30–2 Fishes

If you think of Earth as land, then the name "Earth" is not particularly appropriate for the planet on which you live, for more than two thirds of its surface is water. And almost anywhere there is water—fresh or salt—there are fishes. At the edge of the ocean, blennies jump from rock to rock and occasionally dunk themselves in tide pools. Beneath the Arctic ice live fishes whose bodies contain a biological antifreeze that keeps them from freezing solid. In some shallow desert streams, pupfishes tolerate temperatures that would cook almost any other animal.

What Is a Fish?

You might think that with such extreme variations in habitat, fishes would be difficult to characterize. However, describing a fish is a rather simple task. **Fishes are aquatic vertebrates that are characterized by paired fins, scales, and gills.** Fins are used for movement, scales for protection, and gills for exchanging gases. You can observe most of those characteristics in **Figure 30–6.**

Fishes are so varied, however, that for almost every general statement there are exceptions. For example, some fishes, such as catfish, do not have scales. One reason for the enormous diversity among living fishes is that these chordates belong to very different classes. Thus, many fishes—sharks, lampreys, and perch, for example—are no more similar to one another than humans are to frogs!

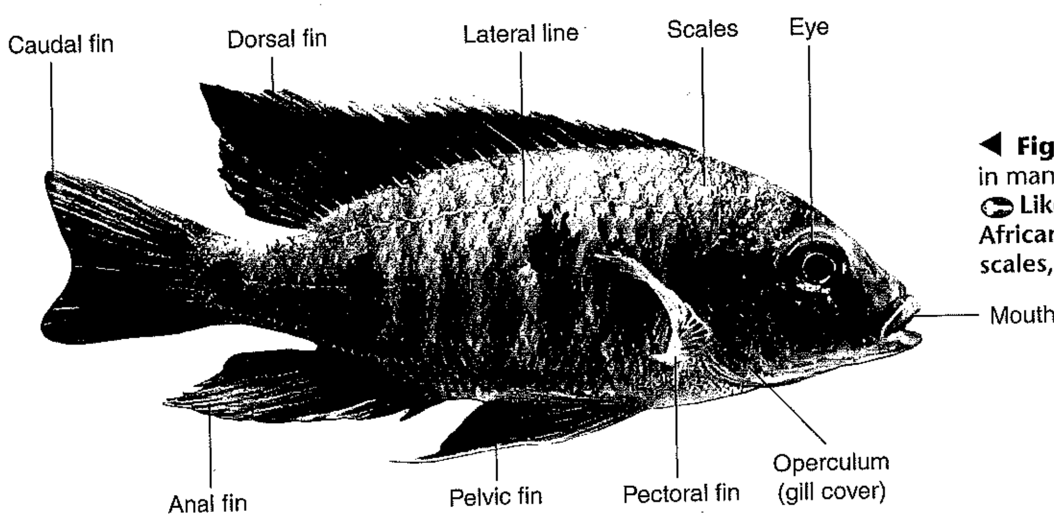
CHECKPOINT *What are the basic functions of fins, scales, and gills?*

Guide for Reading

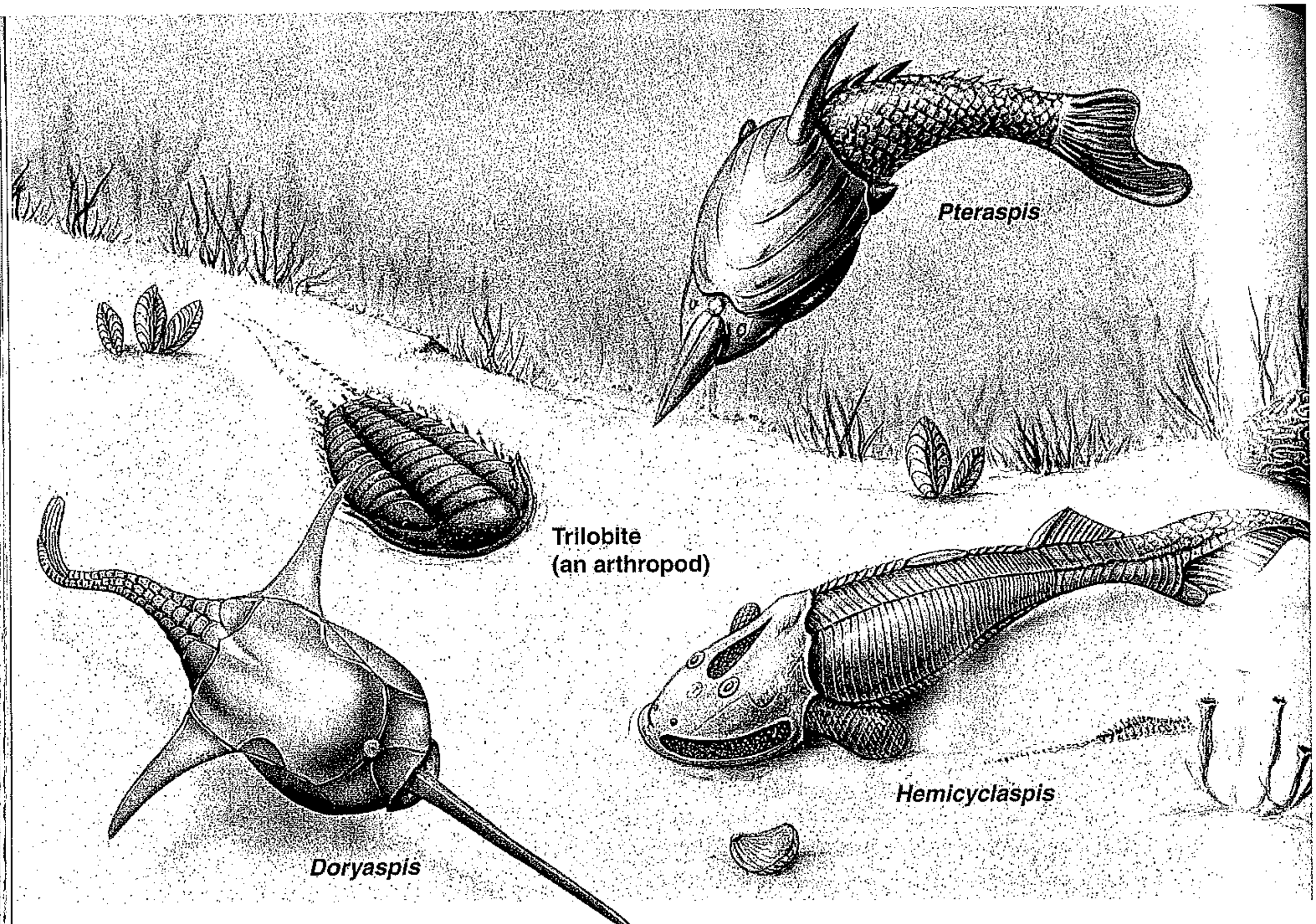
Key Concepts
- What are the basic characteristics of a fish?
- What were the important developments during the evolution of fishes?
- How are fishes adapted for life in water?
- What are the three main groups of fishes?

