intervening stages are missing from the record.

The Sea Lamprey and its Nest: The group to the left of the Cyclostome case was brought as a unit from a stream near Smithtown, Long Island. These fishes, by means of their suctorial mouths, root up and push about the pebbles of clear, shallow streams in order to make a nest in which to spawn.

DIPNOANS

Lungfishes

[Case 1]

All fish breathe oxygen, which is dissolved in the water that passes over their gills, but a few fishes also have true lungs, by means of which they can breathe even when the water in which they live gets foul or dries up. These are the famous Lungfishes of Australia, Africa, and South America.

These interesting relics of long past ages also have four limbs, in the shape of paddles, which are equivalent to the fore and hind limbs of land-living animals.

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[1]These fishes and their development have been described in detail by Bashford Dean, in his "Chimæroid Fishes and their Development." Publications of the Carnegie Institution of Washington, 1906, number 32. 195 pages, plate, 144 figures.

The Lungfishes are distantly related to the ancestors of the swamp and land-living amphibians.

The Australian Lungfish (*Neoceratodus*) is found today only in the Burnett and Mary Rivers in Queensland, Australia, but many millions

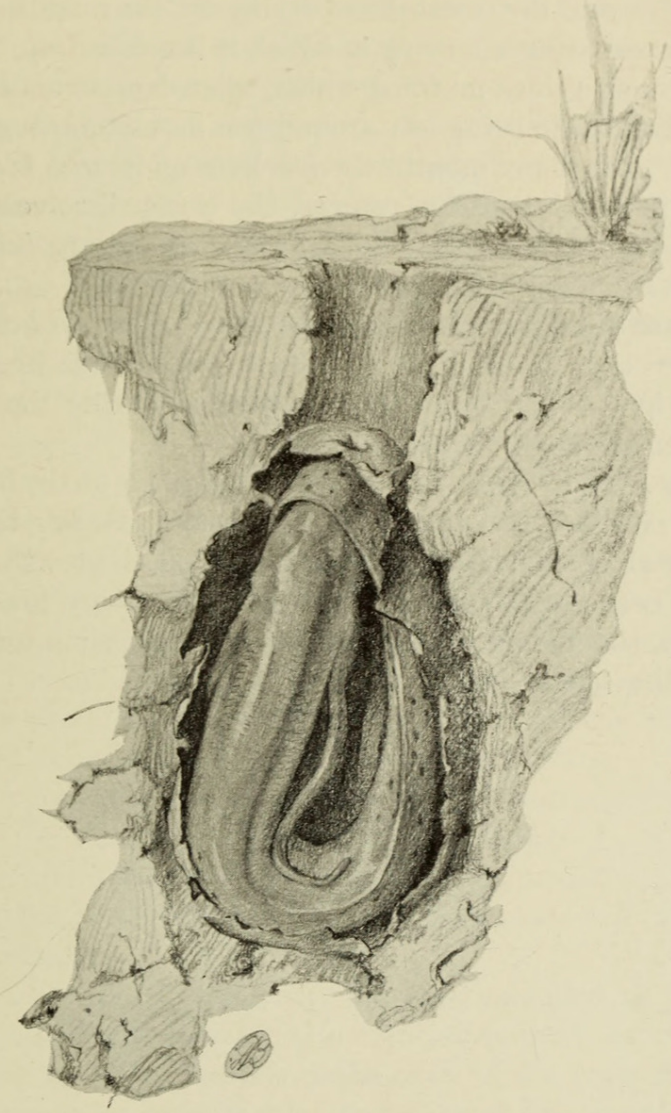

Fig. 5. A Lungfish in its Burrow. Drawn by D. Blakely.

of years ago its ancestors left their peculiar fan-like dental plates and other traces in the swamps of the Devonian and subsequent ages in many parts of the world, from India to Pennsylvania and from Great Britain to Australia.

The modern fish lives in stagnant pools or waterholes. At irregular intervals, it rises to the surface and protrudes its snout in order to

empty its lung and take in fresh air. The development of this fish from the egg is shown on the wall chart nearby.

The African Lungfish (*Protopterus*) has the fore and hind limbs prolonged into tapering filaments, which may be useful in creeping over the bottom of the marshes in which it lives. When the dry summer season comes on and the marshes are drying up, the lungfish buries itself in the mud, excavating a burrow in which it lies coiled up. The glands of the skin secrete a thick mucous, which, when dry, covers the fish like a bag, only a little hole being left around the mouth, through which the fish breathes. For many months the fish lives on its own fat, in a torpid state. When the rainy season returns, the water dissolves the cocoon-like bag and the fish escapes, none the worse for its long fast. A model of the Lungfish in its mud ball may be seen in Case 53.

The South American Lungfish (*Lepidosiren*) is even more eel-like in appearance than its African relative. It also lives in swamps and buries itself in the mud in a tubular burrow during the dry season, escaping when the rainy season returns.

The eggs are deposited in underground burrows at the bottom of the swamp; the male fish standing guard over them. During this period its hind limbs become enlarged and covered with a rich growth of blood-red filaments. These are thought to serve as an accessory breathing organ which enables the male to guard the nest without being forced to leave it and go to the surface to breathe air.

SECTION II

THE BIOLOGY OF FISH

[Cases 53, 54]

Development of Fish from the Egg: [Case 53 and wall chart]: Fishes, like all other backboned animals, reproduce themselves from a *zygote* which results from the union of two germ cells, one from the female, the other from the male parent.

The female germ cell is called an *ovum*, or egg, (plural *ova*); the male germ cell is called a *spermatozoon* (plural *spermatozoa*), or sperm. The egg is commonly said to be "fertilized" by the male element because the male cell starts the process of development. But the male cell does much more than this since it brings with it all the hereditary tendencies derived through the father, while the egg carries the hereditary tendencies derived through the mother.

Spawning (External Fertilization): In the higher fishes, the union of the male and female germ cells usually takes place in the water, into which they are discharged by the parents at the time of mating. In this case, fertilization is said to be external. When the eggs are discharged into the water and fertilized, they either float near the surface (pelagic eggs) or sink to the bottom (demersal eggs).

The pelagic eggs are very small, often less than a millimeter in diameter. They are transparent and often contain a large globule of oil. Such eggs are produced in countless numbers by pelagic fishes of many families (cods, flounders, mackerels, some herrings, etc.).

The demersal eggs are larger, heavier and more opaque. Those of the salmon, for example, are about 5 millimeters ($\frac{3}{16}$ of an inch) in diameter. In many demersal eggs, the outer egg membrane is viscid and adhesive, so that the eggs readily stick to each other or to rocks, stones, or bits of seaweed.

When fertilization is external, the eggs extruded at one time are usually very numerous, sometimes amounting to many millions, in order to compensate for the wholesale destruction of the eggs and young by other creatures or by unfavorable conditions of the environment. The rate of development is dependent upon the size of the egg (large eggs with much yolk tend to develop slowly); the temperature (cold water slows down the development), and racial tendencies which tend to retard or accelerate development. In the small eggs of the anchovy, development from the time of fertilization to hatching takes only two or three days, while the larger yolked eggs of the salmon develop in colder water in 35 to 148 days. After perhaps several weeks, a tiny larval fish is ready to start life on its own account. It begins by taking in only very small

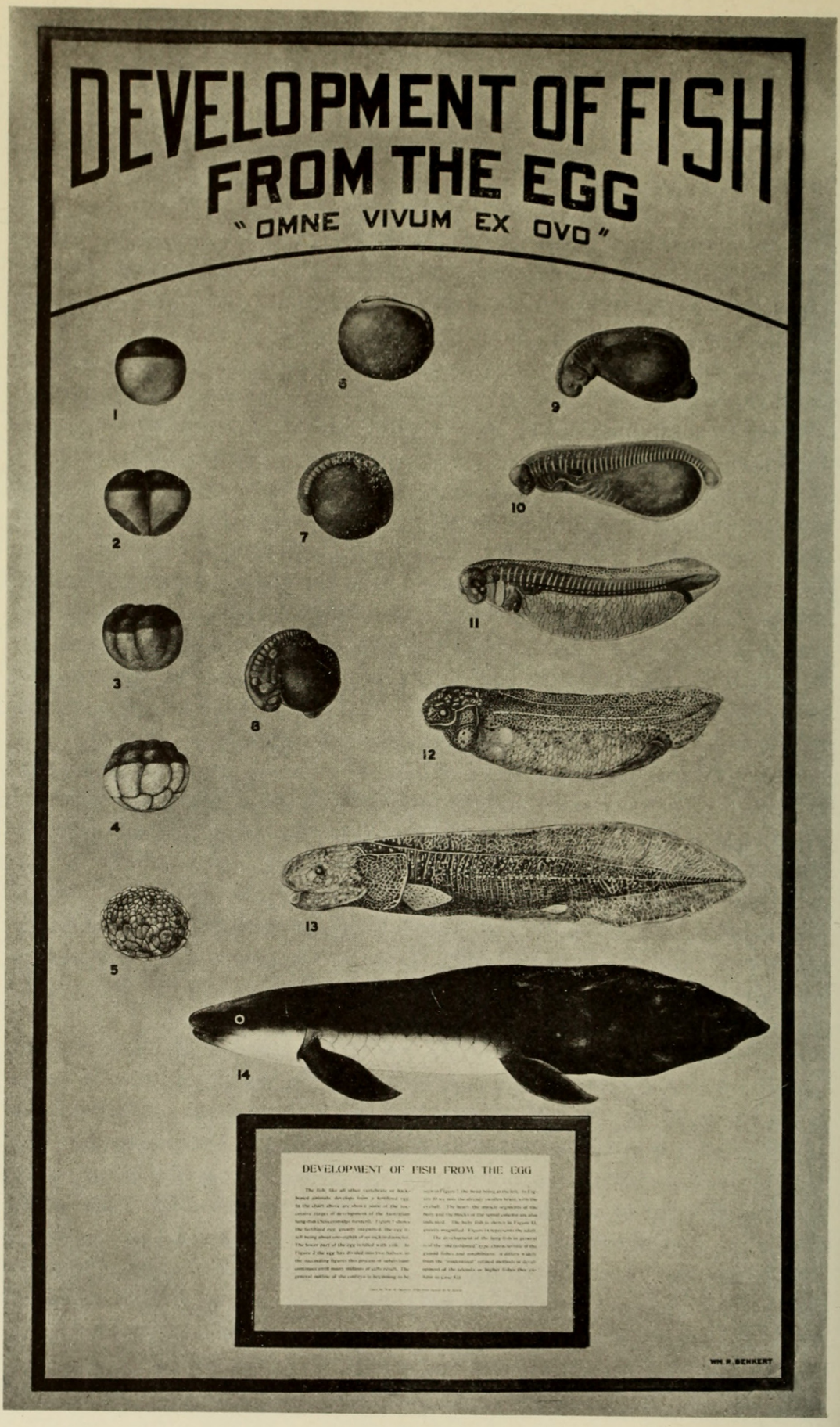

Fig. 6. Development of the Fish from the Egg. The Australian Lungfish. Chart drawn by W. Benckert.

organisms and then passes step by step to larger and larger kinds of food as its size and strength increase.

Differing widely from the modernized methods of development of the Teleosts or higher fishes [Case 53], is the old-fashioned type of development characteristic of the Ganoids, the Lungfishes and the amphibians. On the chart to the left of the Shark Group, are shown some of the successive stages in the development of the Australian Lungfish, *Neoceratodus forsteri*. Figure 1 shows the fertilized egg, greatly magnified, the egg itself being about one-eighth of an inch in diameter. The lower part of it is filled with yolk. In Figure 2, the egg has divided into halves. In the succeeding figures, this process of subdivision continues until many millions of cells result. The general outline of the embryo is beginning to be seen in Figure 7, the head being at the left. In Figure 10, we note the already swollen brain, with the eyeball. The heart, the muscle segments of the body, and the blocks of the spinal column are also indicated. The baby fish is shown in Figure 13, greatly magnified. Figure 14 represents the adult. [*See also* Case 1.]

Viviparity (Internal Fertilization): The eggs of sharks, chimæroids, and rays are frequently covered with a horny shell which is secreted by the walls of the egg duct. In "oviparous" sharks, such as the European Dogfish, these eggs are laid and the young, in due time, hatch out from them. In many other kinds of sharks, however, the young are long retained within the enlarged egg duct and the egg shell is either broken up or absorbed so that the young are "born alive," or released in an advanced stage of development.

Parental Care: In many cases, one or both parents, instead of abandoning their progeny to be the sport of the elements and the prey of innumerable enemies, either construct a nest, as in the case of the Bowfins and the Sticklebacks, or in some other way guard and protect the young. For example, the eggs may be deposited in some secure retreat, as in old oyster shells, or the gill cavities of clams, mussels or oysters. Among the Sea Horses, the males of certain species receive the eggs in a brood pouch of skin beneath the abdomen, where they undergo their development, while in the Cichlids, and certain Catfishes, one or the other parent takes the eggs in its mouth or pharynx and does not eat anything until the young are large enough to be released safely. In such cases, the number of eggs produced at one time may be small, since the parental care greatly improves the chances of survival for the offspring, while the eggs themselves may be large to increase the food for the young.

Adaptive Radiation in Jaws:[1] On the right of Case 53, is an exhibit showing how, in many groups, the jaws, starting with a primitive or normal type, tend to become very long and highly predacious or very short, nibbling, pinching or crushing in type.

Locomotion of Fish. [Case 54]: *Engines of the Fish's Body:* As a living, self-directing machine with a mind of its own, the fish needs all the complex apparatus shown in the models in Case 54. Its jaws, mouth, and digestive system capture and prepare its fuel. Its heart and circulatory system distribute the fuel to its engines and propellers (the muscles and the fins). By means of the oxygen absorbed by its gills from the water, it consumes the fuel, and releases the necessary energy which is expended in driving the body forward and is lost in the form of heat.

Millions of delicate sense organs are constantly recording the changes in the surrounding medium and in the position of the various parts of the body, while the nose, eyes, internal ears, brain and spinal nerve cord also act as an automatic control or steering system. Its framework, the skeleton, consists of a system of jointed levers and supports. The rear part of the hold of this living ship is freighted with live eggs.

