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. Evolution by natural selection and other processes has resulted in a great diversity of fishes.

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; most fishes have 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 fishes?
- 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.

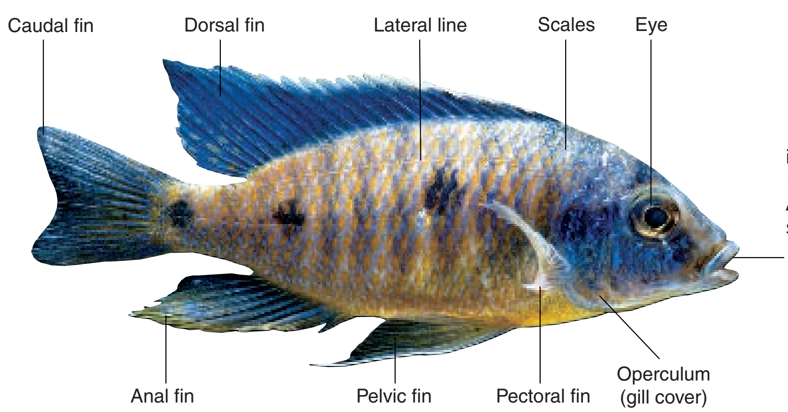


Figure 30–6 Fishes come in many shapes and sizes. **Like most fishes, this African cichlid has paired fins, scales, and gills.**

SECTION RESOURCES

Print:
- ***Teaching Resources,*** Lesson Plan 30–2, Adapted Section Summary 30–2, Adapted Worksheets 30–2, Section Summary 30–2, Worksheets 30–2, Section Review 30–2, Enrichment
- ***Reading and Study Workbook A,*** Section 30–2
- ***Adapted Reading and Study Workbook B,*** Section 30–2
- ***Issues and Decision Making,*** Issues and Decisions 37

Technology:
- ***iText,*** Section 30–2
- ***Transparencies Plus,*** Section 30–2

Section 30–2

1 FOCUS

Objectives

30.2.1 ***Identify*** the basic characteristics of fishes.
30.2.2 ***Summarize*** the evolution of fishes.
30.2.3 ***Explain*** how fishes are adapted for life in water.
30.2.4 ***Describe*** the three main groups of fishes.

Guide for Reading

Vocabulary Preview
Read aloud the Vocabulary terms so that students can hear the correct pronunciation of each word. Encourage students to use the phonetic spellings in the text to practice saying the words aloud.

Reading Strategy
Encourage students to write down the Vocabulary terms and their meanings as they read. Also encourage them to sketch some of the diagrams to help them visualize some of the body systems in fishes.

2 INSTRUCT

What Is a Fish?

Build Science Skills

Using Models Challenge students to create a model of a fish based on the defining characteristics of most fishes: aquatic vertebrate with fins, scales, and gills. Encourage students to design their model fish to have specific adaptations to survive in its particular environment. Students can simply illustrate their fish models or create a three-dimensional model. Have students present their models to the class. L1 L2

Answer to . . .

CHECKPOINT *Fins: movement; scales: protection; gills: gas exchange*

30–2 (continued)