Vocabulary
- cartilage • atrium • ventricle
- cerebrum • cerebellum
- medulla oblongata
- lateral line system
- swim bladder • oviparous
- ovoviviparous • viviparous

Reading Strategy: Using Prior Knowledge
Before you read, make a list of the things you already know about fishes. After you have finished reading, check the list. Correct any errors and add new facts.



◀ **Figure 30–6** Fishes come in many shapes and sizes. **Like most fishes, this African cichlid has paired fins, scales, and gills.**



▲ **Figure 30–7** Ancient jawless fishes swam in shallow seas during the early Devonian Period, about 400 million years ago. Lacking jaws, early jawless fishes were limited in their ability to feed and to defend themselves against predators. **The evolution of paired fins, however, gave these fishes more control over their movement in the water.**

Evolution of Fishes

Fishes were the first vertebrates to evolve. They did not arise directly from tunicates or lancelets, but fishes and nonvertebrate chordates probably did evolve from common invertebrate ancestors. During the course of their evolution, fishes underwent several important changes. **The evolution of jaws and the evolution of paired fins were important developments during the rise of fishes.**

The First Fishes The earliest fishes to appear in the fossil record were odd-looking, jawless creatures whose bodies were armored with bony plates. They lived in the oceans during the late Cambrian Period, about 510 million years ago. Fishes kept this armored, jawless body plan for 100 million years.

The Age of Fishes During the Ordovician and Silurian Periods, about 505 to 410 million years ago, fishes underwent a major adaptive radiation. The species to emerge from the radiation ruled the seas during the Devonian Period, which is often called the Age of Fishes. Some of these fishes were jawless species that had very little armor. These jawless fishes were the ancestors of modern hagfishes and lampreys. Others, such as those in **Figure 30–7**, were armored and ultimately became extinct at the end of the Devonian Period, about 360 million years ago.

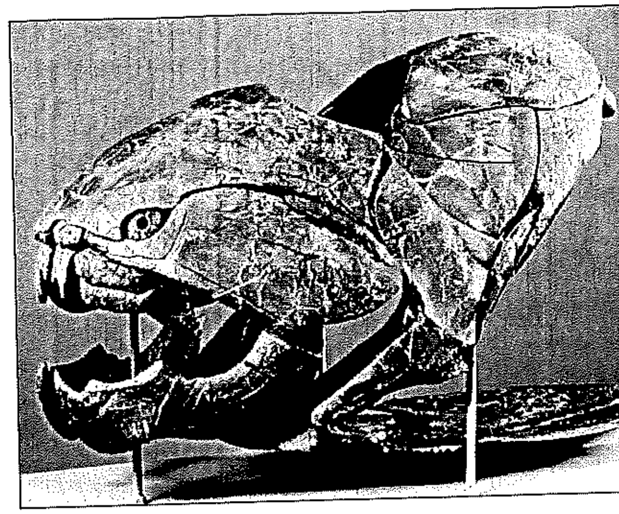
The Arrival of Jaws and Paired Fins Still other ancient fishes kept their bony armor and possessed a feeding adaptation that would revolutionize vertebrate evolution: These fishes had jaws. Observe the powerful jaws of the ancient fish in **Figure 30–8.** Jaws are an extremely useful adaptation. Jawless fishes are limited to eating small particles of food that they filter out of the water or suck up like a vacuum cleaner. Because jaws can hold teeth and muscles, jaws make it possible for vertebrates to nibble on plants and munch on other animals. Thus, animals with jaws can eat a much wider variety of food. They can also defend themselves by biting.

The evolution of jaws in early fishes accompanied the evolution of paired pectoral (anterior) and pelvic (posterior) fins. These fins were attached to girdles—structures of cartilage (KAHR-tl-ij) or bone that support the fins. **Cartilage** is a strong tissue that supports the body and is softer and more flexible than bone. **Figure 30–9** shows the fins and fin girdles in one ancient fish species.

Paired fins gave fishes more control of body movement. In addition, tail fins and powerful muscles gave fishes greater thrust when swimming. The combination of accuracy and speed enabled fishes to move in new and varied patterns. This ability, in turn, helped fishes use their jaws in complex ways.

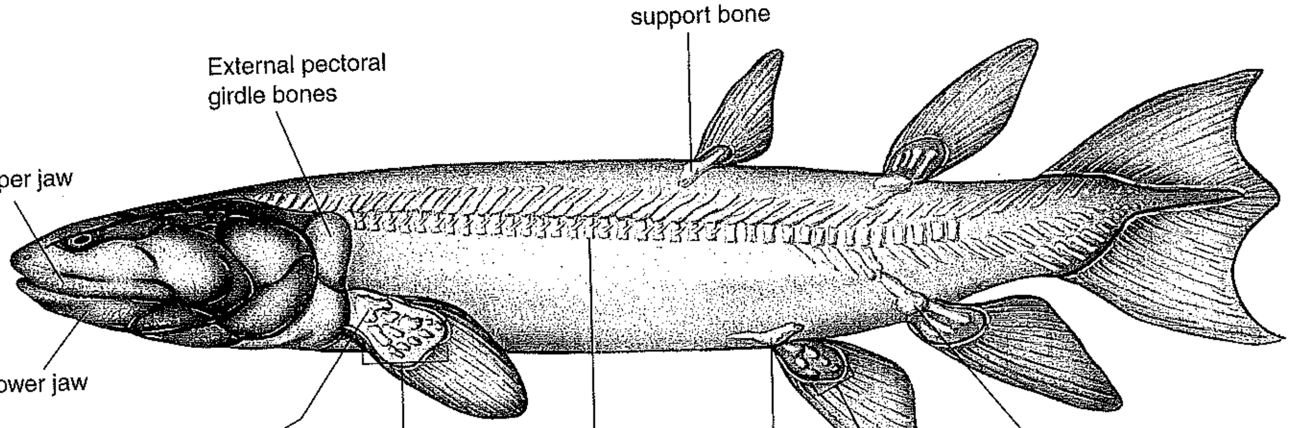
The Rise of Modern Fishes Although the early jawed fishes soon disappeared, they left behind two major groups that continued to evolve and still survive today. One group—the ancestors of modern sharks and rays—evolved a skeleton made of strong, resilient cartilage. The other group evolved skeletons made of true bone. A subgroup of bony fishes, called lobe-finned fishes, had fleshy fins from which the limbs of chordates would later evolve.