The locomotor machinery takes up the greater part of the entire body of the normal fish. This, in brief, consists of a close-set series of zig-zag muscle segments running along the sides of the body from the head to the tail, making undulation possible. The fins act as keels, rudders, and brakes, and partly as paddles; the swim bladder as an additional balance.

Types of locomotion[2]*:* The Eel and the Trunkfish illustrate two extremely different methods of locomotion which have been named, respectively, the *anguilliform* and the *ostraciiform* types. The Eel has very numerous joints in its backbone, with an equally high number of zig-zag muscle segments on the sides of the body. By means of these, the eel throws its long, slender body into a series of small waves which pass backward faster than the fish moves forward. The Trunkfish, on the other hand, has a rigid body which swings from side to side with the sculling movement of the flexible tail.

Almost exactly between these two extremes stands the *carangiform* movement, as typified in the Crevalle or Horse Mackerel (*Caranx*). The body is short, but not rigid. The movement is essentially the same

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[1]For monograph, *see* Gregory, William King. "Fish Skulls: a Study of the Evolution of Natural Mechanisms." Trans. Amer. Philos. Soc., 1933, vol. 23, pp. 75-481. 302 figs.

[2]For detailed article *see:* C. M. Breder, Jr. "The Locomotion of Fishes." Zoologica, 1926, vol. 4, no. 5; pp. 159–297. 44 figs.

as in the Eel, except that only one large curve can be formed at a time. Movement starts by throwing the head to one side, the tail being then drawn in toward midline. The movements of the fins follow the same principles as do those of the body. Thus very long fins may be thrown into eel-like or anguilliform movement, while short, paddle-like fins recall the movement of the tail in the Trunkfish or ostraciiform type.

Streamline Body Forms[1]: Ships, submarines, torpedoes, airplanes, etc., are designed and built with "streamline" bodies which slip through the water or air with the least resistance from eddies that can be planned for under the given conditions of speed, displacement, etc. The typical fish body has streamline contours in the top, side, front, bottom, and rear views. Even aberrant body forms seem to conform to the same principle. A potent factor in determining the various streamline body forms of fishes is the universal force of gravitation which causes the pressure to increase as we descend beneath the surface of the water. The proportions of the body vary enormously in different fishes, *i.e.*, the proportion of the body length to the body height, the width, the relative size of any single part, as of the jaws or any one of the fins. Between any two extremely unlike body forms there are many intermediate conditions even among still existing species and we realize that the differences have probably grown greater with the passage of geologic time, and that such extremes have probably been derived from parent stocks of more normal shape.

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[1]For further data *see:* William King Gregory. "Studies on the Body Forms of Fishes." Zoologica, 1928, vol. 8, no. 6, pp. 325–341. 35 figs.

SECTION III

DEEP-SEA AND REEF FISHES

[Case 52 and Inner Room]

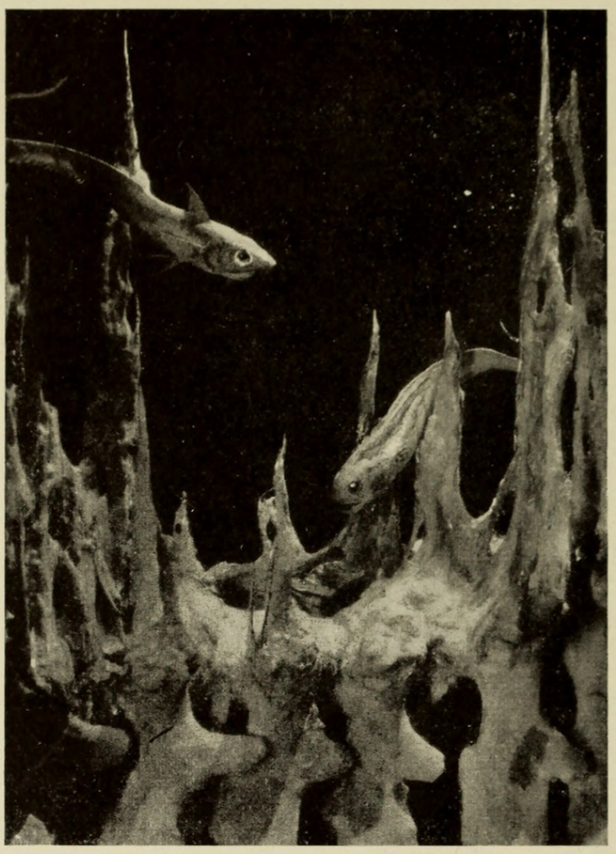


Fig. 7. Wandering Ghosts.

The walls of the inner room represent, on one side, the vividly colored fishes of a coral reef, and, on the other side, the silvery fishes of a black volcanic reef. Space in this room is being reserved for a future reef group.

The Rays and Skates shown here are discussed on pages 14 and 15.

Oarfish: Above the inner doorway, hangs the model of a rare and highly specialized deep sea fish, remarkable for its peculiar skull structure and its fragility and flatness of body in proportion to the great length. The length of body, the peculiar upturned mouth, and the crest of scarlet fin rays rising from the top near the head have supplied picturesque detail to the stories of fishermen who believed they had seen a "sea serpent" rising beside their boat.

The Sargasso Fish: This is a small exhibit showing a characteristic few inches of those miles of golden weed which stretch from south and east of Bermuda out toward Africa. Picking its way among this weed, is found the small fish known as the Sargasso Fish, *Pterophryne.*

Deep Sea Fishes: Case 52 contains enlarged models of Deep-Sea Anglers (Ceratioids). Other examples will be found in Case 35, where they are shown in their proper systematic position, and in the Deep-Sea Panels. On the northwest wall of the Hall is a case containing a model of one of these fishes, with a parasitic male fish attached to her cheek.

These strange black monsters of the deep are living fish-traps. Above or below the cavernous mouth with its long, bristling teeth, dangles a lure that in the darkness glows with a phosphorescent light. When smaller fishes draw near, attracted by this bait, they are engulfed by the large black mouth.

In some Ceratioid genera the males are free-swimming; in others they are parasitic upon the larger females and spend their lives attached to some portion of her body. In *Photocorynus* the male, two-fifths of an inch long, is attached to the top of the two and one-half inch female's head, above the right eye; in *Ceratias,* the parasitic male hangs from her cheek; parasitic males have been found attached to the abdomen of *Linophryne.*

In the outer room of the enclosure stands the old Deep Sea Group, now replaced by the Deep Sea Panels at the other end of the room. Since this old group was made it has been possible to make more accurate models of these fishes through material studied on various deep sea expeditions and investigations. A series of transparencies at one end of the room show photographs of one of these expeditions, that of the "Arcturus" in 1925, under the leadership of Dr. William Beebe and of under water exploration in the "bathysphere." In a nearby case are some of the actual specimens of these incredibly fragile fishes which live in the black depths of a mile or more under the surface of the ocean, where every square inch of their body is exposed to a water pressure of over a ton. Enlarged drawings of the same specimens are also shown here. The recently invented bathysphere,—a steel sphere with quartz windows—is so made and equipped that it has been possible for two investigators to descend in it to over 2200 feet beneath the surface of the sea. By its means Dr. Beebe has invaded the black depths in which deep sea fishes live and has seen them there with his own eyes.

The bathysphere, was first used off Nonsuch Island, Bermuda, during the summer of 1930.

Deep Sea Panels: Through the doorway underneath the Oarfish is a group of seven panels representing a descending series of zones of fish

life. The original material and data for these were, for the most part, collected by the Arcturus Expedition, in the Pacific near the Galapagos Islands. The exhibit was designed by William King Gregory and Dwight Franklin and executed by the latter with the cooperation of the Museum's Department of Preparation. The models are wax, the skins of most deep sea fishes being too flimsy to mount. The lighting of the three groups on the left (luminous fishes) is designed to first show the visitor the color and shape of the fishes, and then to exhibit these luminous fishes as they probably appear to each other in the dense blackness in which they live, only the luminous spots being visible.

Beginning at the right end of the groups, we see first the bottom of the ocean, gradually progressing until at the left end we are shown some of the fishes which live in the great depths, but occasionally come near enough the surface at night to be caught in nets.

Groups 1 and 2. "The Country of Perpetual Night," "Wandering Ghosts": These two groups show the ocean floor, 1000 fathoms down, where deep sea fishes wander about the bleached skeleton of a whale in total darkness, water pressure of over a ton, and a temperature around freezing.

Group 3. "Little Sea Devils": These are some of the small Oceanic Anglers. Their trap-like mouths are open to catch the prey attracted by the bit of luminous skin at the end of their rod-like appendages.

Group 4. "Black Pirates": These degraded eels have lost almost everything but their voracious appetites, for which their enormous mouths and distensible stomachs are well equipped. One of them has just swallowed a fish larger than himself.

Groups 5, 6, 7 (Luminous Fishes): "The Dragon Strikes" represents a group of Big Heads being pursued by a dragon-like fish, *Chauliodus*. "Blazing Jewels" shows the Jewel Fishes, flashing, luminous fishes living far down where the last feeble light from the surface merges into the blackness of the depths. "Neptune's Fireflies" shows the Lantern Fishes, rows of phosphorescent spots on their sides and head, with *Astronesthes* in pursuit.

SECTION IV

GAMEFISHES

[North end of Hall]

This collection forms the north end of the Hall and includes the results of cruises and fishing trips from Mexico to Maine and even farther afield.

A 74 lb. Channel Bass, 588 lb. Broadbill, 758 lb. Tuna, and a 2000 lb. Ocean Sunfish, looking down from the walls would seem like the answer to the fisherman's prayer:

"Lord, grant to me to catch a fish
So big, that even I
In talking of it to my friends
May never need to lie!"

In 1928, Zane Grey gave his gamefish collection of rod and reel catches to the Museum. This, with the Sailfish Group, forms the bulk of the Gamefish Section. The Sailfish in this group is the mounted skin of a fish caught off the rocky coast of Cape San Lucas, Lower California. Many other fishes well known to anglers and sportsmen, or greatly desired as closer acquaintances, hang in these cases,—Salmon, Trout, Perch, Muskellunge, Barracuda, Yellowjack, Bonefish, etc. Of the last named, we have a world record of 13¾ lb., from Bimini, Bahamas.

Dr. Grey's collection is especially noteworthy for its superb Tunas and Marlins. On the wall nearby hang colored photographs of the capture of some of these fishes and of some of his more recent Tahitian catches.

Charts of the World Record rod and reel catches hang on the wall in this section.

Fig. 8. Zane Gray and a Giant Tahitian Marlin. By permission Dr. Grey.

SECTION V

THE HIGHER FISHES

Ganoids and Teleosts

[Cases 18–38 and Groups]

THE GANOIDS, "LIVING FOSSILS"

[Case 18; groups]

Possibly three hundred million years ago, the remote ancestors of these living fossils were the Old Ganoid fishes of the Devonian period. These were, in general, shark-like forms, but with the body covered with an armor of shiny "ganoid" scales. (*See* Fossil Fish Exhibit.) Louis Agassiz, a famous American authority on fossil fishes, in 1833 classified them according to the character of their scales. His Ganoid group included all those in which the scales were covered externally with a thick, shiny, enamel-like layer (whence the name 'Ganoid,' meaning 'glistening'). Such scales were usually rhombic, or lozenge-shaped, with stratified bony tissue beneath the surface.

Each living survivor of this ancient world retains some of the features of the olden time, but has acquired certain specializations of its own. The Paddlefish of the lower Mississippi River (Group 1) retains the ancient shark-like body, but has lost most of its scales and acquired a spoonbill snout. The Sturgeon (group 2), well known commercially because of the use of its roe as caviar and of its air bladder as isinglass, also retains the shark-like form, but its mouth is sucking in type and its body covered with bony plates.

Two mounts of Russian sturgeon, from which most caviar is obtained, are shown in a northwest wall case. Only the Garpike (group 3) has inherited the complete armor of rhombic, enamel-covered scales, but its jaws are snipe-like and its skeleton completely bony. The Bowfin (*Amia*) (group 4) which is a descendant of the later, or New Ganoid, stock, is the most advanced of the series and has almost attained the rank of the Teleosts or higher fishes. This group shows the nest made by the Bowfin in which to deposit its eggs.