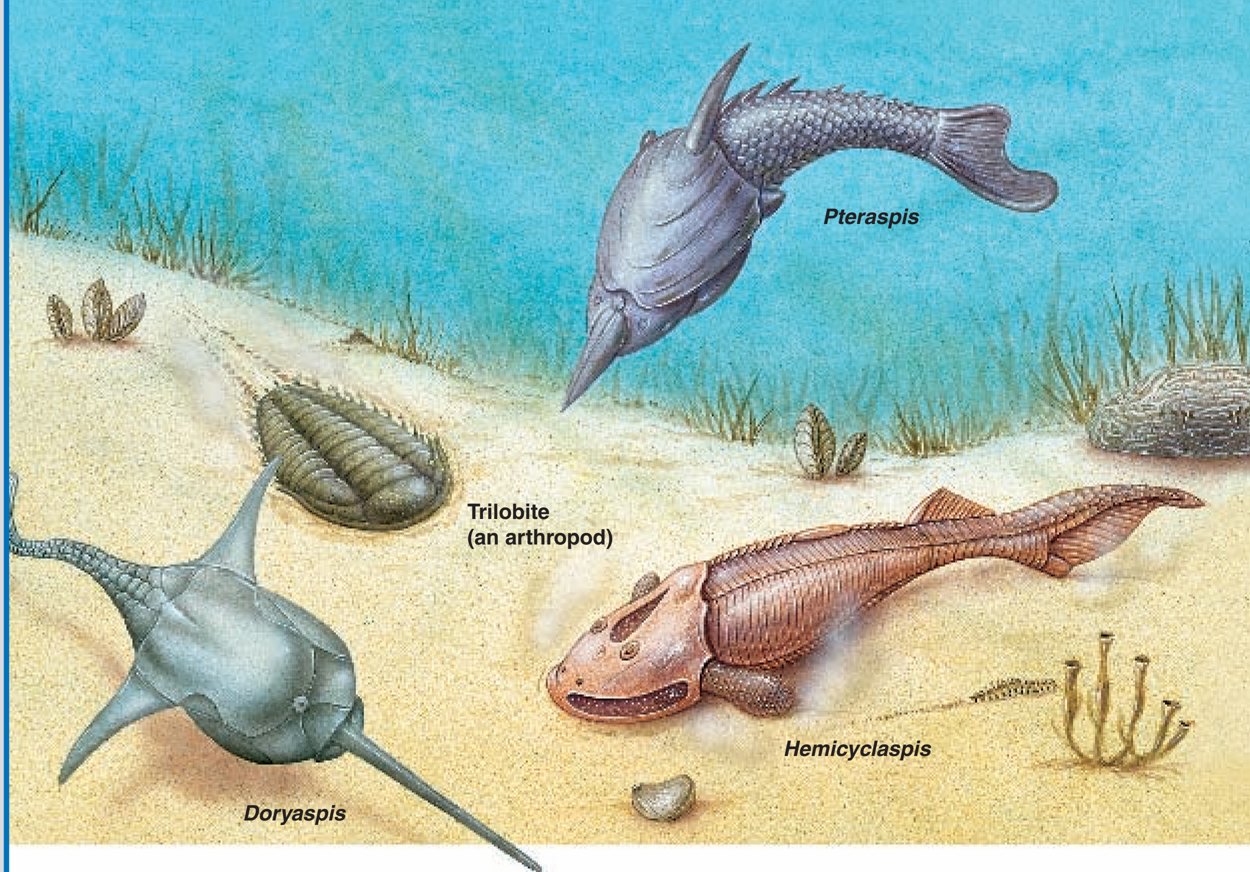
Evolution of Fishes

Address Misconceptions

Some students might be under the impression that the fossil record for fishes is complete. Ask: **What parts of an organism fossilize well?** *(Hard parts, such as bone and teeth)* **Which parts do not?** *(Soft tissue)* Explain that many early fishes had few hard body parts (bones) and that scientists make many inferences about the gaps in the fossil record based on the structures of living organisms and fossils. L2

Use Visuals

Figure 30–7 Challenge students to infer how the various adaptations of the fishes in the illustration made them better suited to their environment. Explain that after the adaptive radiation during the Ordovician and Silurian Periods, fishes inhabited every kind of environment in the oceans. Ask: **Why do you think some of these early fishes eventually became extinct at the end of the Devonian Period?** *(They were not as efficient at moving, getting food, and protecting themselves against predators as fishes with jaws and paired fins.)* L2



▲ **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.

ESL SUPPORT FOR ENGLISH LANGUAGE LEARNERS

Comprehension: Ask Questions

Beginning To help students understand the basic characteristics of fishes, distribute a rewritten, modified version of the second paragraph on page 771. Read this paragraph aloud, and then help students construct a cluster diagram with "Characteristics of fishes" in the center and the specific characteristics listed outside. L1

Intermediate Have students read the modified paragraph that you prepared for the beginning level and then read the actual text paragraph. Ask students questions that can be answered from the rewritten text. For example: For what do fishes use fins? What structure do fishes use for gas exchange? Then, ask questions that cannot be directly answered using the rewritten text, such as: What might happen to a fish that has injured fins? L2

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 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.