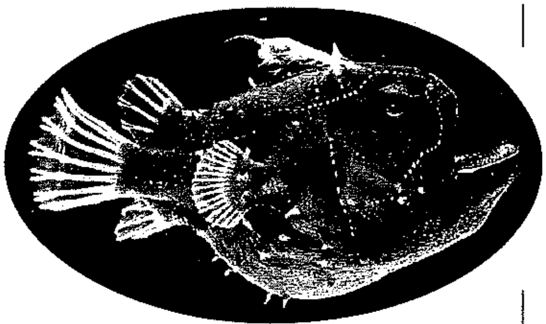
✓CHECKPOINT *Which two groups of early jawed fishes still survive today?*



▲ **Figure 30–8** This photograph shows a reconstruction of an ancient armored fish called *Dunkleosteus*, an enormous predator that lived in the inland seas of North America during the late Devonian Period. **Drawing Conclusions** ***What feature made this fish a successful predator in its time?***

▼ **Figure 30–9** This ancient Devonian fish is called *Eusthenopteron*. Although its skeleton differs from those of most modern fishes, its basic features—vertebral column, fins, and fin girdles—have been retained in many species. **Comparing and Contrasting** ***How does this fish differ from the fishes in Figure 30–7?***





▲ **Figure 30–10** **Adaptations to aquatic life include various modes of feeding.** This deep-sea anglerfish has a built-in "fishing pole" that it uses to attract prey.

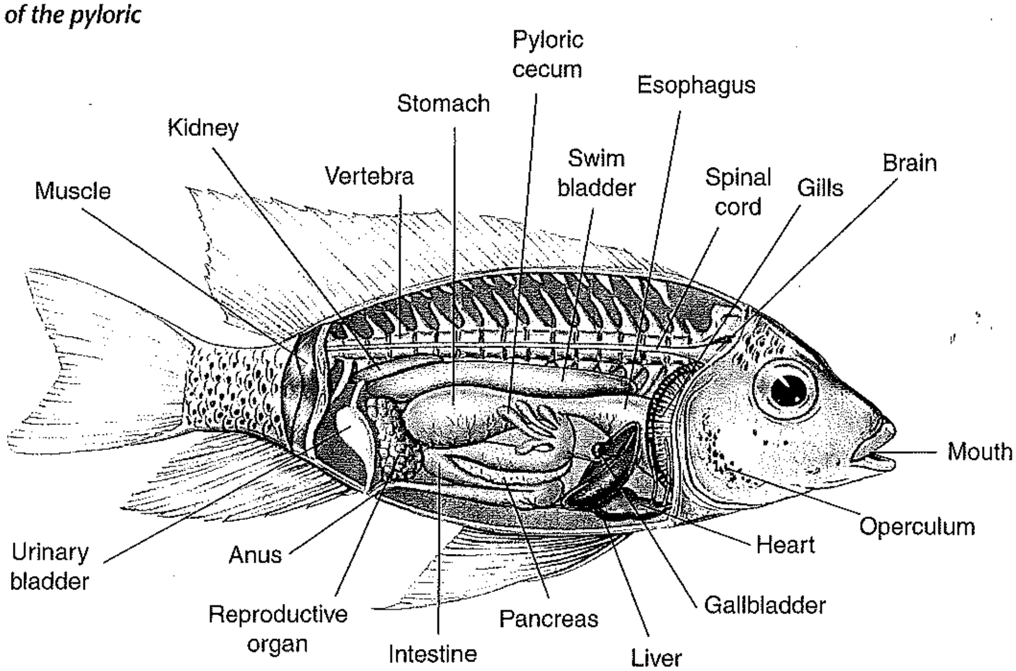
Form and Function in Fishes

Over time, fishes have evolved to survive in a tremendous range of aquatic environments. **Adaptations to aquatic life include various modes of feeding, specialized structures for gas exchange, and paired fins for locomotion.** Fishes have other types of adaptations, too, as you will learn.

Feeding Every mode of feeding is seen in fishes. There are herbivores, carnivores, parasites, filter feeders, and detritus feeders. In fact, a single fish may exhibit several modes of feeding, depending on what type of food happens to be available. Certain carp, for example, eat algae, aquatic plants, worms, mollusks, arthropods, dead fish, and detritus. Other fishes, such as barracuda, are highly specialized carnivores. A few fishes, such as some lampreys, are parasites. **Figure 30–10** shows a fish that even uses a fleshy bait to catch its meals!

Use **Figure 30–11** to locate the internal organs that are important during the fish's digestion of its food. From the fish's mouth, food passes through a short tube called the esophagus to the stomach, where it is partially broken down. In many fishes, the food is further processed in fingerlike pouches called pyloric ceca (py-LAWR-ik SEE-kuh; singular: cecum). The pyloric ceca secrete digestive enzymes and absorb nutrients from the digested food. Other organs, including the liver and pancreas, add enzymes and other digestive chemicals to the food as it moves through the digestive tract. The intestine completes the process of digestion and nutrient absorption. Any undigested material is eliminated through the anus.

▼ **Figure 30–11** The internal organs of a typical bony fish are shown here. **Applying Concepts** *What is the function of the pyloric cecum?*



Quick Lab

How do fishes use gills?

Materials fish food, food coloring, plastic cup, dropper pipette, live fish in an aquarium

Procedure

1. Mix some fish food and food coloring in a small volume of aquarium water in a plastic cup.
2. Use a dropper pipette to release the mixture near a fish in an aquarium. Release the mixture gently so that it does not scatter.
3. Observe what happens when the fish approaches the mixture. Watch the fish's gills especially closely.

Analyze and Conclude

1. **Drawing Conclusions** Describe what happened to the food coloring. What does this tell you about how water moves through a fish's body?
2. **Inferring** Why do most fishes seem to move or swallow continuously? What might happen if a fish were not able to move or stopped "swallowing"?