THE TELEOSTS

[Cases 16–36]

During the Cretaceous period, when the giant dinosaurs ruled the land, the mail-clad Ganoid fishes were largely crowded out by their more highly evolved descendants, the Teleosts, who at present constitute about ninety percent of the fish fauna of the world. The name Teleost, meaning 'completely bony,' refers to the fact that the notochord, or

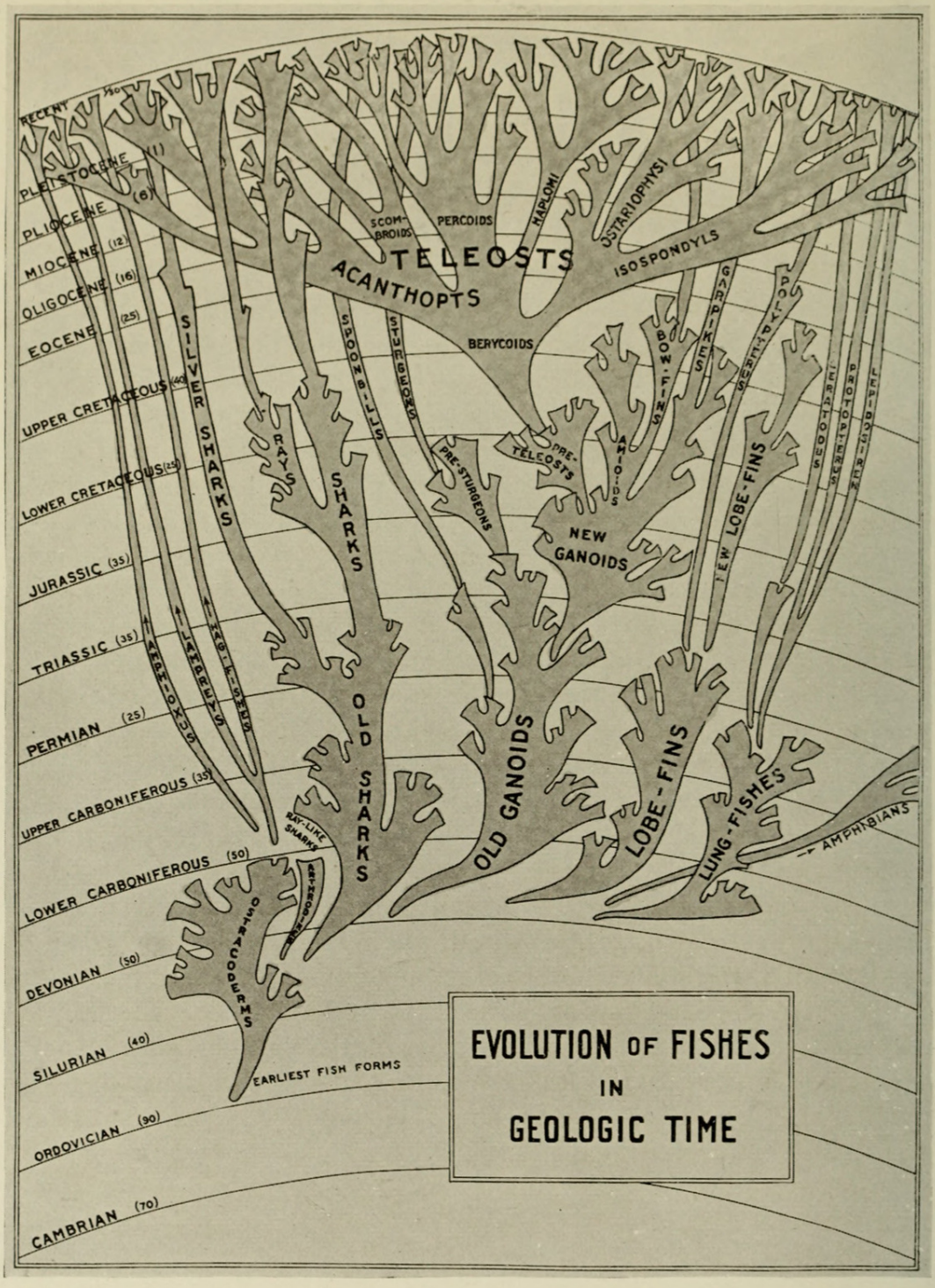


Fig. 9. Evolution of Fishes in Geologic Time.

primitive axial rod, of the larval stages of development is replaced in the adult fishes of this division by complete, bony, checker-like vertebral bodies or centra.

Order Isospondyli. (Tarpons, Herrings, Trouts, etc.). [Cases 16, 17]: This order, a main subdivision of the Teleost series, is a rather loose assemblage of fishes that are higher in rank than the Ganoids but lower than the spiny-finned fishes (Acanthopterygii). It comprises first such veterans as the Bonefish (*Albula*), the Tarpon, and the Herrings,—all survivors from the dawn of Teleost history in the Cretaceous, and, secondly, the more modernized Trouts, Salmons, etc., which are the younger scions of an ancient branch and date only from the Miocene

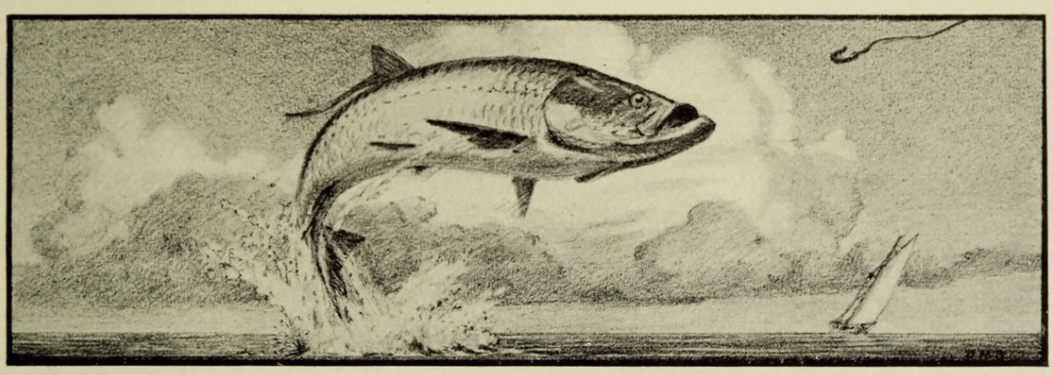


Fig. 10. Tarpon leaping. Drawn by D. Blakely.

epoch. Between these two divisions come the Osteoglossids, dating from the Eocene.

Beneath a great diversity of outward form, these essentially conservative fishes retain the soft or branched fin rays of the Ganoids; the air bladder retains the primitive duct that connects it with the throat, and the ventral fins are abdominal (*i.e.*, inserted under the abdomen). The name Isospondyli, meaning 'equal vertebræ,' refers to the fact that, in contrast with the fishes of the Carp-Catfish order, the first four vertebræ behind the skull are not strongly modified.

The oldest members of this order are the Leptolepidæ of the Jurassic,—small, herring-like Teleost fishes of very generalized type. Next in line come the existing Bonefishes and their Cretaceous and Eocene ancestors, while the Herrings and Tarpons follow at no great distance. The Tarpons are related to the Herrings through the fossil *Thrissopater* from the Cretaceous.

The order Isospondyli, while vastly outnumbered in species by the higher orders of Teleosts, includes a very wide range of body form, in

adaptation to different modes of locomotion, and of jaws, teeth and snouts, in adaptation to different methods of feeding.

The Elephant Fishes (Mormyridæ) are a highly specialized fresh-water group, apparently allied with the Albulidæ. These strange fishes of the River Nile were venerated by the ancient Egyptians who believed that the Mormyrids had eaten a piece of the body of the god Osiris.

The Moon-Eyes or Gold-Eyes (Hyodontidæ) are herring-like fishes of the fresh waters of North America. They stand near the common center of a number of other specialized relics of long past ages, such as the Featherbacks (Notopteridæ) of West Africa, India and Sumatra, and the Osteoglossidæ from eastern South America, West Africa and the Malay-Australian region.

The Dorab (*Chirocentrus*) of the Indian Ocean is the dwarfed survivor of a Cretaceous family that includes the gigantic *Portheus*. (*See* Fossil Fish Exhibit).

The Salmon and Trout (Salmonidæ) are the highest and most beautiful members of the soft-rayed group of fishes. They are limited to the northern world, except those that have been transplanted to New Zealand and Tasmania, and delight in cool waters, many species of trout being found in the lakes and streams that were left as remnants of the great glaciers of the Glacial period.

The Salmons are famous for their habit of coming up from the sea to spawn, travelling upstream sometimes for hundreds of miles, jumping the rapids and penetrating as far as possible toward the purer waters of the north. At the end of this journey they release the eggs and milt that give rise to the next generation and, having done so, perish by the thousands until, in Alaska, the streams are choked with their dead bodies and the sea gulls fly miles inland to feed upon them. The young Salmon, or Smolts, gradually make their way down to the sea.

Unlike their relatives the Herrings, the Salmons and Trouts are predacious fishes with strong teeth. The family, as far as known, dates only from the Miocene.

Deep Sea Relatives of the Salmon and Trout: The fantastic forms and coloring of the deep sea relatives of the Salmon and Trout (the Alepocephalidæ, Gonorhynchidæ and Stomiatidæ) are in keeping with the world of darkness and cold in which they live and rear their sensitive young. Their large eyes serve to catch the phosphorescent glow produced by other creatures, while their own light-producing organs (marked by light spots on the sides of the body) serve to attract their prey.

ORDER OSTARIOPHYSI. (Characins, Carps, Catfishes, etc.). [Cases 19, 20]: The members of this order are nearly all fresh-water fishes and to

this group belong most of the fresh-water fishes of the world. The Catfishes, its most specialized members, date from the Eocene epoch, so the earlier ancestral forms must be sought perhaps in the Cretaceous. Thus the group may have been derived from some very early Teleosts, perhaps the Leptolepidæ of the Jurassic.

The Weberian Apparatus: The members of this group possess one of the most remarkable of all animal mechanisms,—the Weberian Apparatus. This consists chiefly of a linked series of small, bony levers and springs which is attached at the lower end to the swim bladder and at the upper end to the back of the so-called inner ears, or organs of balance. Some authors hold that this apparatus serves to collect pulsations coming in from the water, to magnify them and to transmit them to the nerves of the internal ears. Others hold that its chief function is to transmit not sounds, but sensations of varying pressure. The small, bony levers and springs represent highly modified ribs and other parts of the first four vertebræ behind the skull. This apparatus is found in no other order of fishes.

Carps and Loaches (Sub-order Eventognathi): Everyone who has watched a living Goldfish must have noticed how it can shoot out its toothless jaws and draw in bits of food; but not everyone knows that the Goldfish, like all other members of the Carp family, carries an elaborate dental apparatus in its throat. This apparatus consists of four series of finger-like teeth located on the upper and lower pharyngeal bones, which are the rear segments of the jointed gill arches. It is to this peculiar arrangement that the name 'Eventognathi,' meaning 'wholly internal jaws,' refers.

Carps are mostly sluggish fish that feed on vegetable matter found on the muddy bottom. The carps form one of the dominant fresh-water families of Asia, Europe and North America and have undergone a wide adaptive radiation in body form as may be seen in this exhibit. To this order belongs the Bleak, *Alburnus*, the silvery substance of whose scales is used by the Japanese in the manufacture of artificial pearls. In the wall case opposite hangs a mounted skin of a giant member of this family,—the Mahseer, *Barbus tor*, or Giant Carp, found in India where it occupies probably the highest rank as a game fish.

Fossil Carps are not yet known below the Miocene of Europe.

Chinese Carps: The carps of China are related to the Suckers and Carps of North America, but whereas in the latter country the representatives of other fresh-water families are far more numerous, in China the Carps are dominant and have given rise to a great variety of forms which in external appearance recall diverse fishes of other parts of the world.

Characins (Sub-order Heterognathi): The vicious Piranha, or so-called "Man-eating Fish," forms the central type of this South American and African group. Unlike their distant relatives the Carps, the Characins are mostly carnivorous and have well developed teeth on the outer jaws, but no carp-like teeth in the throat. The name Heterognathi refers to their various kinds of jaws and teeth. They may also be distinguished from the Carps by the possession of a small adipose fin on the back, in front of the tail.

Electric Eels (Sub-order Gymnonoti): *Electrophorus electricus*, the eel-like fish from South America, is able to give a strong electric shock to any animal that touches it. Its electric organs, which fill long strips on either side of the body, represent highly modified muscle plates, richly provided with nerves. This fish is not related to the true eels, which it resembles only in general appearance, but is really an eel-like Characin.

Catfishes (Sub-order Nematognathi). [Case 20]: Catfishes for the most part are the scavengers of the river bottoms where they lurk in the mud and feed upon offal. Their scaleless, slimy bodies are covered with sensory cells that taste the food dissolved in the water. The long black barbels around their mouth doubtless aid them in feeling their way about in the semi-darkness and partly compensate for their very small eyes. The teeth in their jaws are small or lacking, and their mouth serves as a wide scoop. The maxillary, or rear upper jaw bone, is reduced to a small movable base for the main barbel (whence the name Nematognathi, meaning 'thread-jaw'). Catfishes have lost their scales, but some of them, especially the Armored Catfishes (family Loricariidæ), have acquired secondary derm bone plates covering the body. The pectoral and dorsal fins bear strong single spines which are often dangerous weapons.

Order Haplomi. (Pikes, Killifishes, etc.). [Case 21]: The Pike-Killifish order is intermediate in its anatomical characters between the Isospondyli or the lower Teleosts and the spiny-finned or higher Teleosts. The name Haplomi (simple shoulder) is given in allusion to the simplified character of the shoulder girdle which lacks the "mesocoracoid" arch, or middle inner brace of the bony base of the pectoral fin. This structure is possessed by all Ganoids and lower Teleosts in which the pectorals are held in a more horizontal plane, but is lost in the higher Teleosts in which the resting pectorals are held in a more vertical plane.

The Pikes and Pickerels which are the typal forms of this order, lie in wait for their prey and make swift rushes to snap it up with their long, sharp-toothed jaws. Their whole appearance is in keeping with their piratical life. Their small relatives, the Killifishes, are chubby caricatures

of the Pikes, with tiny mouths instead of gaping jaws, but they retain the pike-like backwardly placed dorsal and anal fins, and broad tails that enable them to make very quick turns.

Several members of the Killifish family have been successfully used in destroying mosquitoes.

Order Iniomi. (Lizardfishes). [Case 21]: These large-mouthed, needle-toothed fishes are in certain respects intermediate between the Salmon-like forms of the soft-rayed order and the Pikes and their allies of the order Haplomi. Many of the deep sea members of the family (Myctophids) have a series of light-producing spots on the body and head. These light organs, which are described in other exhibits, have been developed independently in different groups of deep-sea fish.

In some of the Lizardfishes that live at great depths, *e.g.*, *Bathypterois*, the eyes are reduced or absent, while the rays of the breast fins are prolonged into delicate feelers. The family is an ancient one, dating from the Upper Cretaceous period.

Order Heteromi. (Halosaurs). [Case 21]: These distant relatives of the isospondyls reveal their deep sea habit in the combination of very dark colors, eel-like form with very long tapering tail, and small eyes. Only the lower part of the tail fin is developed.

Order Thoracostraci. (Sticklebacks, Tubefish, Seahorses.) [Case 21]: This order includes a number of very peculiarly formed fishes.

The Sticklebacks (Gasterosteidæ): These fishes are so called because of the three isolated spines which represent the spinous dorsal. The small two and three-spined Sticklebacks can be moved from fresh to salt water or vice versa without harm. The larger fifteen-spined *Spinachia* is entirely marine. The male fish builds the nest of weeds, held together by a thread-like secretion from the kidneys, and then guards the eggs deposited by the female. These fishes are short-lived and probably only breed once.