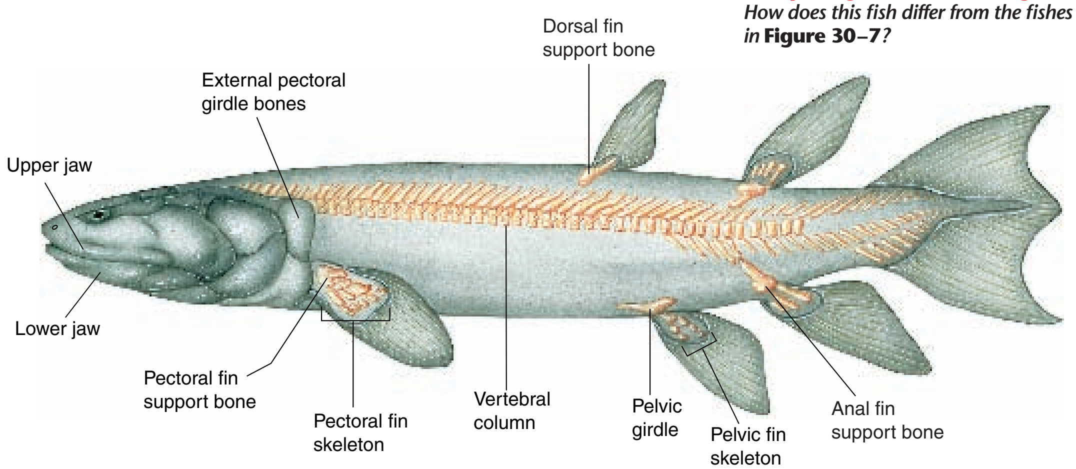
Paired fins gave fishes more control of body movement. In addition, tail fins and powerful muscles gave fishes greater thrust when swimming. The combination of accuracy and speed enabled fishes to move in new and varied patterns. This ability, in turn, helped fishes use their jaws in complex ways.

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***?*



Demonstration

Show students how jaws enabled fishes to eat a larger variety of food by comparing a drinking straw to your hand mimicking the action of a jaw. Use the straw to try to pick up a variety of objects that represent food. Then, use your hand acting as a jaw to pick up those same objects. Ask: **What advantage did a jaw give to fishes?** *(Jaws enabled fishes to open up their mouths and close them with force in order to bite larger pieces of food from a larger variety of food sources. In addition, jaws enabled fishes to manipulate food. They also provided a means for defense—biting.)* L1 L2

Make Connections

Physics Explain that a fish must overcome inertia, or the resistance to motion, to move through water. Most of this resistance is in the form of drag, which is caused by the friction of water as it flows over the body of the fish. Drag is also caused by the backward pull of the eddies of water that form behind the fish's tail. If the fish is streamlined, the water flowing past both sides of the fish meets and blends together, producing less turbulence and, hence, less drag. Students can experiment with different body shapes moving through water to observe this phenomenon. They might compare the eddies of a round object, a square object, and a streamlined (spindle-shaped) object as they move them through water. L2 L3

BIO INSIGHTS FACTS AND FIGURES

New tail design makes fish faster
Primitive fishes had asymmetrical tails in which the vertebral column pointed either upward or downward as it extended from the body. When the fins pushed against the water to propel the fish forward, the movement was inefficient. The forward push was unevenly distributed along the body of the fish. Such fishes did well as bottom feeders, where food consisted of stationary plant material or organic debris.

Modern fishes have tails in which two symmetrical lobes extend from the end of the vertebral column. The forward thrust provided by this tail is greater and more evenly distributed along the length of the body. Fishes with symmetrical tails swim faster. Most of the back-and-forth motion that propels the fish forward comes from the posterior end of the fish, keeping the anterior end still and better streamlined.

Answers to . . .

CHECKPOINT *Sharks and rays and bony fishes*

Figure 30–8 *Powerful jaws*

Figure 30–9 *It has jaws.*

30–2 (continued)

Form and Function in Fishes

Use Visuals

Figure 30–11 Have students trace the path of food through the digestive system in the illustration. Ask: **Where does digestion occur?** *(Stomach, pyloric ceca, intestine)* **Where does nutrient absorption occur?** *(Pyloric ceca, intestine)* Explain that the size of the stomach and intestines varies among fishes, depending on their mode of feeding. Ask: **Would you expect herbivores or carnivores to have a longer digestive tract?** *(Herbivores; plant matter is more difficult to digest because of the cellulose in the cell walls of plant cells.)* L1 L2

Use Community Resources

Take students to a local aquarium, zoo, or fish store to give them the opportunity to observe many different fishes and their adaptations. Before going, make a class list of adaptations to look for, such as specific adaptations for getting food, attracting mates, defending against predators, and moving. When viewing the fishes, discuss their specific adaptations and how they help the fishes to survive. L2

▲ **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.