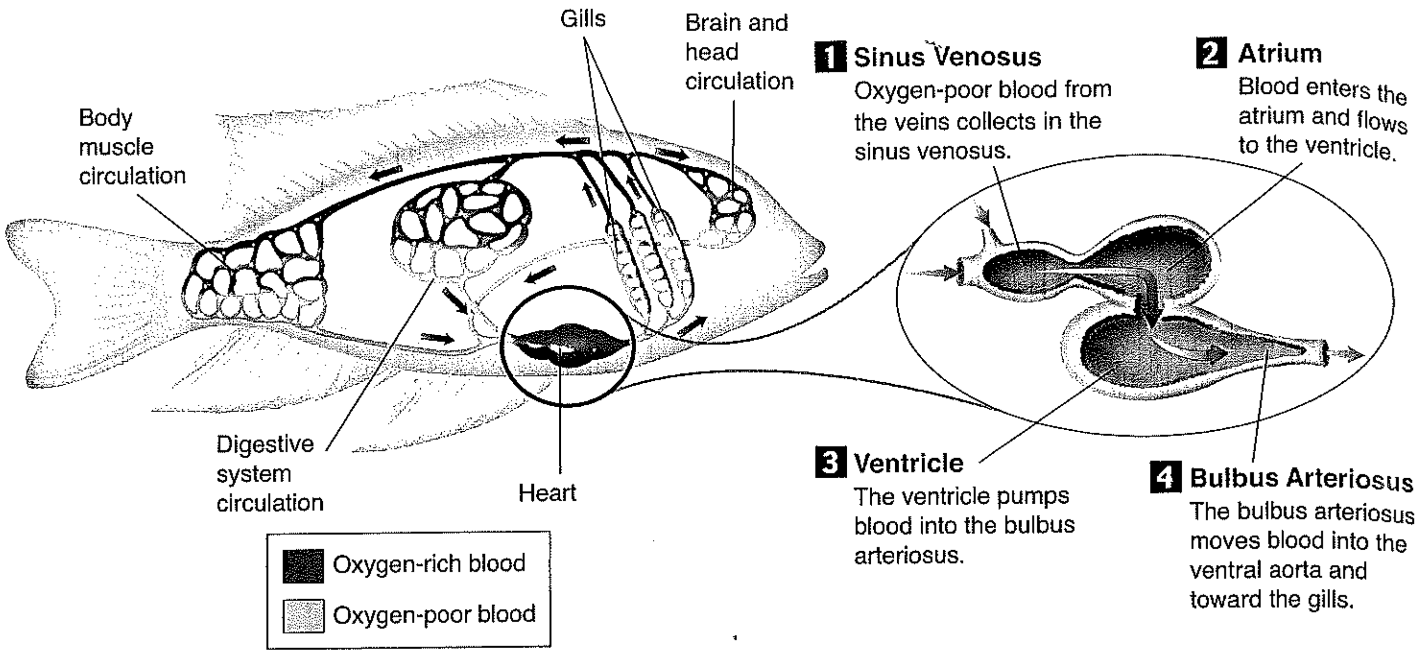
Respiration Most fishes exchange gases using gills located on either side of the pharynx. The gills are made up of feathery, threadlike structures called filaments. Each filament contains a network of fine capillaries that provides a large surface area for the exchange of oxygen and carbon dioxide. Fishes that exchange gases using gills do so by pulling oxygen-rich water in through their mouths, pumping it over their gill filaments, and then pushing oxygen-poor water out through openings in the sides of the pharynx.

Some fishes, such as lampreys and sharks, have several gill openings. Most fishes, however, have a single gill opening on each side of the body through which water is pumped out. This opening is hidden beneath a protective bony cover called the operculum.

A number of fishes—such as the lungfish in **Figure 30–12**—have an adaptation that allows them to survive in oxygen-poor water or in areas where bodies of water often dry up. These fishes have specialized organs that serve as lungs. A tube brings oxygen from the air to this organ through the fish's mouth. Some lungfishes are so dependent on getting oxygen from the air that they will suffocate if prevented from reaching the surface of the water.

✓CHECKPOINT *What structures do fishes use for gas exchange?*

▶ **Figure 30–12** This African lungfish has a breathing adaptation that allows it to survive in shallow waters that are subject to drought. It burrows into mud, covers itself with mucus, and becomes dormant. For several months until the rains fall, the lungfish breathes through its mouth and lungs. **Drawing Conclusions** *How is it an advantage for this lungfish to cover itself with mucus?*



▲ **Figure 30–13** Blood circulates through a fish's body in a single loop—from the heart to the gills to the rest of the body, and then back to the heart again. **Interpreting Graphics** *Is the blood that flows from the heart to the gills rich in oxygen or does it lack oxygen?*

Circulation Fishes have closed circulatory systems with a heart that pumps blood around the body in a single loop—from the heart to the gills, from the gills to the rest of the body, and back to the heart. **Figure 30–13** shows the path of blood and the structure of the heart.

In most fishes, the heart consists of four parts: the sinus venosus (SYN-us vuh-NOH-sus), atrium (AY-tree-um), ventricle, and bulbus arteriosus (BUL-bus ahr-teer-ee-OH-sus). The sinus venosus is a thin-walled sac that collects blood from the fish's veins before it flows to the **atrium,** a large muscular chamber that serves as a one-way compartment for blood that is about to enter the ventricle. The **ventricle,** a thick-walled, muscular chamber, is the actual pumping portion of the heart. It pumps blood to a large, muscular tube called the bulbus arteriosus. At its front end, the bulbus arteriosus connects to a large blood vessel called the aorta, through which blood moves to the fish's gills.

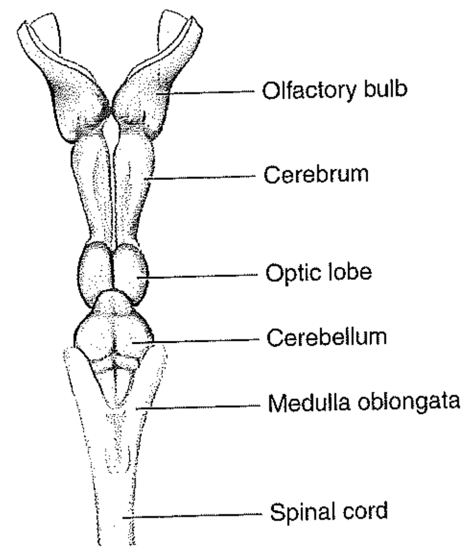
Excretion Like many other aquatic animals, most fishes rid themselves of nitrogenous wastes in the form of ammonia. Some wastes diffuse through the gills into the surrounding water. Others are removed by kidneys, which are excretory organs that filter wastes from the blood.