Fishes with Tubiform Snouts. (Aulorhynchidæ, Aulostomatidæ, Centriscidæ): These fishes have elongate bodies and produced, tubiform snouts. The Aulorhynchidæ are closely related to the Sticklebacks. Their elongate snouts approach those of the Trumpet Fishes, or Aulostomatidæ, of the West Indies, Polynesia and Asia. A species of *Aulostomus* is found in the Eocene of Italy. The Shrimp Fishes, Centriscidæ, possess a transparent bony cuirass covering their back and extending beyond the tail. The small, toothless mouth is at the end of a long snout.

Fishes that Swim Vertically. (Amphisilidæ, Syngnathidæ): The Syngnathidæ, including the pipefishes and seahorses, are more or less

elongate, and protected by an exoskeleton forming rings. The snout is somewhat produced and tubiform and the tail sometimes prehensile. In most species, the male takes charge of the eggs in a pouch under the tail or on the abdomen. (*See* p. 21.) The Australian Seahorse, *Phyllopteryx*, is remarkable for its seaweed-like appendages. The Northern Seahorse is common to our coast in summer, from Charleston, South Carolina to Cape Cod, Massachusetts. Where it goes in winter is as yet unknown.

Like the Seahorses, the Amphisilidæ swim vertically. There are three or four species of this family, found in the Pacific and Indian Oceans. The body is much compressed and completely enclosed in a thin, bony armor which is fused with the endoskeleton.

Order Apodes. (The Eels). [Case 22]: The Eels have cast aside all superfluous fins, drawn out the smooth cylindrical body into a compressed tapering end, and multiplied the muscle segments until they can undulate as easily as a streamer waves in the wind. (*See* p. 22.). In some families of Eels, the scales are entirely lacking, but in the most common eel, *Anguilla*, they are present, although rudimentary and imbedded.

The true Eels of Europe and America all go to the deep sea to spawn. There is one area south of Bermuda where all such Eels have been thought to spawn, and certainly they seek either this or similar ocean conditions. The eggs hatch flat, translucent, un-eel-like larvæ known as Leptocephali. These are so unlike the adult that they have sometimes been classified as distinct fishes. Those to the westward gradually drift, as they grow, toward America; those to the eastward toward Europe. When they approach the shore, they are several inches long. On entering coastal waters they shrink to a smaller size and take on the appearance of Eels, though still more or less transparent. Some of these remain and grow in coastal salt or brackish waters, and others penetrate far inland becoming the Fresh-water Eels of the interior.

The Conger Eel does not enter fresh water; it moves away from the shore to spawn but it too dies after spawning.

The Morays are typically reef fishes. They are the largest of the Eel tribe and have powerful jaws armed with sharp teeth.

Order Synentognathi. (Flying Fishes, Needlefishes, etc.) [Wall Case]: Several unrelated groups of fishes have developed independently the ability to fly, but the Exocœtidæ, or Marine Flying Fishes, characteristic of the trade wind belts of open, tropical oceans, excel all others in aërial powers. These, of all flying animals, most closely re-

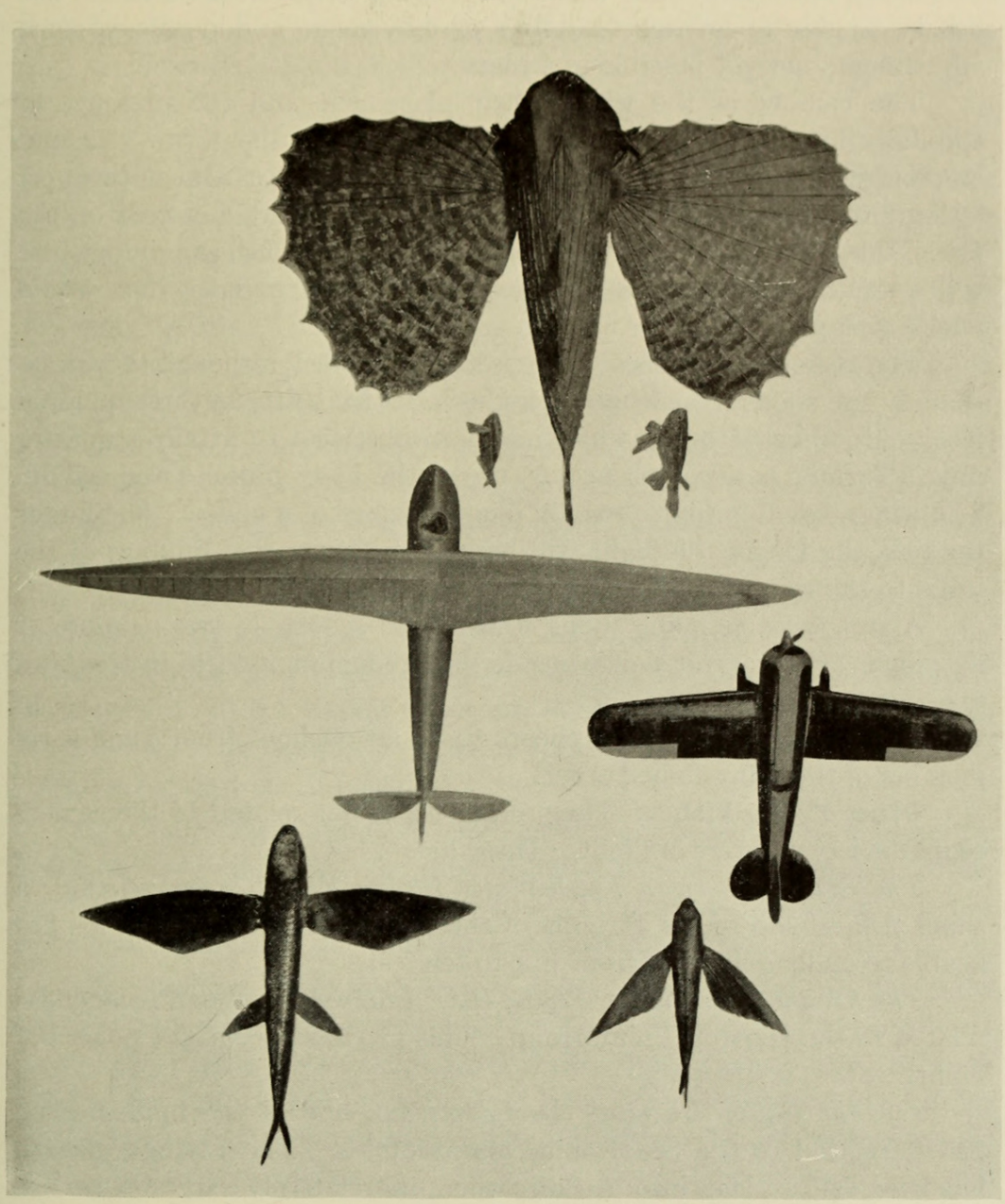


Fig. 11. Flying Fish and Airplane Compared.

semble the modern airplane. The proportions of flying fish and air plane are very close in spite of the disparity in size.

Being an organic unit and not a rigidly articulated machine, the fish is capable of greater flexibility of movement and possesses some adjustments not yet possible in a plane.

The camber of the wings, their placement and the presence of stabilizer fins at their proper places, considering the form, size and landing requirements of each, are remarkably similar. One of the most striking differences is the complete absence of any landing gear on the fish. This is a notable economy, possible because the fish can plunge into the water head-first or drop without injury in a manner that would wreck a plane.

The average rise of these fishes is about five feet, although they occasionally rise higher; the length of flight varies from fifty to three hundred feet, and, when with the wind, has been observed to attain a quarter mile. Turning is accomplished by use of the body muscles and tail fin. The wings, when in flight, remain like the wings of a glider. The larger the fish, the longer the flight will be and the fewer the dippings of the tail into the water for added power.

About twice as many flying fishes fly in schools of two or more as fly alone. *Parexocœtus mesogaster* is the predominant form in the Gulf Stream.

The Flying Fish group appears to be an offshoot from some early member of the spiny-finned order.

Other Flying Fishes: Three other fishes not related to the Synentognaths have powers of flight. These are:

The South American Fresh-Water Flying Fish (*Gasteropelecus*), a small fish related to the Piranha of the family Characinidae. This fish is able to make a flight of from five to ten feet.

The African Fresh-Water Flying Fish (*Pantodon*), a small Isospondyl related to the Herring-Trout group. This fish has very slight powers of flight.

(?) *The Flying Gurnard* (*Dactylopterus*), one of the mail-cheeked fishes, related to the Sea Robins and Sculpins. The Flying Gurnard has been said to leap into the air, where its relatively large breast fins are able to support it for a short journey.

Order Percesoces. (Barracuda, Mullets, etc.) [Case 27]: The Barracuda (*Sphyræna*) is one of the most piratical looking of all sea-going crafts, and its record of attacks on human beings justifies its evil reputation. While in general appearance it recalls the Pikes, it may be recognized readily by its separate spiny dorsal fin. This fin is also possessed

by such peaceful kinsfolk of the Barracuda as the Silversides (Atherinidæ), and Mullets (Mugilidæ). The latter feed on other small animals, algæ and occasionally vegetable matter. They resemble the Flying Fishes in the high position of their breast fins, and the group as a whole may be distantly related to that assemblage.

Order Acanthopterygii. (The Spiny-Finned Fishes.) [Cases 24–36]: The vast majority of existing species of fishes belong to the "spiny-finned" order, the peculiar features of which are illustrated in the skeleton of a Striped Bass. The word 'spiny-finned' is a translation of Acanthopterygii. The first few bony rays of the dorsal fin are tipped with sharp points and there are also such points on the first ray of the pectoral and ventral fins and on the first few rays of the anal fin.

The typical spiny-finned fish has a fairly stout body with a broad strong tail base and broad tail,—all signs of vigorous swimming ability. The pelvis or bony base of the ventral fins is prolonged forward and fastened between the ploughshare-like lower end of the pectoral girdle. This arrangement facilitates quick turning and stability. These fishes usually have strong jaws and teeth, and prey upon other fish. The front upper jaw bone (premaxilla) is prolonged backward and downward so as to shut out the second upper jaw bone (maxilla) from the corner of the mouth. The maxilla is thus toothless and acts only as a lever for pushing forward the premaxilla.

The bony operculum, or chief gill-cover, usually has a point or spike on its hinder end. The supraoccipital bone usually forms a prominent crest above the back of the skull. To this crest on either side are attached the muscles that run along the top of the back.

The skull forms a strong wedge which is pushed through the water by the forward thrust of the backbone. The skull may also be considered as the pivot upon which the body is thrown into waves. Even without the tail fin, the fish can move forward by waving the body. The tail fin serves both as a flexible paddle and as a rudder. The other fins serve as keels, brakes and rudders.

The Basses and their Allies: (Sub-Order Percoidei). [Cases 23, 24, 25]: The true Basses (Serranidæ) and their allies stand near the center of the great assemblage of spiny-finned fishes. They are mostly stout-bodied fishes, usually swift and voracious. Most of them prey upon smaller fishes, crabs, shrimps and other crustaceans. Many are brilliantly colored and some, such as the Rockfishes, can change their colors to suit the color of their background.

Snappers, Grunts and Porgies. [Case 23]: The Snappers (Lutianidæ) are carnivorous food fishes, closely allied to the true Basses, but often having a longer face from the tip of the upper jaw to the lower border of the eye. The back part of the upper jaw slips under the lower border of the enlarged front suborbital bone and is thus concealed when the mouth is closed. Above the ventral fins there is often a scaly flap. These fishes are usually very brightly colored.

The Grunts (Hæmulidæ) are also called Roncos, from the Spanish word, *roncar*—to grunt or snore, referring to the noise they make either with the very large pharyngeal teeth or the complicated air bladder. These also are tropical fishes.

The Porgies (Sparidæ) are well known in our markets through the Northern Porgy, commercially called Porgy. In these fishes, the pharyngeal, or throat, teeth become very large, and in one form, the Sheepshead, the front teeth of the upper and lower jaws are also strongly developed so that with them the fish can pluck up crustaceans which are then crushed by the teeth in the throat. The Porgies occur chiefly in warm waters and many of them are vividly colored, the common Mediterranean species being crimson with blue spots.

The Basses. [Case 24]: The true Basses (Serranidæ) include the Sea Bass, Striped Bass, White Perch of this vicinity, the Rockfish and the Groupers of the Florida Keys and Cuba, besides many others in various parts of the world.

Most of these have three well developed spines in the anal fin, and the back part of the upper jaw is quite distinct when the mouth is closed. The upper corner of the gill cover often has one or two spines.

Fishermen apply the name Bass indiscriminately to bass-like fishes belonging to other families as well as to the fishes above named, such as the Large-mouth Black Bass and the Small-mouth Black Bass, both of which actually belong to the Sunfish family (Centrarchidæ), and the Channel Bass and California Sea Bass which belong to the Weakfish family (Sciænidæ).

The White Perch (*Morone*) is not, strictly speaking, a Perch at all, but a Bass.

The Perches and Darters. [Case 24]: These fishes of the family Percidæ have more joints in the backbone than the Basses and differ in other ways.

The Bluefishes (Pomatomidæ). These are swift, carnivorous fishes which approach the Mackerels in appearance.

The Triple-tails (Lobotidæ) are powerful, deep-bodied fishes.

The Berycids are chiefly deep sea forms, near relatives of the Squirrel Fishes.

Croakers and Weakfishes. [Case 25]: The Croakers (Sciænidæ) are closely related to the true Basses, but differ in their small anal fins in which the spines are reduced. In the long dorsal fins there is a deep notch between the spiny and soft parts, but the two are in contact at the base. A system of large pits on the top of the skull lodges sacs containing the sense organs of the lateral line system.

Local members of this marine family are the Weakfish, Channel Bass, Spot, Croaker, Kingfish (*Menticirrhus*), and Sea Drum. The latter has strong, paved teeth in its throat for crushing shellfish and makes a loud grunting sound with them.

Crab-Eaters, Shark Suckers, etc. (Sub-order Discocephali) (Case 25]: This sub-order includes the Crab-eater, Cobia, and the Shark Sucker, *Echeneis.* The latter has an adhesive disc on top of its head, by means of which it is able to cling to the sides of larger fishes, particularly the sharks.