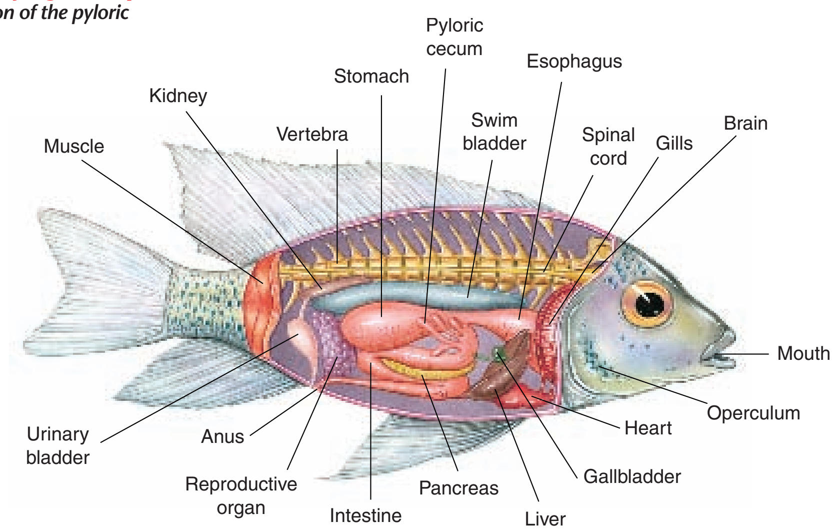
Form and Function in Fishes

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?***



BIO INSIGHTS

FACTS AND FIGURES

Getting a hold on food
Scientists observe as many different mouth and teeth adaptations in fishes as there are modes of feeding. Most carnivores have simple, cone-shaped teeth on the jaws and roof of the mouth and in the pharynx. The teeth in the pharynx region are commonly called throat teeth. In many carnivores, the teeth hold prey and orient it for swallowing. Such fishes have a flexible esophagus to accommodate the size of the food. Some carnivores have cutting teeth for biting chunks off their prey.

Many fishes have only throat teeth, which are used to crush or grind food. Others have no teeth at all. These fishes, often those that eat plankton, have many long, stiff rods, called gill rakers, attached to the gill bars. These rakers strain food from the water as it passes over the gills.

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 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 air containing oxygen 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?*

Quick Lab

Objective Students will be able to infer how fishes use gills. L2

Skills Focus **Drawing Conclusions, Inferring**

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

Time 10 minutes

Advance Prep Do not feed the fish for 2 or 3 days before the activity.

Strategies
- For optimum visibility of the flow of food coloring, transfer the fish to any clear container with water about 4 cm deep and place the container on a white background.
- Do not operate air pumps during the activity.

Expected Outcome Students should observe the food coloring move into the fish's mouth and out through its gills.

Analyze and Conclude

1. The food coloring moved into the fish's mouth and out through its gills. This shows the path of water through a fish's body.

2. To keep water moving over the gills; it could die from lack of oxygen.

Build Science Skills

Applying Concepts Ask: **What structures increase the surface area of gills?** *(Feathery filaments)* **What advantage does this give fishes?** *(Take in more oxygen and remove more carbon dioxide in less time)* Challenge students to consider other biological processes, organisms, or objects in which an increased surface area is advantageous. *(Examples include wide leaves—getting energy from sunlight; intestinal villi—provide increased surface for absorbing nutrients; wide fan blades—moving air; ramps—moving objects.)* L2

BIO INSIGHTS — FACTS AND FIGURES

Water over the gills

A shark has five to seven gill slits on both sides of its head. In order for a shark to breathe, water must continually flow across these gill slits. Like most bony fishes, the majority of sharks have a muscle-powered pumping mechanism that forces water to flow across the gills. In addition, the forward movement of some sharks contributes to gill ventilation. In this technique, called ram ventilation, the shark opens its mouth slightly as it moves forward; because of the forward motion, water enters the shark's mouth and flows over the gills.

Sharks have spiracles, which are an extra pair of gill slits located behind the eyes. These gill slits enable sharks to breathe while their mouths are full. Spiracles help bottom-dwelling sharks breathe while they are resting on the ocean floor.

Answers to . . .

CHECKPOINT *Gills or lunglike organs*

Figure 30–11 *The pyloric cecum secretes digestive enzymes and absorbs nutrients.*

Figure 30–12 *Mucus prevents the fish from drying out as water evaporates.*

30–2 (continued)

Use Visuals

Figure 30–13 Ask: **What makes the circulatory system in fishes a closed system?** *(The blood is enclosed in vessels.)* As students study the direction of blood flow in the diagram, point out that the blood travels in one loop and that the fish heart has only one atrium and one ventricle. Ask: **Does the heart pump oxygenated blood?** *(No)* **Why not?** *(The heart pumps deoxygenated blood from the body directly to the gills; from the gills, the oxygenated blood goes directly to the body tissues.)* L1 L2