Kidneys help fishes control the amount of water in their bodies. Fishes in salt water tend to lose water by osmosis. To solve this problem, the kidneys of marine fishes concentrate wastes and return as much water as possible to the body. In contrast, a great deal of water continually enters the bodies of freshwater fishes. The kidneys of freshwater fishes pump out plenty of dilute urine. Some fishes are able to move from fresh to salt water by adjusting their kidney function.

Response Fishes have well-developed nervous systems organized around a brain, which has several parts, as shown in **Figure 30–14.** The most anterior parts of a fish's brain are the olfactory bulbs, which are involved with the sense of smell, or olfaction. They are connected to the two lobes of the cerebrum (SEHR-uh-brum). In most vertebrates, the **cerebrum** is responsible for all voluntary activities of the body. However, in fishes, the cerebrum primarily processes the sense of smell. The optic lobes process information from the eyes. The **cerebellum** (sehr-uh-BEL-um) coordinates body movements. The **medulla oblongata** (mih-DUH-luh ahb-lahn-GAHT-uh) controls the functioning of many internal organs.

Most fishes have highly developed sense organs. Almost all fishes that are active in daylight have well-developed eyes and color vision that is at least as good as yours. Many fishes have specialized cells called chemoreceptors that are responsible for their extraordinary senses of taste and smell. Although most fishes have ears inside their head, they may not hear sounds well. Most fishes can, however, detect gentle currents and vibrations in the water with a sensitive receptor called the **lateral line system.** Fishes use this system to sense the motion of other fishes or prey swimming nearby. In addition to detecting motion, some fishes, such as catfish and sharks, have evolved sense organs that can detect low levels of electric current. Some fishes, such as the electric eel shown in **Figure 30–15,** can even generate their own electricity!

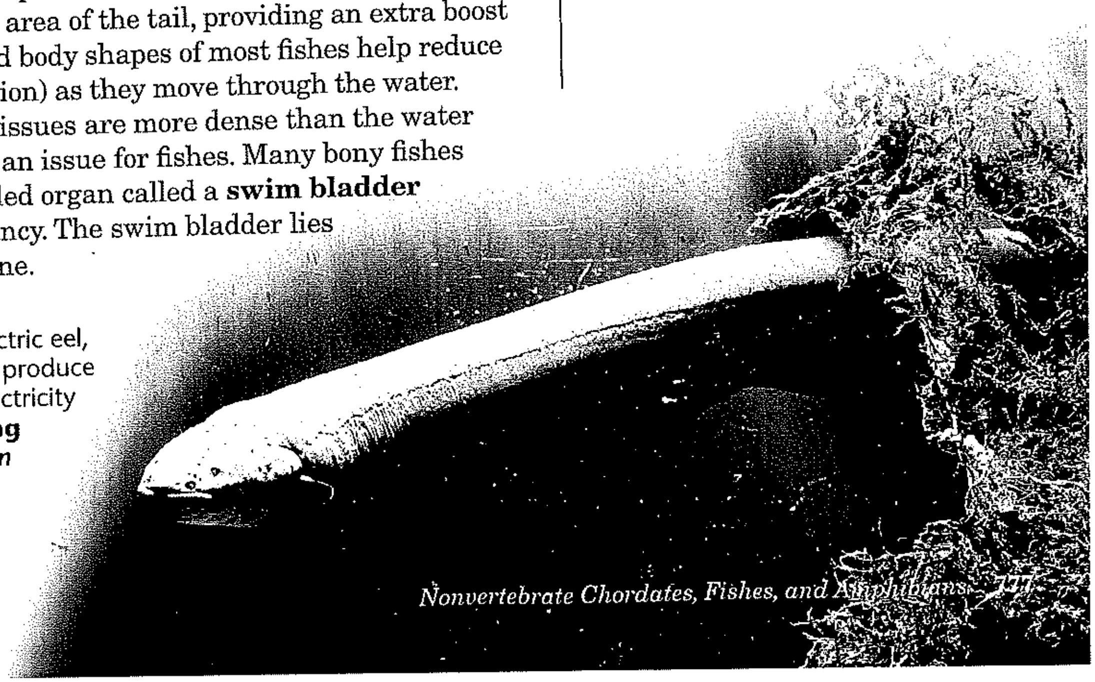
CHECKPOINT *What are the parts of a fish's brain?*



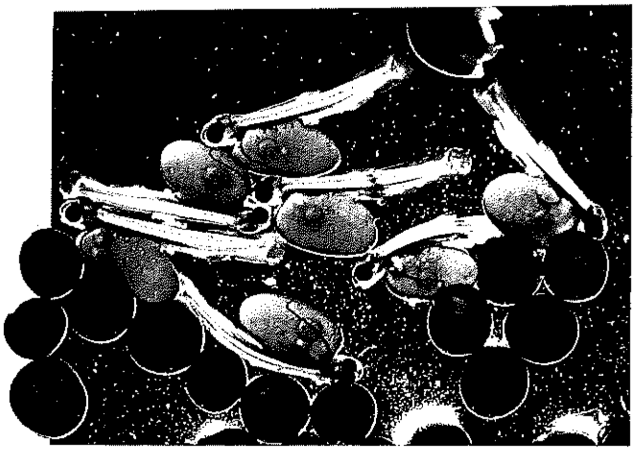
▲ **Figure 30–14** The brain of a fish, like all vertebrate brains, is situated at the anterior end of the spinal cord and has several different parts. **Inferring** *How might the size of the various parts of the brain differ in a blind cave fish that relies primarily on its sense of smell?*

Movement Most fishes move by alternately contracting paired sets of muscles on either side of the backbone. This creates a series of S-shaped curves that move down the fish's body. As each curve travels from the head toward the tail fin, it creates backward force on the surrounding water. This force, along with the action of the fins, propels the fish forward. The fins of fishes are also used in much the same way that airplanes use stabilizers, flaps, and rudders—to keep on course and adjust direction. Fins also increase the surface area of the tail, providing an extra boost of speed. The streamlined body shapes of most fishes help reduce the amount of drag (friction) as they move through the water.

Because their body tissues are more dense than the water they swim in, sinking is an issue for fishes. Many bony fishes have an internal, gas-filled organ called a **swim bladder** that adjusts their buoyancy. The swim bladder lies just beneath the backbone.