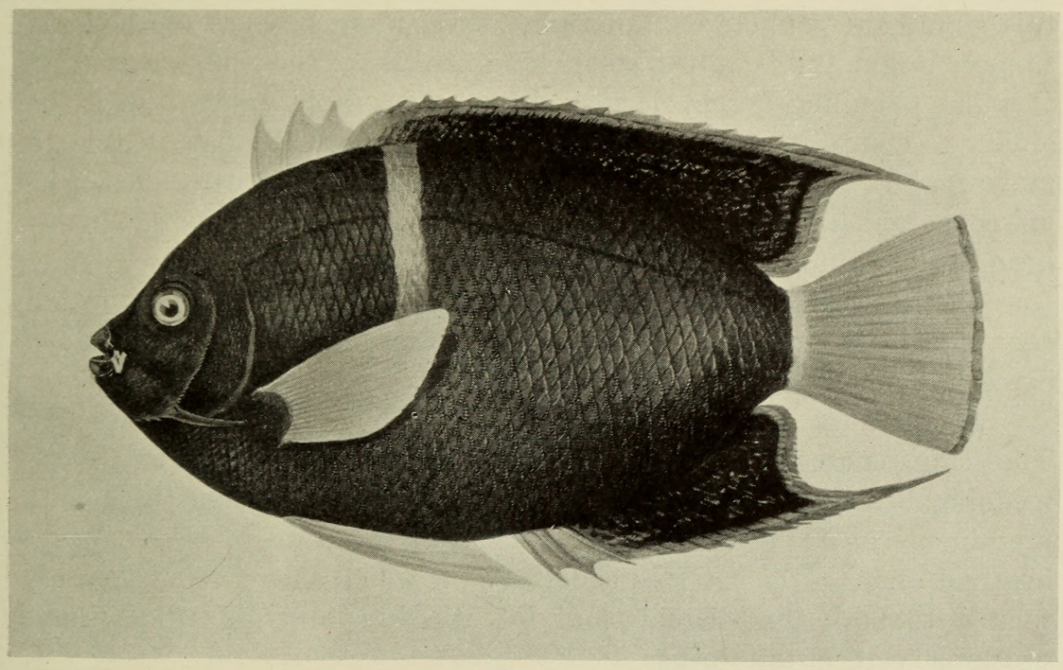


Fig. 12. Galapagos Angelfish. From painting by W. Belanske. From W. K. Vanderbilt collection of scientific paintings of fishes caught from his yacht, the Ara.

Angel, Butterfly and Surf Fishes. (Sub-Order Squamipinnes). [Case 27]: The Angelfishes (*Holacanthus, Pomacanthus, Angelichthys*) and their relatives the Butterflyfishes (Chætodontidæ) have small, nibbling mouths which act like pincers in plucking off small living organisms from the rocks and coral reefs. The great depth of the body and the strength of the fins give the fish a very firm stance and power in

plucking. The brilliant or dense colors are in wide contrast to the pale or silver hue of open-sea fishes. In the Butterfly Fishes, the teeth are very fine and brush-like.

The Viviparous Surf Fishes. (Embiotocidæ): The Surf Fishes are deep-bodied offshoots of the Bass stock which develop the young within the body of the mother. This is very unusual among Teleost fishes.

Fighting Fish, Climbing Perch and Snake Heads. (Sub-Order Labyrinthici). [Case 27]: The Labyrinthici are so-called because of the peculiar structure of the pharyngeal bones and respiratory apparatus. In these labyrinth-gilled fishes, the gill filaments discharge their normal function, but in addition, the fourth branchial arch is extremely developed and provided with thin folds forming chambers in which air is retained for respiration.

Betta pugnax, the Fighting Fish of Siam, is said to be used by the natives in the same way cocks are used for cock fights, only in this case the combat takes place in a glass aquarium bowl. The various species of this genus are popular as aquarium fishes, more because of their extremely bright and beautiful colors than because of their pugnacity.

The Climbing Perch, *Anabas scandens*, has been credited with the ability to climb trees. This is an exaggeration, but the fish is able to move rapidly overland by means of the mobility and sharp spines of its gill cover, aided by its strong pectoral fins and tail. *Channa*, the Snake-head Mullet, is a native of Ceylon and China.

The Osphronemidæ (Snake-heads) have not such a complicated accessory breathing structure as the others and are probably degraded descendants of the Labyrinthici.

Abudefdufs and Cichlids. (Sub-Order Chromides). [Case 28]: The strange name *Abudefduf* is Arabic in origin, coming from two words meaning literally, 'father,' and 'side' or 'flank,' *i.e.*, something with prominent sides. These jolly little fishes of the coral reefs are always bustling about after the small pickings on which they feed. They are related to both the Cichlids and the Wrasses, and, like them, have crushing teeth in the throat.

The Cichlids are especially plentiful in Lake Tanganyika, Africa. They are small relatives of the Wrasses and have invaded the brackish and fresh waters of Africa, Madagascar, Syria, India, Ceylon, South America and Central America, and as far north as Texas. The duty of caring for the eggs and young is performed by the females in certain species; in others, the males take over this responsibility. In either case, the eggs and young are sheltered in the mouth or in the pharynx of the self-denying parent who is necessarily deprived of food until the young are able to take care of themselves.

Wrasses and Parrot Fishes. (Sub-Order Labroidei). [Case 28]: Apparently nature grew reckless when she colored the Wrasses and Parrot Fishes, for these are among the most bizarre sights that bewilder the eye of the visitor to undersea gardens in tropical waters. Only the Cunner and the Tautog, among the northern outliers of the family, have been toned down into sobriety and sombreness in the chill waters of New England. The Cunner retains the loose, protruding lips and retreating forehead of its tropical ancestors, but the Tautog has acquired a short stiff mouth, a prominent chin and a generally determined countenance.

The Wrasses are more or less omnivorous, nibbling and biting with their strong incisors and crushing with the remarkable pebble-coated millstones in their throats. In the Parrot Fishes, the front teeth have fused into a large, nipper-like beak, while the mill in the throat is surmounted by cylindrical teeth of oval or flattened section. The origin of this apparatus may be traced to the simple conical teeth clustered on the surface of the gill skeleton in primitive Wrasses. In leisurely swimming, many of the Wrasses and their allies use chiefly the pectoral fins, holding the large tail fin as a rudder.

Sculpins, Gurnards, Scorpion Fishes, etc. (Sub-Order Scorpænoidei). [Case 29]: This group of fishes is generally known as the Cheek-Armored Fishes, in reference to the fact that one of the bones surrounding the eye is much enlarged and arches backward over the cheek so as to gain a broad contact with the forepart of the bony gill cover. Thus it forms the so-called "bony stay" that strengthens the skull in this group.

The Gurnards, or Sea-Robins, with their broad heads enclosed in this bony shield, bear little resemblance to the Basses, yet the Sculpins and the Rose Fishes tend to connect them with the primitive Sea Bass stock.

Most of the fishes of this group are marine forms, living either among the rocks, or on or near the bottom, sometimes at considerable depths. The most primitive forms are the Rose Fishes; the most advanced the Flying Gurnards.

The Gurnards have the first three rays of the breast fins specialized as 'legs.' Due to this specialization, their movement among seaweed or along any surface much resembles walking on these fins.

In the Lumpfishes and Sea Snails, the ventral fins are modified into a sucker, by means of which these fishes cling to the rocks.

In the Platycephalids, the flattened head presents a curious resemblance to that of bottom-living forms of widely different groups, such as the extinct Ostracoderms (*see* Fossil Exhibit), and the Armored Catfishes (case 20).

The Gobies. (Sub-Order Gobioidei). [Case 29]: The Gobies have pushed their way into all the seas outside the Arctic and Antarctic circles, and have representatives in the fresh waters of all parts of the world. The central form, *Gobius*, is not very different from the Johnny Darters of the Perch-Bass group, except that the ventral fins together tend to form a sucking disc by means of which the fish clings to rocks. In the Mud Skipper, *Periophthalmus*, the breast fins are modified into flippers and the fish skips about on these over the mud flats o

Fig. 13. *Periophthalmus*, the Mud-Skipper. Drawn by D. Blakely.

eastern tropical rivers. Its eyes are greatly enlarged and protruding. In the Blind Goby of California, on the other hand, the eyes are reduced to mere vestiges and the fish lives like a slug under the rocks.

In size the Gobies vary from the minute *Mistichthys* of the Philippines, which measures only twelve to fourteen millimeters in length, to the *Eleotris marmorata* of Siam, which grows to nearly three feet. The Gobies differ from the cheek-armored group in lacking the bony stay of the cheek.

Cods, Hakes, Rat-tails, etc. (Sub-Order Anacanthini). [Case 30] These mulluscous, obese offshoots of the vigorous spiny-finned order are

highly specialized, and in many respects degraded. Even in the rat-tailed Grenadiers (Macrurids) which are less specialized than the Cods, the true tail fin has been lost and the hind end of the body has been prolonged into a trailing wisp. In the Cods and their allies, the tail, while outwardly not unlike that of more normal fishes, appears to be merely an imitation, fashioned from the rear parts of the elongated, subdivided soft dorsal and anal fins, as shown by the construction of the bony rods supporting the tail. In the Grenadiers and Cods the ventral fins are normal, but in the Hakes they have been reduced to greatly elongate feelers.

This group as a whole is essentially marine and ranges from the greatest depths to the shallower waters of the coastal belt. The abundance of these fishes is truly astounding. For example, 14,000,000 pounds of Silver Hake were marketed in Massachusetts and Maine in 1919. As to their fertility,—the roe of a seventy-five pound Cod contained, according to a careful estimate, no less than nine million, one hundred thousand eggs.

Long before the landing of the Pilgrims at Plymouth, boats had come from Europe to the New England coasts and north to the Grand Banks to fish for cod. These fisheries, which have now been developed into a huge industry, were of the utmost economic importance in the life of the early settlers in New England. They center at present in Boston and Gloucester, Massachusetts. The Cod fisheries are also a big industry in France which sends a large fleet to the Iceland fishing grounds, and in Norway which carries on big fisheries in the Lofoten Islands.

Blennies. (Sub-Order Blennioidei). [Case 30]: The Blennies are active little fishes living around rocky or coral reef shores. Certain Blennies, for instance the Lizard Skipper of Samoa, even leap from rock to rock at low water, in this respect parallelling the unrelated mud-skipping Goby. Most of them are small, but there is one gigantic and ferocious-looking marine Blenny, with strong tusk-like front teeth. This is the Sea Wolf, *Anarrhichas.* It also has large, rounded crushing teeth on the roof of the mouth and inner side of the jaw, enabling it to devour crabs and shelled molluscs.

The Eel-Pouts are elongate derivatives of the Blenny stock.

The Weavers. (Sub-Order Jugulares). [Case 30]: The Weavers are distant relatives of the Perch-like fishes. Some of them have poisonous spikes on the gill-covers. The Electric Star-gazers of this group have a pair of powerful electric organs behind the eyes.

Mackerels, Tunas, Dolphins, etc. (Sub-Order Scombroidei). [Cases 31, 32, 33]: The Mackerel group represents one of the culminating phases in the evolution of the Bass-like fishes from which group its more

typical members are distinguished by the torpedo-like body, the delicate, thin-boned skull, absence of spines on the gill cover, reduction of the scales, presence of a horizontal keel at the base of the tail, and the symmetrical arrangement of rear fins above and below the horizontal axis.

Pedigree of the Mackerels and their Allies. [Case 31]: This Sub-Order divides itself into four principal lines: (1) The Mackerel Series, culminating in the Albacores and Bonitos. These are the swiftest and most active of all the Mackerels, with beautifully streamlined bodies. (2) The Spanish Mackerels and Wahoos, chiefly distinguished by their pointed snouts, their long, low body and long dorsal fin. (3) The Swordfish and Sailfish in which the forepart of the skull is produced into a long, sharply pointed beak. In the Sailfishes, the dorsal fin is of enormous size. (4) The Escolar-Cutlass Fish line which runs out into fierce eel-like forms.

Bonitos, Tunas and Mackerels. [Case 32]: The acme of speed, of "fineness" and of streamline form is attained by the Bonitos, Tunas, Mackerels and their allies. In the Bonitos and Tunas the body is short and comparatively stiff; the tail large and lunate but with a slender, strong base. These fishes often leap from the water like Dolphins, or like a projectile that strikes and ricochets from the surface. In the Mackerels the body is more elongate and torpedo-like, with forked tail. In the Cutlass Fishes, the body has become eel-like and the tail is reduced to a point. The Oil Fish, *Ruvettus*, a deep-sea relative of the Mackerels, is here shown with the wooden hook used for its capture in the South Seas.

Dolphins, Pompanos, Moonfishes. [Case 33]: The central type of these pearly, silvery fishes is the Pompano, from whose orb-like body we may derive, on one hand, the much deepened disc of the Moonfish and Lookdown, and, on the other, the progressively elongate form of the Jacks, or Amberfishes.

The ornate Roosterfish may be regarded as an Amberfish with an enlarged and plume-like first dorsal fin. The Dolphin (*Coryphæna*), another long-bodied offshoot of the Pompano stock, is famous for its brilliant and changing blue and golden hues. The Dolphin of heraldry and sculpture is a composite of this fish and the true Dolphin which is a kind of porpoise or toothed whale.

In the wall case opposite this alcove is a cast of the Opah or Moonfish, *Lampris luna*, a round, iridescent fish with scarlet fins, a very rare visitor on our coasts. This fish reaches a length of six feet and a weight of five hundred to six hundred pounds.

Flatfishes. (Sub-Order Heterosomata). [Case 38]: In this group belong the Flounders, Halibuts, Turbots and their allies,—fishes which habitually lie on one side on sandy bottoms. They have been derived

from deep-bodied fishes allied to the John Dory (*Zeus faber*). The oldest known member of the group, *Amphistium* of the Upper Eocene, was a deep-bodied, symmetrically built form which had not yet become twisted for lying on its side.

It is to this group that the Soles belong. The "filet of sole" of American restaurants is usually made of the Winter Flounder, *Pseudopleuronectes americanus*. The European Sole belongs to the same family as the American Sole, but none of the American species are particularly valued as food.