Make Connections

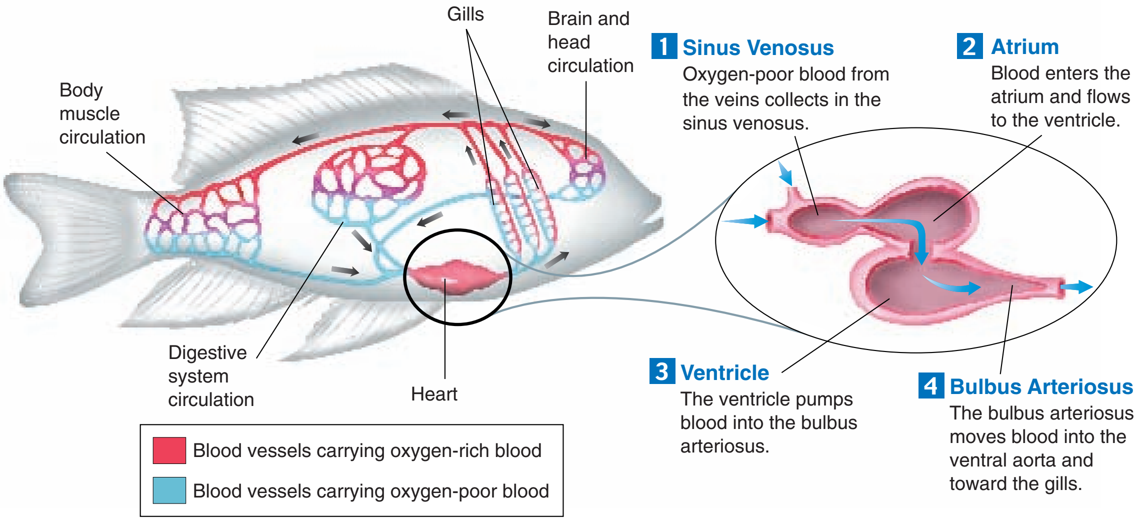
Chemistry To review osmosis, soak cucumber slices in a saltwater solution and in salt-free distilled water for about 30 minutes. Discuss the results of the experiment, focusing on where water had the higher and lower concentrations. *(Salt water: lower concentration of water, cucumber shriveled; distilled water: higher concentration of water, cucumber swelled)* Ask: **What could happen to saltwater fishes if they did not have kidneys?** *(Shrivel up because the water concentration is less outside their bodies)* **To freshwater fishes?** *(Bloat because the water concentration is greater outside their bodies)* L1 L2

Address Misconceptions

Students might get the mistaken idea that fishes moving from salt water to fresh water can consciously adjust their kidneys to function one way or another. Relate the involuntary control fishes have over their internal organs to the involuntary control that students have over some of their own body functions, such as digesting food. L1 L2

Go Online NSTA SCI LINKS

Download a worksheet on fishes for students to complete, and find additional teacher support from NSTA SciLinks.



▲ **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. (Note that in diagrams of animals' circulatory systems, blood vessels carrying oxygen-rich blood are red, while blood vessels carrying oxygen-poor blood are blue.) **Interpreting Graphics** ***Is the blood that flows from the heart to the gills oxygen-rich or oxygen-poor?***

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, 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.

Go Online NSTA SCI LINKS

For: Links on fishes
Visit: www.SciLinks.org
Web Code: cbn-9302

BIO INSIGHTS — FACTS AND FIGURES

Salty fish

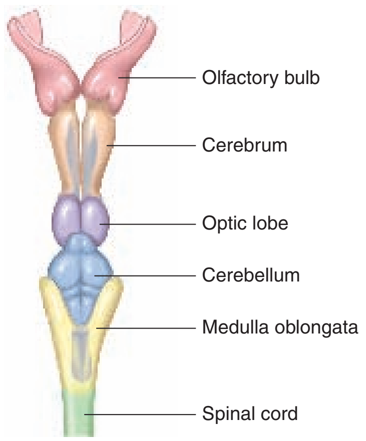
Both saltwater fishes and freshwater fishes have an internal salt content of about one percent. With the concentration of salt in ocean water at about 3.5 percent, the body systems of saltwater fishes must work to conserve water. Most saltwater fishes drink ocean water and secrete excess salt from the gills. Sharks and rays, however, maintain a high concentration of salt within the body by storing urea in the blood. These fishes do not lose water by osmosis and do not need to drink water.

Freshwater fishes live in environments with a very low concentration of salt. Freshwater fishes do not drink water, and their kidneys serve to pump water out of their bodies in very dilute urine. Freshwater fishes still lose salt, however, and take in the dilute salts in the water with the gills.

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. 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** coordinates body movements. The **medulla oblongata** 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 sensitive receptors that form 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!