▶ **Figure 30–15** The electric eel, *Electrophorus electricus,* can produce several hundred volts of electricity in brief bursts. **Formulating Hypotheses** *What function might such powerful electric bursts serve?*



▲ **Figure 30–16** Some newly hatched fishes, such as these coho salmon, are nourished by yolk sacs on their bellies. **Inferring** *What are the orange spheres at the bottom of the photograph?*

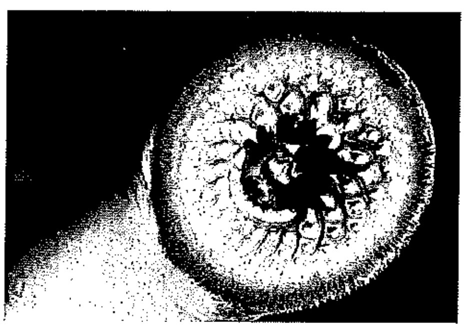
Reproduction The eggs of fishes are fertilized either externally or internally, depending on the species. In many fish species, the female lays the eggs and the embryos in the eggs develop and hatch outside her body. Fishes whose eggs hatch outside the mother's body are **oviparous** (oh-VIP-uh-rus). As the embryos of oviparous fishes develop, they obtain food from the yolk in the egg. The salmon in **Figure 30–16** are oviparous. In contrast, in **ovoviviparous** (oh-voh-vy-VIP-uh-rus) species, such as guppies, the eggs stay in the mother's body after internal fertilization. Each embryo develops inside its egg, using the yolk for nourishment. The young are then "born alive," the way the young of most mammals are. A few fish species, including several sharks, are viviparous. In **viviparous** (vy-VIP-uh-rus) animals, the embryos stay in the mother's body, as they do in ovoviviparous species. However, these embryos obtain the substances they need directly from the mother's body, not from material stored within an egg. The young of viviparous species are also born alive.

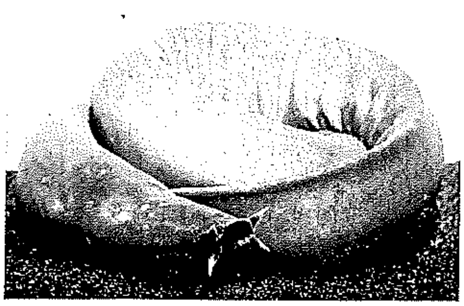
✔CHECKPOINT *What are the three different modes of fish reproduction?*

Groups of Fishes

With over 24,000 living species, fishes are an extremely diverse group of chordates. These diverse species can be grouped according to body structure. **When you consider their basic internal structure, all living fishes can be classified into three groups: jawless fishes, cartilaginous fishes, and bony fishes.**

Figure 30–17 **Jawless fishes make up one of three major groups of living fishes.** Modern jawless fishes are divided into two classes: lampreys (top) and hagfishes (bottom).





Jawless Fishes As their name implies, jawless fishes have no true teeth or jaws. Their skeletons are made of fibers and cartilage. They lack vertebrae, and instead keep their notochords as adults. Modern jawless fishes are divided into two classes: lampreys and hagfishes.

Lampreys are typically filter feeders as larvae and parasites as adults. An adult lamprey's head is taken up almost completely by a circular sucking disk with a round mouth in the center, which you can see in **Figure 30–17.** Adult lampreys attach themselves to fishes, and occasionally to whales and dolphins. There, they scrape away at the skin with small toothlike structures that surround the mouth and with a strong, rasping tongue. The lamprey then sucks up the tissues and body fluids of its host.

Hagfishes have pinkish gray, wormlike bodies and four or six short tentacles around their mouths. Hagfishes lack eyes, although they do have light-detecting sensors scattered around their bodies. They feed on dead and dying fish by using a toothed tongue to scrape a hole into the fish's side. Hagfishes have other peculiar traits: They secrete incredible amounts of slime, have six hearts, possess an open circulatory system, and regularly tie themselves into knots!

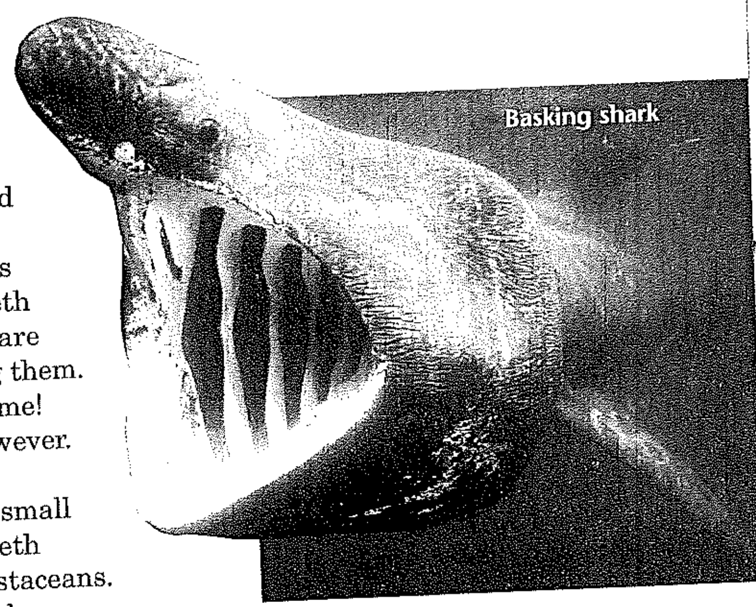
Sharks and Their Relatives The class Chondrichthyes (kahn-DRIK-theez) contains sharks, rays, skates, and a few uncommon fishes such as sawfishes and chimaeras. Some chondrichthyes are shown in **Figure 30–18.** *Chondros* is the Greek word for cartilage, so the name of this class tells you that the skeletons of these fishes are built entirely of cartilage, not bone. The cartilage of these animals is similar to the flexible tissue that supports your nose and your external ears. Most cartilaginous fishes also have toothlike scales covering their skin. These scales make shark skin so rough that it can be used as sandpaper.

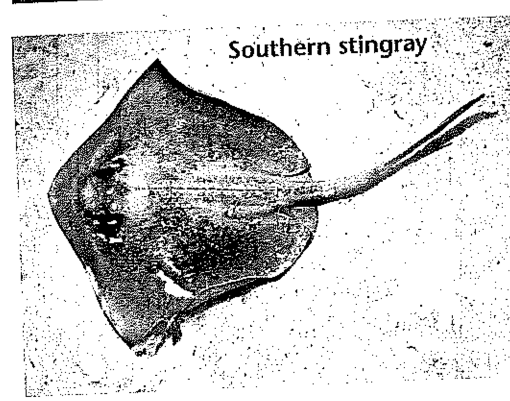
Most of the 350 or so living shark species have large curved tails, torpedo-shaped bodies, and pointed snouts with the mouth underneath. One of the most noticeable characteristics of sharks is their enormous number of teeth. Many sharks have thousands of teeth arranged in several rows. As teeth in the front rows are worn out or lost, new teeth are continually replacing them. A shark goes through about 20,000 teeth in its lifetime!