Migration of the Eye in Flatfishes: When the Flatfish are hatched, the young are normal in appearance, with even coloration and an eye on either side. They swim in a normal, fish-like way. However, as the fish begins to develop, it tilts over toward one side, and finally becomes adapted for resting and swimming in this position. One result of this is that the color on the more exposed side grows deeper, while that on the under side remains light. Meanwhile, the eye of the down-turned side migrates over the top of the skull, so that, in the adult, both eyes lie on the upper side of the head. The mouth also is partly twisted onto the upper surface.

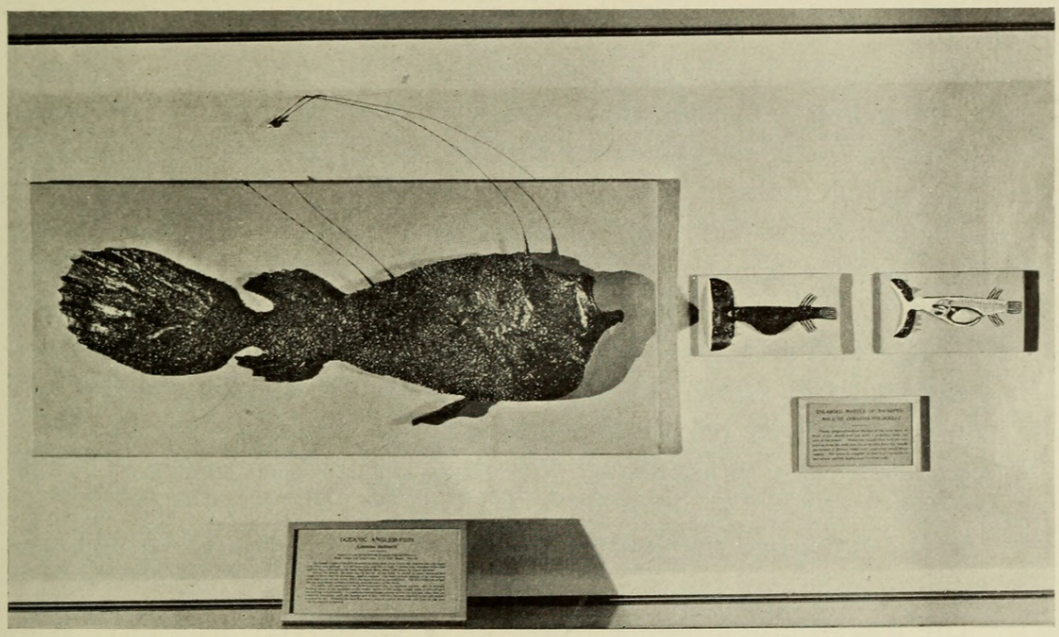


Fig. 14. *Ceratias*, the Oceanic Angler and Parasitic Male.

Order Pediculati. (Anglers, Batfishes, etc. *See also* Section III). [Case 35]: The terrible living trap set by the Angler Fish lies concealed in wait for the unwary fish that stops to examine its dangling bait.

This trap consists of the sharp-toothed jaws and cavernous interior of its enormous mouth, and the bait is a bit of skin floating from the top of a movable fishing rod which is made from an enlarged and separated ray of the dorsal fin. In the Oceanic Deep Sea Anglers (Ceratiidæ), living in abyssal darkness, the "bait" becomes luminous.

The males in several species of Oceanic Anglers are of extremely small size and live dangling like pendants from the side of the head of the gigantic females. An exhibit in a window case shows a replica of a cast in the British Museum (Natural History) of *Ceratias holboelli*, the Oceanic Angler, with its parasitic male. We quote from the original British Museum label:

"The female Angler Fish with attached parasitic male from which the original cast was made, was taken near Iceland. It is 40 inches long and has a male 4 inches long attached in the mid ventral line a little behind the head. Unlike the female, the male has no fin ray on the head; its mouth is small, toothless and closed in front, and the alimentary canal is vestigial. Fleshy outgrowths from the face of the male unite in front of the mouth and fuse with a projection from the skin of the female. Dissection reveals that both the outgrowth from the male and the projection from the female are formed of fibrous tissue with numerous small blood vessels. The union is complete so that it is impossible to say where one fish begins and the other ends. The blood system appears to be continuous with that of the female, from which the male derives its nourishment. The Ceratioids are unique among backboned animals in having dwarfed males of this kind."

The habits and conditions of life of the Ceratioids—few in numbers, solitary, slow swimmers, floating about in the darkness of the middle depths of the ocean—would make it difficult for a mature fish to find a mate. It is probable that the males, as soon as they are hatched, when they are relatively numerous, see the females and if they find one become attached to her and remain attached for life. Probably the male first nips a piece of skin of the female, and then its lips fuse with the papillæ so formed.

In the Batfishes the body is flattened and the fins serve as limbs for moving about on the sea-bottom.

The Angler group may be regarded as excessively specialized relatives of the Blennies [case 30], the Toadfishes being in some respects intermediate between the two groups.

Order Plectognathi. (Puffers, Trigger Fishes, etc.). [Cases 35, 36]: This group as a whole appears to be derived from the stem of the Trigger Fishes.

The Puffers and Porcupine Fishes. [Case 35]: The frog that tried to swell to the size of an ox finds a certain parallel in the Puffers (Tetrodontidæ) and Porcupine Fishes (Diodontidæ), which, however, unlike the frog, do not burst, but readily deflate themselves before their elastic limit is reached. They puff themselves out by pumping in water through the mouth by means of the action of certain specialized muscles behind the enlarged shoulder plates. Apparently it is as hard for a larger fish to bite an inflated Puffer as it is for a boy to bite an apple floating in the water. In both the Puffers and the Porcupine Fishes, the fore part of the jaws are modified into powerful nippers for biting and crushing resistant objects. In the Puffers the beaks of the opposite sides are separate; in the Porcupine Fishes they are fused together.

The Ocean Sunfish (*Mola*), of which there is a large specimen in the Gamefish section, is a gigantic relative of the Porcupine Fish. It is a slow-swimming, lethargic fish, fond of coming to the surface of warm waters to sun itself, and easily caught.

The Trigger Fishes. [Case 36]: The Trigger Fish is an inoffensive fish which goes bustling around the coral reefs searching for something good to nibble, but if a larger fish attempts to swallow him, he erects his tall spike, stretches his leathery skin and awaits developments. His "trigger" is the small spike on his back, lying behind the large one. When it is pulled into place by the muscles beneath, it serves to lock the larger spike in an erect position so that the latter cannot be lowered until the trigger is withdrawn. The Triggers are more specialized relatives of the Surgeon Fishes.

The Surgeon Fishes. [Case 36]: The Surgeon Fishes, or Xesuri, are so called because they carry sharp knives, one on either side of the base of the tail. These actually represent a greatly enlarged scale which is sometimes depressible in a case or groove. The fish seems to be able to give a vicious "side swipe" with its tail.

In *Xesurus* and related genera, the knife is replaced by three or more forwardly-directed spikes. Probably the 'knife' of the true Surgeon Fishes represents a specialized survivor of one of these three spikes.

The group as a whole constitutes a specialized offshoot from the stem of the Butterfly and Angel Fishes.

THE BASHFORD DEAN MEMORIAL EXHIBIT
OF
FOSSIL FISHES

Southeast Pavilion
Fourth Floor

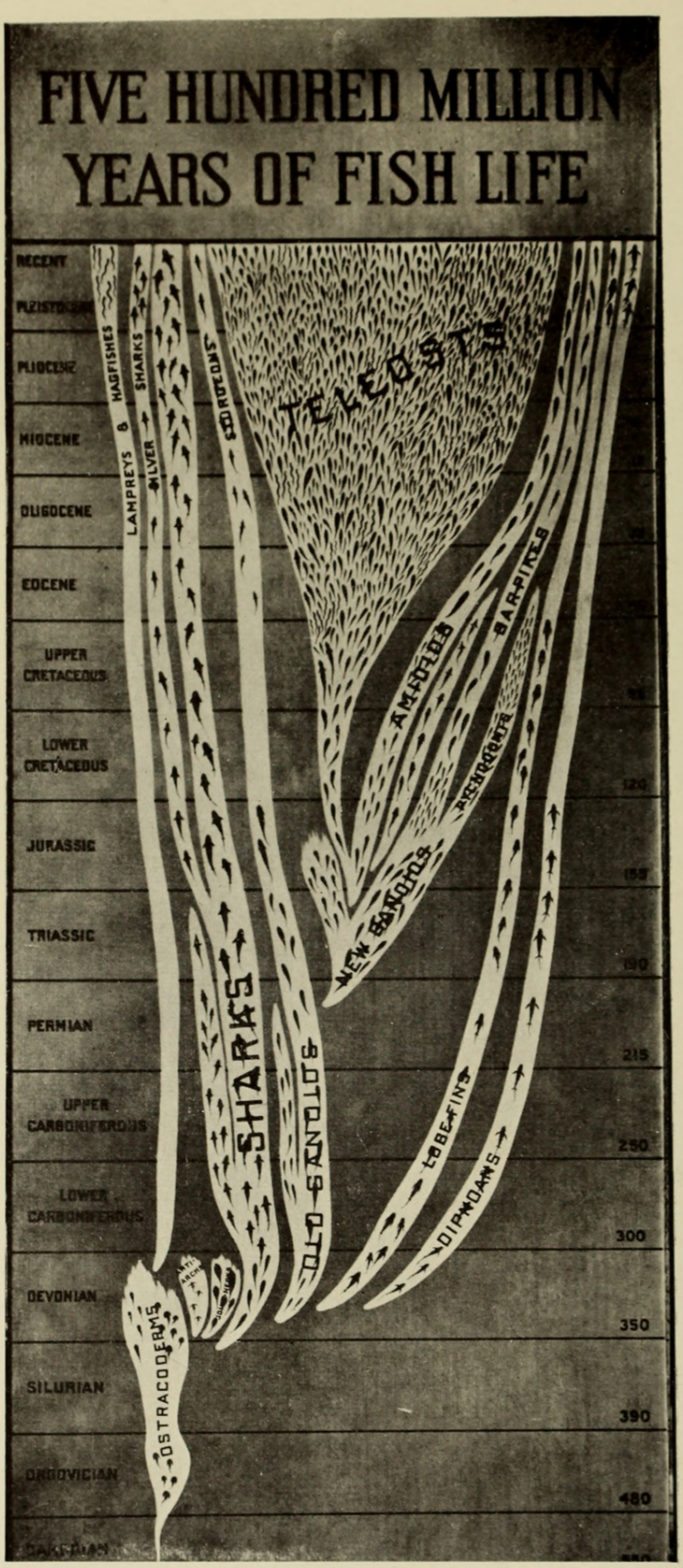


Fig. 15. Five Hundred Million Years of Fish Life. Chart drawn by W. Benckert.

THE BASHFORD DEAN MEMORIAL EXHIBIT OF FOSSIL FISHES

Southeast Pavilion
Fourth Floor

This exhibit of Fossil Fishes was rearranged in 1929 as a memorial to Dr. Bashford Dean (1867–December 1928), first Curator of the Department of Fishes in this Museum; later its Honorary Curator; always its friend and contributor, and author of many authoritative works on fishes living and fossil.

The bronze portrait plaque of Dr. Dean, hanging to the right of the entrance, is the memorial gift of friends and colleagues in America, Europe and Asia. Below is a small case containing a monograph by Dr. Dean, one of his field notebooks and a letter from him written from Japan to his friend and colleague Professor Henry Fairfield Osborn.

On the left of the entrance is a bronze portrait plaque of Professor John Strong Newberry (1822–1892), professor of geology at Columbia College; well-known for his studies on the fossil fishes of the Devonian, and the friend and teacher of Bashford Dean. His collection, the property of Columbia University, is deposited in this museum.

The fossil fish exhibit consists of selected material from the museum's large study collection. It includes parts of the following collections as well as important single specimens:

Newberry Collection: deposited by Columbia University in 1903. Brought together by Professor J. S. Newberry. About 3350 specimens.

Cope Collection: presented by the late president of this Museum, Morris K. Jesup. About 2425 specimens.

Dodge Collection: presented by William E. Dodge. About 100 specimens of Placoderm fishes from Ohio, collected by Mr. Jay Terrell.

Day Collection: presented by Rev. D. Stuart Dodge. About 1200 specimens collected in the Cretaceous of Syria by the late Dr. Alfred Ely Day.

Hall Collection: brought together by Professor James Hall. About 250 specimens.

Stuart Collection: presented by Robert L. Stuart. 40 specimens.

Kepler Collection: 75 specimens of Placoderms and primitive sharks, collected in Ohio by Rev. William Kepler and purchased by the Museum in 1904.

American Museum Collection: specimens collected in the field by various expeditions, and otherwise obtained by purchase, gift, exchange, etc.

NOTE: The guide to this exhibit is based on the explanatory labels found in each case.

FIVE HUNDRED MILLION YEARS OF FISH LIFE

[Wall Chart, Case 11]

The class of Fishes was the first of the vertebrates to appear in the history of the earth, fragmentary fossil remains of Ostracoderms having been found in rocks of the Lower Ordovician Age near Canyon City, Colorado.

According to the most recent geological estimates, the age in years of these rocks would be about four hundred million years. It is not improbable that even in the Lower Cambrian (five hundred and fifty million years) the predecessors of the Ostracoderms were already distinct from the trilobites, worms, molluscs and other animals of that far-off time. This chart represents in a general way the main branches of fish life as indicated by fossils from successive geological horizons.

Sequence of Fishes in Geologic Time. [Case 11]: Many hundreds of extinct species of fishes are already on record. Nevertheless, the history of each of the main divisions of the fishes is very defective at many points, the forces of destruction having completely wiped out both the fossil-bearing beds and their contained fossils. The diagram in this case indicates only a few of the better known species of fossil fishes. Each group is derived from a central or generalized type. This, then, gives rise to many peculiar specialized side lines which sooner or later become extinct. Meanwhile, the central stock gradually progresses to the next higher grade.