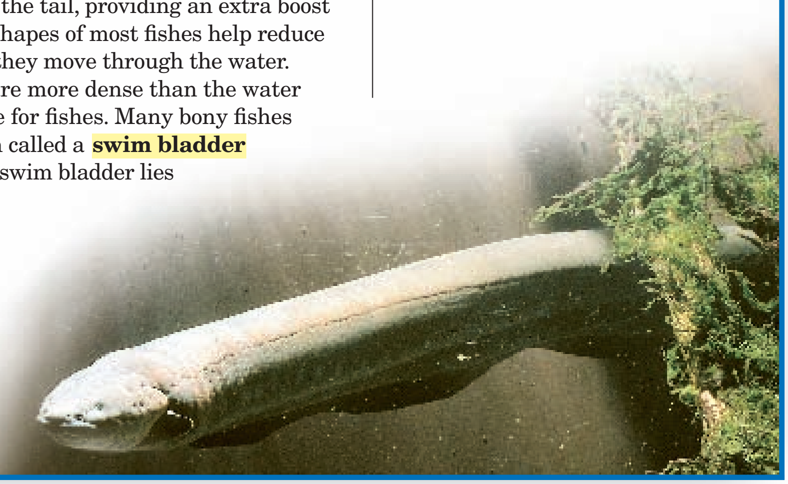
CHECKPOINT *What are the parts of a fish's brain?*



▲ **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?*

Build Science Skills

Posing Questions Challenge students to consider a fish's senses and the environment in which it lives. For example, have students consider the different environments of fishes living near the water's surface and those living along the bottom. Have small student groups work together to develop a scientific question about the senses of these two groups of fishes and how they might be similar or different. Remind students that a scientific question is very specific so that it can be answered through observation and experimentation. Discuss each group's question and possible methods of finding its answer. L2

Demonstration

Show students how a swim bladder works by tying a small screw to the neck of a deflated balloon and then putting the screw into a tub of water. Ask: **Why did the "fish" sink?** *(The "fish" weighed more than the force of the water pushing up on it.)* Then, blow up the balloon, reattach the screw, and place it into the water. Ask: **Why did the "fish" float?** *(The buoyant force of the water was greater than the weight of the "fish.")* Explain that this is similar to how a submarine works, except internal tanks are filled with water to make the submarine sink. They are emptied to make the submarine float. L2

BIO INSIGHTS — FACTS AND FIGURES

Some fishes are all "charged up"

By detecting low levels of electric current, sharks and several other fishes can detect the presence of nearby fishes or other animals. Every time an animal moves, even slightly, its muscles create a small electric current. Even a camouflaged animal that is hiding from a shark or other predator with the ability to sense electricity can be detected by the predator because the hiding animal is producing an electric current by moving the muscles required for breathing.

Fishes, such as eels, that produce their own electric current are able to detect animals as well as nonliving objects that might be in their path. The electric field that they create around the body helps them to find prey or to navigate. As an added benefit, eels use their electricity to stun or kill prey and to repel predators.

Answers to . . .

CHECKPOINT *Olfactory bulbs, cerebrum, optic lobe, cerebellum, medulla oblongata*

Figure 30–13 *Oxygen-poor*

Figure 30–14 *The brain of the cave fish might have a smaller optic lobe and a larger cerebrum and olfactory bulbs because the fish relies on its sense of smell.*

Figure 30–15 *To stun prey and deter predators*

30–2 (continued)

Groups of Fishes

Build Science Skills

Classifying Give student groups 10 to 15 pictures of different kinds of fishes. Challenge students to develop criteria for dividing the fishes into groups. Have students share their method of classification with the class. They should explain the criteria they used to categorize the fishes. Discuss the similarities and differences in the classification systems among the student groups. L2

Make Connections

Environmental Science Explain that lampreys once lived in Lake Ontario but not the other Great Lakes. They could not enter the other Great Lakes because of the natural barrier formed by Niagara Falls. In the early nineteenth century, the Welland Ship Canal was built as a shipping lane around Niagara Falls. Over the course of many years, the fish population in the inland Great Lakes began to decrease. In fact, lake trout were almost eliminated. Ask: **What might have caused the decrease in fish population?** *(Invasion of lampreys)* **How could lampreys devastate the fish population?** *(Lampreys are not indigenous to the inland Great Lakes and have few natural predators.)* L2