Not all sharks have such fierce-looking teeth, however. Some, like the basking shark, are filter feeders with specialized feeding structures and teeth that are so small they are virtually useless. Other sharks have flat teeth adapted for crushing the shells of mollusks and crustaceans. Although there are a number of carnivorous sharks large enough to prey on humans, most sharks do not attack people.

Skates and rays are even more diverse in their feeding habits than their shark relatives. Some feed on bottom-dwelling invertebrates by using their mouths as powerful vacuums. However, the largest rays, like the largest sharks, are filter feeders that eat floating plankton. Skates and rays often glide through the sea with flapping motions of their large, winglike pectoral fins. When they are not feeding or swimming, many skates and rays cover themselves with a thin layer of sand and spend hours resting on the ocean floor.

▼ **Figure 30–18** Sharks and rays have skeletons that are made of cartilage. The large jaws and teeth of many sharks make them top predators in the world's oceans. **Applying Concepts** *How is the structure of a basking shark's mouth related to its diet?*





Silky shark

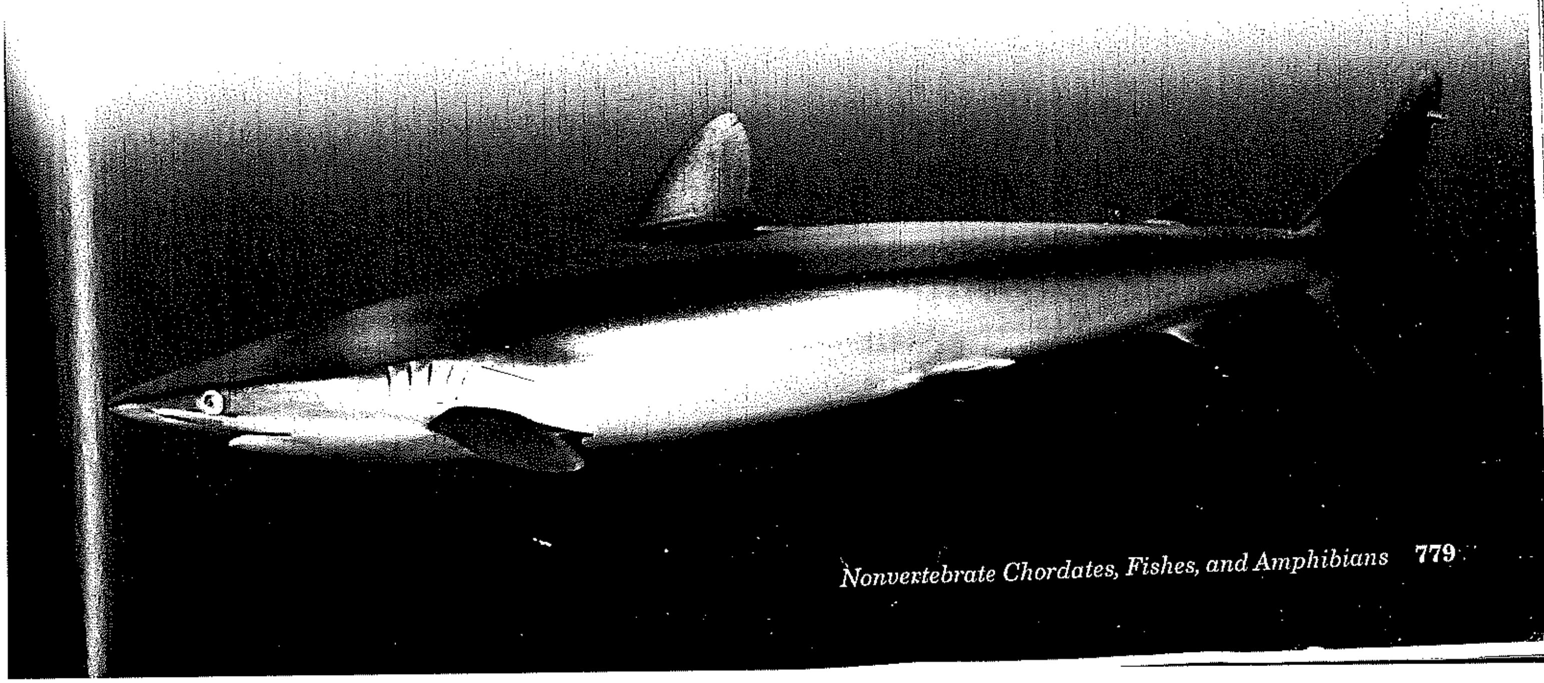
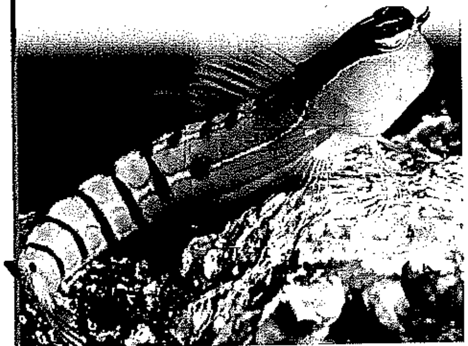
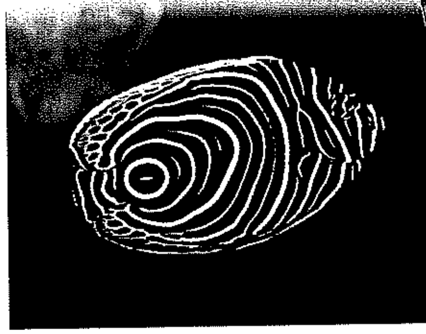
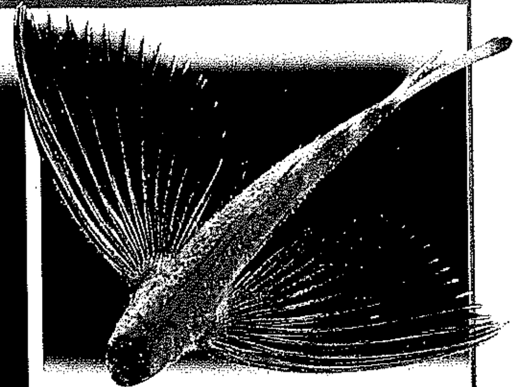
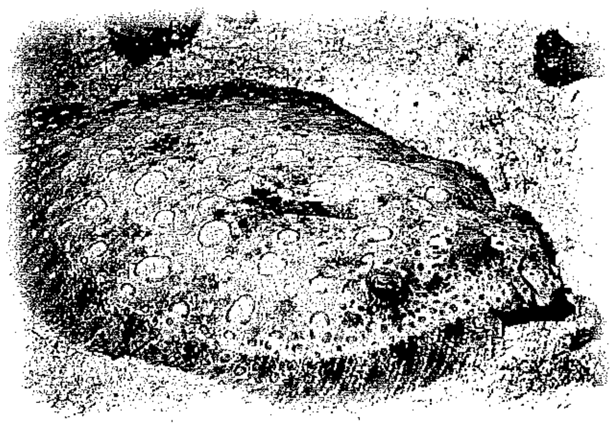