OSTRACODERMS

(The Oldest Fossil Fishes)

[Cases 1 and 3]

Near Canyon City, Colorado, are found red sandstones of the Ordovician period containing small fragments of the most ancient and most primitive of all known fossil fishes. Better preserved specimens of this class occur in the mudstones of the succeeding Silurian period, in Scotland, Norway and New York State. It is estimated that the oldest of these specimens lived about four hundred million years ago. They belong to a large class of extinct, fish-like animals called Ostracoderms.

These fossils are of great interest because they illustrate the 'basic patents' of the vertebrate type of animal. That is, even at that remote period, they already had a fish-like body which moved by lateral undulations caused by the zig-zag muscle segments arranged along the sides of the body; the head comprised three pair of capsules for the nostrils, eyes, and internal ears respectively; behind the mouth was a cavity for

the gills, and presumably the back was stiffened by a simple axial rod or notochord—the forerunner of the complex backbone of vertebrates.

In some Ostracoderm fossils, the fine silt on which the animal died finally penetrated into the blood vessels along the bony channels of its main nerves and into the interior of the brain chamber. Thus, after the silt turned to stone, a natural cast of the brain and of the cranial nerves and blood vessels was left. These casts have been intensively studied by the Swedish palæontologist, Dr. Erik A. Stensiö. He has thus been enabled to compare much of the internal anatomy of these Silurian Ostracoderms with that of the lowest existing fishes, especially the lampreys and hag fishes, which are the nearest living relatives of the Ostracoderms.

The Anaspida. The Ostracoderms differed widely among themselves in external body form and in other details. In the primitive Anaspida, the body was fish-like, the head not enclosed in a single shield, and the eyes were on the side of the head.

The Cephalaspida. In this group, the head and branchial chamber together were enclosed in a large, more or less semicircular bony shield. This shield was produced by the ossification of the many-layered skin covering the forepart of the body. The eyes were on the top of the head.

The Pteraspida. The shield of the Pteraspida was formed without true bone cells. The small eyes were at the sides of the head. In some of these forms, the fine ridges on the surface of the shield in the fossil condition refract the light and give rise to a pearly lustre, hence the name "Ostracoderm," meaning 'shell-skin,' originally applied to members of the Pteraspid group only, and afterward expanded to include the entire class.

THE CYCLIAE

[Case 3]

This is a special group of early chordates, of unknown kinship. The representative is *Palæospondylus*, the "fossil lamprey-eel" much discussed in the literature of fossil fishes. It is characterized by well-marked vertebræ, a prominent head terminating in barbel-like processes, and a paddle-shaped (diphycercal) tail. It was found in the Middle Devonian of Scotland. Recent studies by Professor Graham Kerr of Glasgow and one of his students indicate that "*Palæospondylus*" is a larval lung-fish, the adults of which are found in formations of equivalent age.

ARTHRODIRA

[Cases 2 and 3]

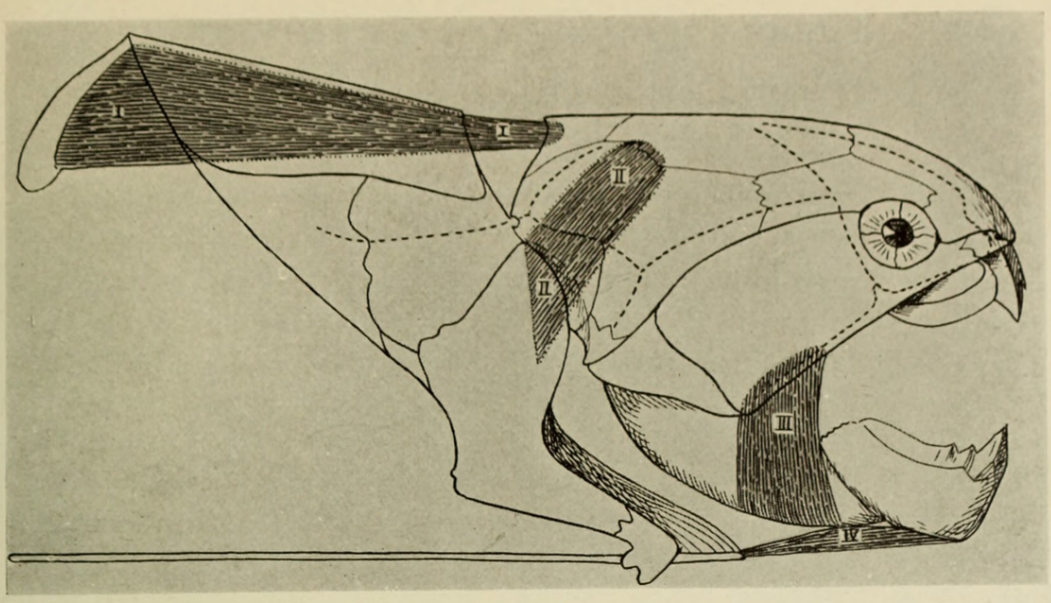
Evolution of the Arthrodira [Case 2]: This exhibit illustrates the evolution of the Arthrodira, or Joint-Necked Fishes, as shown by changes in the size and structure of the head.

The Arthrodira were fish-like animals whose head, shoulders and abdomen were armored with plates of bone; their mouth was provided with powerful "teeth" or cutting plates. They ranged from a few inches to twenty feet in length and lived abundantly in the seas and rivers of the Devonian, becoming extinct during the beginning of the Coal Period (Carboniferous).

The earliest and most primitive type was the small *Phlyctænaspis*, ten or fifteen inches in length, represented both in Europe and America (Old Red Sandstone, Scotland; Lower Devonian, Canada). From a type like this, all other Arthrodira were descended. Among these we note: *Homosteus*, a large form found in the Old Red Sandstone of Scotland; *Coccosteus*, a small fish (one or two feet), most abundant in species of all earlier forms and surviving to the close of the Devonian; *Dinichthys* and *Titanichthys*, Coccosteus-like forms found in the Upper Devonian shales near Cleveland, Ohio, including examples twenty feet in length, the largest of this group.

Titanichthys: On the wall is mounted the head and front portion of the body of the giant Arthrodire, *Titanichthys clarkii* Newberry. The complete animal was probably fifteen to twenty feet in length. It came from the Cleveland shale.

Dinichthys: Below Titanichthys, in the cases between cases 2 and 3, are shown restorations of the head and front portion of the body of one of the larger arthrodires, *Dinichthys terrelli* Newberry. The pieces were found in the Cleveland shale of the Upper Devonian. The entire animal must have measured about fifteen feet in length. These two restorations have been followed, in 1930–31, by the latest restoration, made by Dr. Anatol Heintz of Oslo. A metal model showing roughly the arrangement of the armor plates of the head and thorax in this new restoration is to be seen in the case with the mounted head. This model illustrates the unique jaw mechanism of these fishes who opened their jaws by throwing the head back and drawing down the lower jaw. Four pair of muscles, worked respectively to lift the head roof, to move the head roof downward, to move the lower jaw upward, and to move the lower jaw downward. That is, the first and fourth pair operated to open the mouth and the second and third pair to shut it. This unusual mouth mechanism has never before been observed in any fossil or living animals.



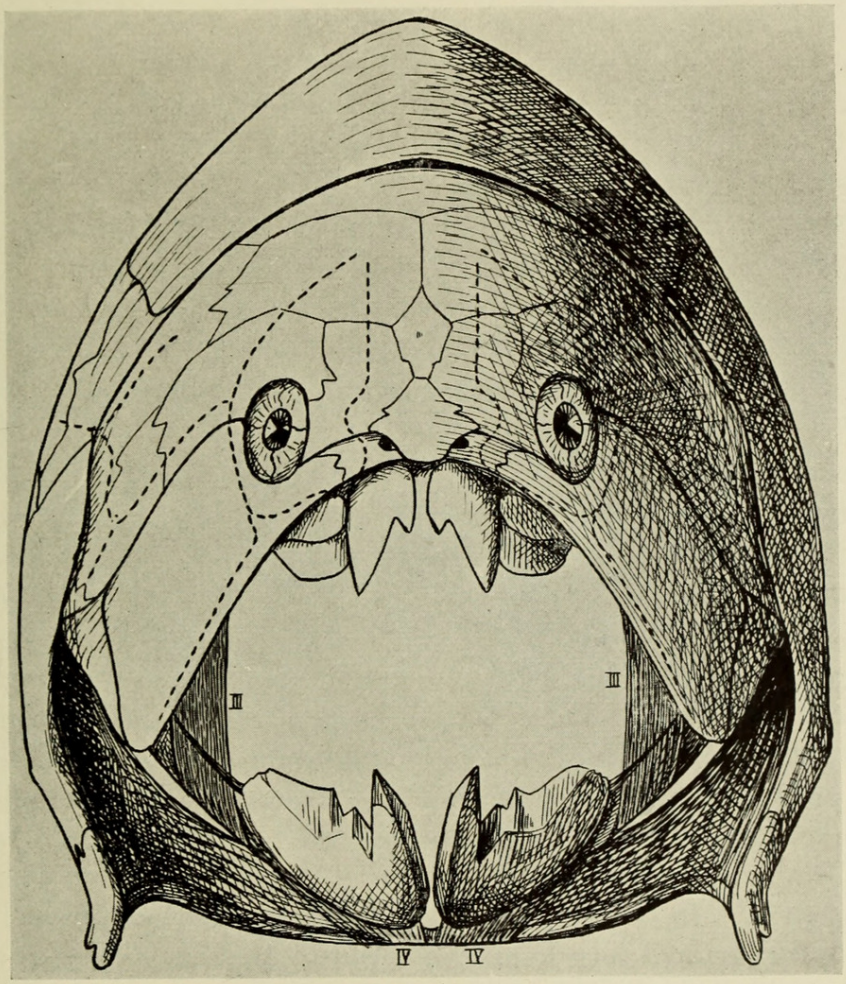


Fig. 16. Restoration of *Dinichthys*. Front and Side Views. By Anatol Heintz.

SHARKS

[Cases 3, 4, 5]

Sharks were among the first vertebrates to appear and have survived throughout all later geologic ages.

Giant Fossil Shark, *Carcharodon megalodon.* [Above entrance to exhibit]: About the time when the glaciers covered the northern part of North America, the seas were inhabited by gigantic sharks. The actual teeth of one of these monsters are shown above the entrance to the alcove. They are from the Tertiary of North Carolina. Their average height is 4¼ inches. They have been set in jaws modelled after those of the Man-Eater Shark, which is the nearest relative of the giant extinct species (*Carcharodon carcharias*). The estimated length of this fish in life is 46 feet. A scale drawing below the jaws shows its size as compared with that of the Man-Eater and that of the average man.

The Fin-Fold Shark, *Cladoselache.* [Case 4]: *Cladoselache* is one of the most primitive known types of shark. It lived in the sea during the Devonian. It was characterized by notochordal skeleton, fin-fold type of fins (embryonic fold of skin in which fin rays are developed), and eyes protected by many enlarged shagreen scales. The specimens in this case are from the Upper Devonian of Ohio. In some of the specimens the myotomes, or muscle segments, on the side of the body are preserved.

Pleuracanthidæ. [Case 3]: These are extinct primitive sharks. Their characters include a notochordal backbone, a strong spine at the back of the head, peculiar forked teeth and paddle-shaped pectoral and ventral fins. They have been found from the Carboniferous and Permian of Europe and North America.

Acanthodia. [Case 3]: The leading characteristics of this order of primitive sharks are shagreen close set and scale-like, each web-like fin supported by a spine, eye protected by a ring of bony plates, backbone cartilaginous (notochordal). They appeared in the Silurian and became extinct in the Permian.

Edestidæ. [Case 5]: These are extinct sharks whose nearest living relative is probably the Port Jackson Shark (*Heterodontus*). Of *Edestus*, the only structures preserved have long been regarded as spirals of teeth which projected in front of the mouth. They have been found in the Carboniferous and Permian of Europe and North America. In most sharks the most used teeth come to lie in the front line and eventually get broken off. In *Edestus*, however, the teeth of the symphyseal region of the lower jaw had such long stout "roots" that they could not break off but gradually grew outward into a tightly wound spiral in which the older and smaller teeth are nearer the center.