▲ **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?*

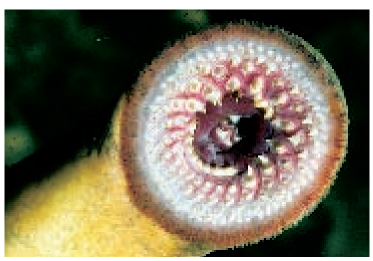
Reproduction The eggs of fishes are fertilized either externally or internally, depending on the species. In many fish species, the female lays the eggs and the embryos in the eggs develop and hatch outside her body. Fishes whose eggs hatch outside the mother's body are **oviparous** (oh-VIP-uh-rus). 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," like the young of most mammals. A few fish species, including several sharks, are viviparous. In **viviparous** (vy-VIP-uh-rus) animals, the embryos stay in the mother's body after internal fertilization, as they do in ovoviviparous species. However, these embryos obtain the substances they need from the mother's body, not from material in 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!

BIO INSIGHTS

FACTS AND FIGURES

Fish mothers and fathers

Most oviparous fishes do not provide any care for their young; they simply produce hundreds, or even millions, of fertilized eggs and "let nature take its course." Most eggs do not even form into young fishes; they are often eaten or damaged.

Some oviparous fishes, however, do care for their young. Some fishes build nests to protect the fertilized eggs. Siamese fighting fish build nests of bubbles, and sticklebacks use twigs. Some cichlids hold their eggs and young in the mouth. Seahorses hold fertilized eggs in a pouch until the eggs are ready to hatch. Fishes that care for their young usually do not produce as many eggs as those that simply lay the eggs and leave.

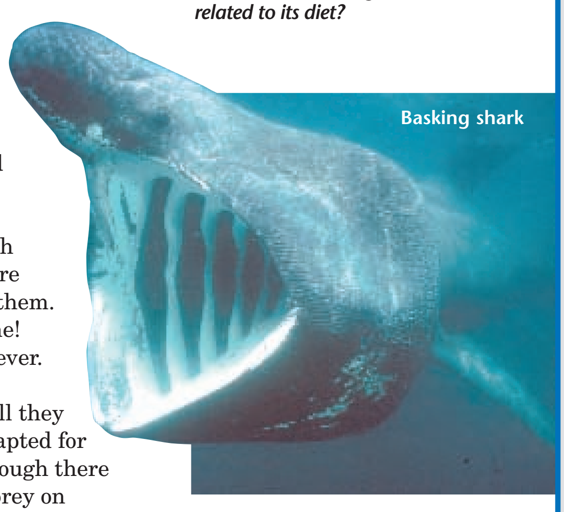
Sharks and Their Relatives The class Chondrichthyes (kahn-DRIK-theez) contains sharks, rays, skates, and a few uncommon fishes such as sawfishes and chimaeras. Some chondrichthyes are shown in **Figure 30–18.** *Chondros* is the Greek word for cartilage, so the name of this class tells you that the skeletons 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.

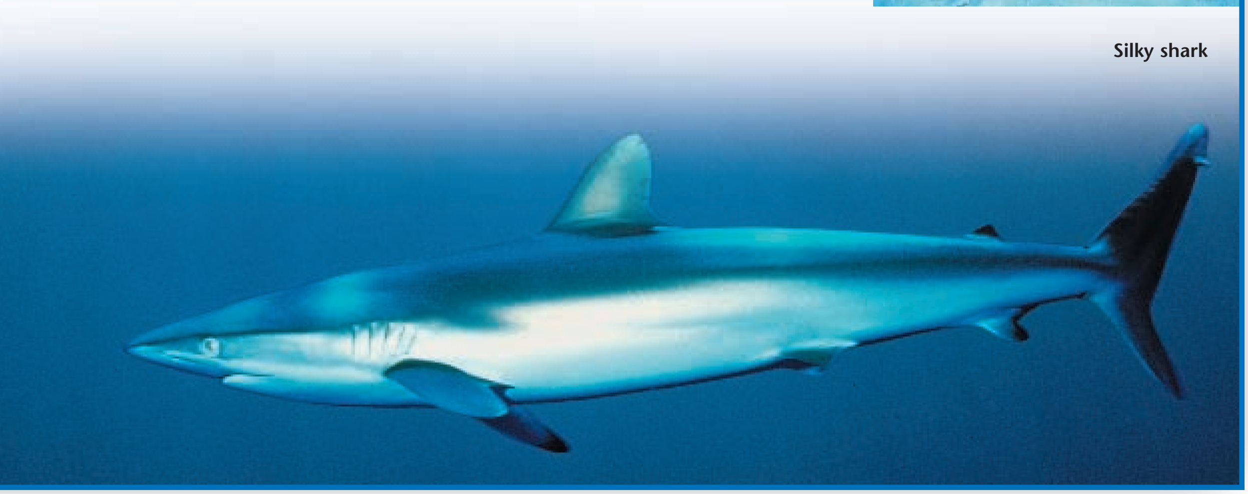
Most of the 350 or so living shark species have large curved tails, torpedo-shaped bodies, and pointed snouts with the mouth underneath. One of the most noticeable characteristics of sharks is their enormous number of teeth. Many sharks have thousands of teeth arranged in several rows. As teeth in the 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. Their teeth 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?*