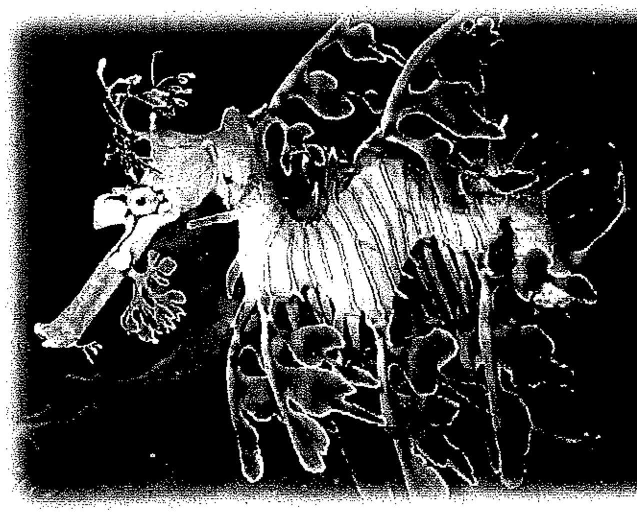
FIGURE 30–19 DIVERSITY OF RAY-FINNED FISHES


Combtooth Blenny

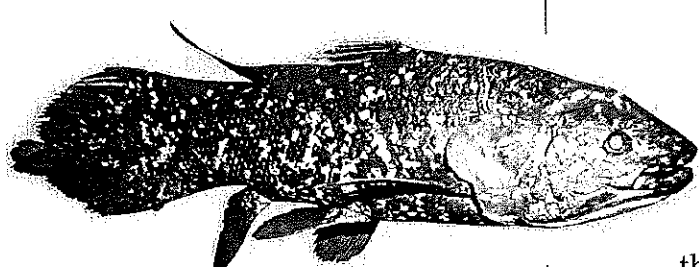

Emperor Angelfish


Flying Fish


Peacock Flounder


Leafy Sea Dragon

Nearly all bony fishes belong to an enormous and diverse group called ray-finned fishes. These fishes have thin, bony spines that form the fins. **Observing** *What unusual adaptations do you see in each of these fishes?*



▲ **Figure 30–20** The coelacanth (genus *Latimeria*) is a lobe-finned fish that was thought to be extinct until one was caught in the Indian Ocean in 1938. Since then, many more specimens have been found. **Classifying** *Which group of living fishes is most closely related to the coelacanth?*

Bony Fishes Bony fishes make up the class Osteichthyes (ahs-tee-IK-theez). The skeletons of these fishes are made of hard, calcified tissue called bone. Almost all living bony fishes belong to a huge group called ray-finned fishes, some of which are shown in **Figure 30–19.** The name "ray-finned" refers to the slender bony spines, or rays, that are connected by a thin layer of skin to form the fins. The fin rays support the skin much as the thin rods in a handheld folding fan hold together the webbing of the fan.

Only seven living species of bony fishes are not classified as ray-finned fishes. These are the lobe-finned fishes, a subclass that includes lungfishes and the coelacanth (SEE-luh-kanth). Lungfishes live in fresh water, but the coelacanth, shown in **Figure 30–20,** lives in salt water. The fleshy fins of lobe-finned fishes have support bones that are more substantial than the rays of ray-finned fishes. Some of these bones are jointed, like the arms and legs of land vertebrates.

▶ **Figure 30–21** Adult salmon return from the sea to spawn in the stream or river in which they were born. Their journey is often long and strenuous. The salmon must swim upstream against the current and may even leap up waterfalls! **Applying Concepts** *What sense do the salmon use to find their home stream?*

Ecology of Fishes

Some fishes—such as lampreys, sturgeons, and salmon—spend most of their lives in the ocean but migrate to fresh water to breed. Fishes with this type of behavior are called anadromous (uh-NAH-druh-mus). Salmon, for example, begin their lives in rivers or streams but soon migrate to the sea. After one to four years at sea, mature salmon return to the place of their birth to spawn. This trip can take several months, covering as much as 3200 kilometers, and can involve incredible feats of strength, as shown in **Figure 30–21.** The adult salmon recognize their home stream using their sense of smell.

In contrast to anadromous fishes, some fishes live their lives in fresh water but migrate to the ocean to breed. These fishes are said to be catadromous (kuh-TAD-ruh-mus). European eels, for instance, live and feed in the rivers of North America and Europe. They travel up to 4800 kilometers to lay their eggs in the Sargasso Sea, in the North Atlantic Ocean. The eggs are carried by currents to shallow coastal waters. As they grow into young fish, the eels find their way to fresh water and migrate upstream.

30–2 Section Assessment

1. **Key Concept** Identify the main characteristics of fishes.
2. **Key Concept** What advantages do jaws and fins provide for fishes?
3. **Key Concept** List four specific ways in which fishes are adapted for aquatic life.
4. **Key Concept** Name the three main groups of fishes and give an example for each group.
5. Why might a scientist investigating evolutionary relationships study a coelacanth?
6. **Critical Thinking Applying Concepts** For fishes to survive in an aquarium, the water must be kept clean and well oxygenated. Explain why water quality is so important to a fish's survival.

iTEXT **Assessment** Use iText to review the important concepts in Section 30–2.

MAKING CONNECTIONS

Comparing and Contrasting In Chapter 27, you learned about the circulatory system of annelids. Create a Venn diagram comparing the circulatory system of an annelid with that of a fish. How are the two circulatory systems similar and different?