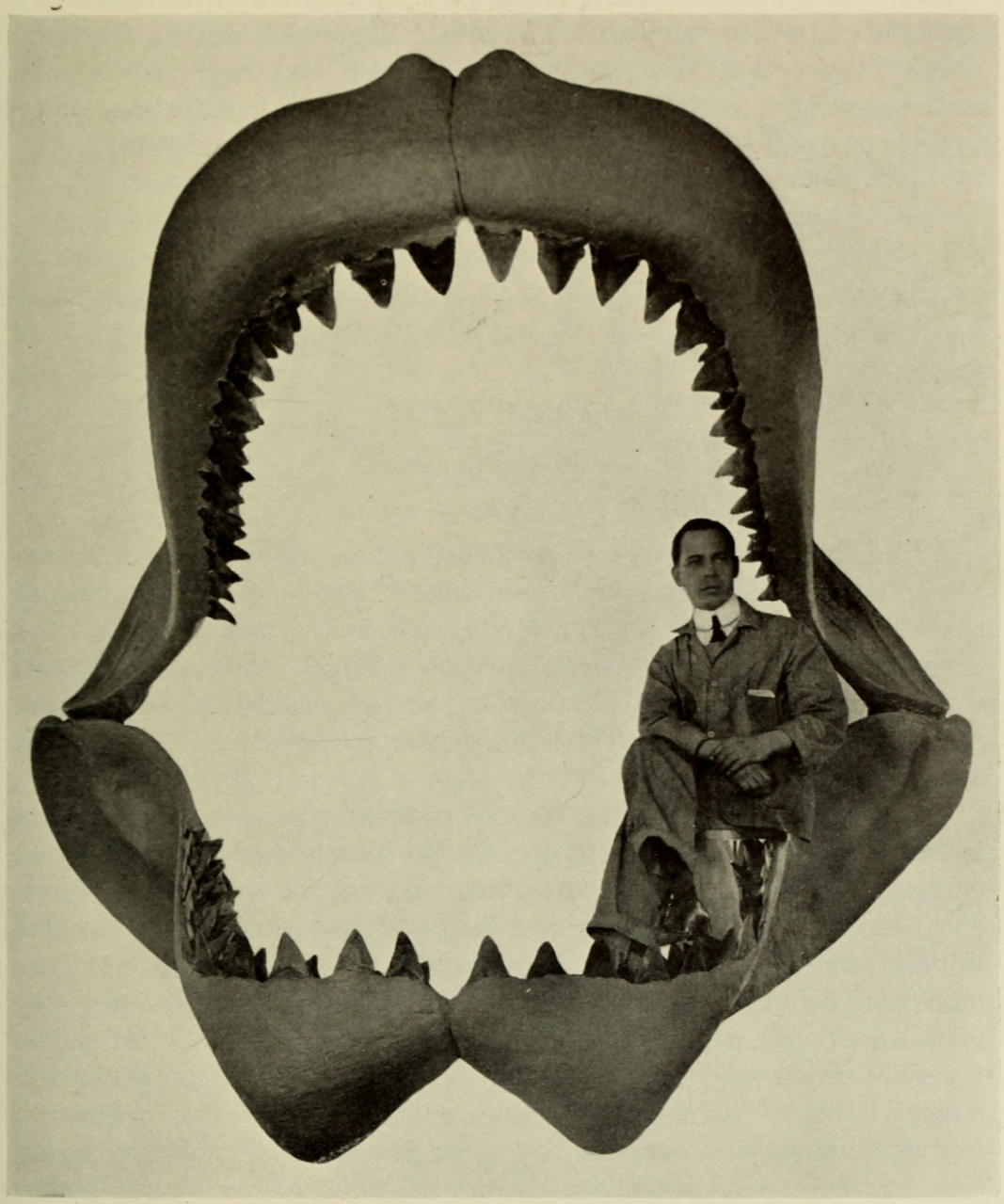


Fig. 17. Jaws of *Carcharodon megalodon.*

Skates and Rays. [Case 5]: Skates and rays are characterized by a cartilaginous skeleton; the skin is often studded with small tubercle-shaped scales; the teeth are flattened, often fused into pavement-like crushing plates; the gills open in separate slits on the under side of the neck. They were dominant in the Carboniferous and are greatly reduced at the present time. The early forms show many curious specializations in fin-spines and teeth, some of the latter pavement or plate-like.

ICHTHYODORULITES

[Case 5]

Ichthyodorulites are spines and spine-like structures of fossil fishes, many of which cannot as yet be associated with any particular kinds of fishes.

CHIMAEROIDS

(Silver Sharks)

[Case 6]

Chimæroids appeared in early geologic times and were most numerous and diversified during the Cretaceous. They form a small group of shark-like fishes whose existing forms with few exceptions inhabit the deep sea. Some extinct species grew to a length of over fifteen feet. Complete fossil Chimæroids are rare. They are mainly known from detached plates and spines. The living genera representing this group are also shown in this case.

This group is interesting to zoologists as survivors of an ancient stock more closely akin to primitive sharks than to any other fishes. In general they retain shark-like features, but in highly modified form. Their head is typically rat-shaped; their body tapering, with a wisp-like tail and large pectoral fins which are the main organs of swimming. The numerous scales of the shark have in large measure disappeared; the many small teeth are represented usually in three pair of dental plates; the many small valves of the base of the main artery become fewer and larger; the intestinal valve is present, not in many low ridges, but in a few ridges of great width, and the upper jaw, instead of being separate from the skull, as in sharks, is fused with it. The skeleton is cartilaginous and the dorsal spines strong.

Ptyctodonts: These fishes shown at the bottom of Case 6 probably belong to the group of Arthrodira, but by some are regarded as Chimæroids. They have been extinct since the Devonian and are known only from dental plates.

DIPNOANS

[Case 7]

These fishes are provided with a lung as well as with gills. They breathe through nostrils; have three pair of dental plates, and paddle-like paired limbs. At present they are represented by but a few species (*see* Hall of Fishes, Case 1), two of which, *Protopterus* and *Neoceratodus*, the African and Australian Lungfishes, are shown here.

The lungfishes, are, in many regards, like Salamanders. They appeared in the early Devonian and attained their greatest development at the close of the Palæozoic. Complete fossil specimens are rare. In early periods of the world's history the Dipnoans were a large and important group, abounding in nearly all fresh water. At present they are represented only by three genera, *Protopterus*, living in the rivers of Africa, *Lepidosiren* in South America, and *Neoceratodus* in Australia.

The structures which distinguish them are a lung, which may be single or double-lobed and which enables the fish to withstand the long rainless season when the rivers in which it lives become dry; teeth which are crushing or cutting plates, each with ridges extending crosswise over its surface, and the paired fins of the kind known as "archipterygia," *i.e.*, with an internal structure consisting of a jointed rod of cartilage having similar or smaller rods branching from it on either side.

The most ancient fossil lungfish is *Dipterus* which lived in the Devonian. It is well known by fossil remains from the Old Red Sand stone of Scotland. It had two separate dorsal fins and its head was covered with numerous small, enamel-coated bones.

It gave rise to *Phaneropleuron* which resembled it in the main, except that it was more slender and the two dorsal fins were united into a single long fin. The family to which *Phaneropleuron* belongs gave rise to two types of lungfishes, one a rather stout form, *Scaumenacia;* the other a more slender fish, *Uronemus*. These two types became in time more and more differentiated, gradually leading up to the families of lungfishes existing at the present time, the one including the Triassic *Ceratodus* and *Neoceratodus* of Australia; the other including the slender, eel-like *Protopterus* of Africa, and *Lepidosiren* of South America.

CROSSOPTERYGII

(Lobe-fins)

[Case 7]

The oldest of this group, from the Old Red Sandstone of Europe were long-bodied, pipe-like fishes with voracious mouths. Their pectoral and pelvic fins however were lobate or fringe-finned, that is with a more or less elongate bony and fleshy core surrounded on the front and

rear borders by long, fringing bony and dermal rays. The shorter lobe-like fins resembled the paired limbs of amphibians in having only a single bone, representing the humerus or the femur respectively at the proximal end of each paddle or limb. These forms (Rhipidistia) also approached the amphibians in skull structure and are believed to have stood close to the ancestral line of the latter. The Rhipidists have two dorsal fins and a peculiar type of tail. Among modern fishes two genera, the *Polypterus* and *Erpetoichthys* of Africa were formerly believed to be the direct descendants of the Devonian Crossopterygians, but Professor E. S. Goodrich has adduced evidence for his conclusion that they differ from the latter in many important structural features and that they may rather have been derived from ancient ganoids of the palæoniscoid type.

One branch of the Rhipidists gave rise to the strange Cœlacanths which lasted from Devonian to Cretaceous times.

GANOIDS

[Cases 8, 9, 12]

The Ganoids comprise an extensive group of fishes whose survivors include the Sturgeon, Garpike and Bowfin. The fossil members of this group were numerous during the late Palæozoic and early Mesozoic. They have prominent enamelled and bony scales and in many structural features are intermediate between Sharks and Teleosts. The specimens in these cases are mainly from the celebrated lithographic stone in Solenhofen, Bavaria. (Jurassic).

Pycnodonts. [Case 8]: The Pycnodonts (*pycnos*-crowded; *odous*—teeth) are extinct Ganoids with deep compressed body, persistent notochord, and numerous small grinding teeth. They were abundant and widely distributed during the Mesozoic era, but gradually became extinct, disappearing in the early Tertiary. Some specimens reached a length of three feet. Other typical extinct Ganoid fishes are shown in Case 9.

The Saw-finned Fish, *Protosphyræna nitida* Cope. [Case 12]: Among the strange fishes that swarmed in the ancient seas of Kansas, none are more noteworthy than the Amioid fish, *Protosphyræna.* Its bony snout was prolonged like that of a Gar; there were two tusk-like teeth in the upper jaw and very sharp teeth in the lower jaw like those of a living Barracuda. The front edge of the enormous pectoral fins was serrated, and it is supposed that the fish used these in attacking its enemies. On the left side of this case is a sketch of the skeleton of this fish; below it a sketch of the skull, and to one side a reconstruction made from the actual parts shown on the plaque with it. Across the bottom of the case stretch the huge, saw-edged pectoral fins.

THE FOSSIL AQUARIUM

The aquarium at the back of the exhibit alcove is a restoration of early fossil fishes from the Old Red Sandstone of Cromarty, Scotland. This group represents fossil fishes which flourished in the ages preceding the appearance of land-living animals such as frogs, reptiles, and mammals. The aquarium is designed as an aid in interpreting the fossils in adjoining cases, and it probably gives the more accurate picture since all the fishes shown were found in a single locality and in a single layer of Old Red Sandstone (Lower Devonian). In their coloring, they have been made to correspond with their nearest living relatives.

The present models show several kinds of sharks, a lungfish, two lobe-finned ganoids, and the earliest form of ganoid, *Cheirolepis*. In addition, there appear two fishes whose race is extinct, and whose relationships are obscure. These are the Placoderms, *Coccosteus* and *Pterichthys*. The habitat of these fishes appears to have been estuarine, fresh water, or brackish. The plants represented are from the same age and two of them from the same locality. The background was made by Charles R. Knight under the direction of Bashford Dean, in 1909.

TELEOSTS

(Bony fishes)

[Case 10]

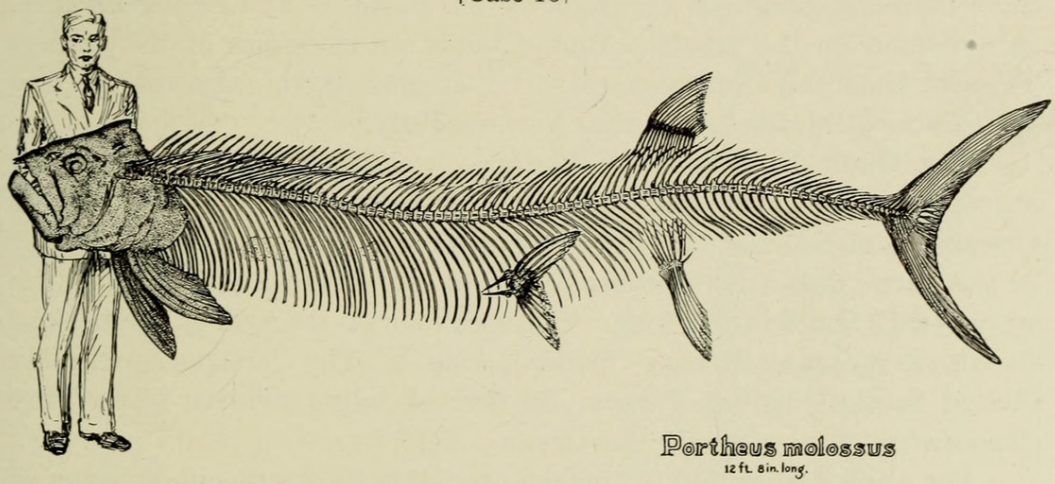


Fig. 18. Portheus, the Giant Bulldog Fish. Drawn by Louise Nash from a photograph of a specimen 12 feet 8 inches long, discovered by George F. Sternberg in the Kansas Chalk (Cretaceous).

To this group belong the majority of food and game fishes of the world—the Bass, Carp, Cod, Eel, Herring, etc. They are the dominant type of fishes at the present time. They are descended from and have supplanted the Ganoids. Many of their forms, including several orders, appeared during the Chalk Period,—the earliest being the Herrings

(Clupeoids) and the Ten Pounders (Elopidæ). An interesting series of transition stages of connecting links can be arranged leading by almost imperceptible degrees from Ganoids to Teleosts.

Structure: The Teleosts are exceedingly diverse in form, size, coloring and anatomical structure, having become adapted to the most varied conditions in seas and lakes and rivers. In size they range from the half-inch *Mistichthys luzonensis* of the Philippines—the smallest vertebrate known, to the gigantic Arapaima of the Amazon, which attains a length of over fifteen feet.

In typical Teleosts, the skeleton is bony or calcified; the fins light, flexible, and provided with complex muscles which insure rapid and diversified movement. The body is covered with thin, flexible, overlapping scales; the brain and sense organs are well developed, especially for sight and hearing.

Fossil localities: Fossil Teleosts are widely distributed. Most of those in this case are from the Green River shales of Wyoming. This geological formation consists of soft, buff-colored shales which appear to have been deposited in an estuary, or in a landlocked bay during the Middle Eocene. The fishes found in these shales are of great variety and beautifully preserved. These formed part of the collection brought together by the distinguished palæontologist, Professor E. D. Cope; the remaining specimens are from various localities and geological ages, as indicated on the labels. Among them are examples of the earliest Teleosts from the Cretaceous of Mt. Lebanon, Syria, also fossils from the Eocene of Monte Bolca, near Verona, Italy.

The Giant Bulldog Fish, *Portheus molossus* Cope. [Above back center of alcove, also Case 12]: This gigantic fossil fish occurs in the Cretaceous of Kansas. Its skull is shown in Case 12, and below it a key to the parts, also a restoration sketch to scale from a photograph of a specimen 12 feet 8 inches long. The specimen on the wall at the back of the alcove measures 15 feet 8 inches in length. The *Portheus* is remotely related to the existing Tarpon, its nearest living relative is the tiny *Chirocentrus dorab* of the Indian Ocean.

For a full description of this fish, *see* Bulletin American Museum of Natural History, 1904, volume 20, article by Henry Fairfield Osborn.

Recommended books for reference:

Jordan, D. S. "Fishes." D. Appleton, New York, 1925.

Norman, J. R. "A History of Fishes." London, 1931.

Nichols, J. T., and C. M., Breder, Jr. "The Marine Fishes of New York and Southern New England." Zoologica, 1927, IX, No. 1.

Breder, C. M., Jr. "Field Book of Marine Fishes of the Atlantic Coast." G. P. Putnam, New York, 1929.

INDEX

Explanation of abbreviations used below: ew=east wall, Hall of Fishes; F=Fossil Fish Alcove, fourth floor; ff=Flying Fish Case, east wall, Hall of Fishes; p=paintings; V=Vanderbilt collection of paintings, Hall of Fishes; ww=west wall, Hall of Fishes.