Use Visuals

Figure 30–18 Explain that shark teeth are made from bonelike material. Scientists infer that they are specialized scales. Ask: **Why is it advantageous for sharks to have teeth that are continually replaced?** *(If teeth are damaged or lost, sharks could not get food.)* Explain that most sharks are very fast swimmers. Ask: **What characteristics of the shark's body make it a fast swimmer?** *(Torpedo body shape, paired fins, strong tail)* L2

Address Misconceptions

Many students might think that sharks are very dangerous animals and should be killed on sight. Remind students that shark attacks are infrequent, but their publicity makes these attacks appear more frequent. Ask: **What role do sharks have in the environment?** *(Most are predators.)* **What might happen if sharks were hunted to the point of extinction?** *(The prey populations might increase to the point where the environment could not support them, causing ecosystem collapse by absence of a key predator.)* L2

BIO INSIGHTS

BIOLOGY UPDATE

Where is the great white shark?

In March 2000, scientists in Australia tagged a young female great white shark with a satellite tag. This was the first shark to ever be tagged in this way. The satellite tag is an electronic tag that transmits its position by satellite to a computer at the research station. From such data, researchers should learn where a great white shark travels and how it interacts with other great white sharks. This information contributes to the knowledge of the great white's behavior and its role in the ecosystem. This knowledge can contribute to the National Recovery Plan being developed in Australia for the great white shark.

Answers to . . .

CHECKPOINT *Oviparous, ovoviviparous, and viviparous*

Figure 30–16 *Salmon eggs*

Figure 30–18 *It's a filter feeder and has specialized structures for filtering plankton.*

30–2 (continued)

Build Science Skills

Observing Allow student groups to dissect a fish obtained from a fish market or scientific supply house. Encourage students to carefully remove muscle tissue to observe the skeleton. As they examine the fish, instruct them to diagram and label the structures that are characteristic of bony fishes, such as the fin rays, swim bladder, and bony skeleton. L2

Use Visuals

Figure 30–19 Ask: **How are all the fishes shown here similar?** (*They are all bony fishes belonging to the group called ray-finned fishes. They all have ray fins.*) **What is the other group of bony fishes called?** (*Lobe-finned fishes*) **How are they different from ray-finned fishes?** (*The fleshy fins of lobe-finned fishes have more substantial support bones than the rays of ray-finned fishes. Some of these bones are jointed.*) L1 L2

FIGURE 30–19 DIVERSITY OF RAY-FINNED FISHES

Combtooth Blenny

Emperor Angelfish

Flying Fish

Peacock Flounder

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?*

Leafy Sea Dragon

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 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.

BIO INSIGHTS — HISTORY OF SCIENCE

Fish tale

Perhaps the greatest American naturalist of the nineteenth century was Louis Agassiz (1807–1873), who from 1848 until his death was a professor of zoology at Harvard University. Agassiz was born in Switzerland, and his earliest scientific work was the classification of fish specimens brought to Europe from Brazil. He won worldwide attention in the 1830s for his study of fossil fishes. That fame led to a course of lectures in the United States in the 1840s. Agassiz made many contributions to science, perhaps the greatest being his revelation that Earth had ice ages in the past. But fishes remained an interest throughout his life. According to legend, he would lock a new student in a room for a day with one object, a dead fish. At day's end, the student faced an unenviable task: reporting to the professor all that he had learned by looking at that fish.

Ecology of Fishes

Most fishes spend all their lives either in fresh water or in the ocean. Most freshwater fishes cannot tolerate the high salt concentration in saltwater ecosystems, because their kidneys cannot maintain internal water balance in this environment. Since freshwater fishes cannot maintain homeostasis in salt water, they cannot survive in the ocean. In contrast, ocean fishes cannot tolerate the low salt concentration in freshwater ecosystems.

However, some fish species can move from saltwater ecosystems to fresh water, and vice versa. Lampreys, sturgeons, and salmon, for example, 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 reproduce. This trip can take several months, covering as much as 3200 kilometers, and can involve incredible feats of strength, as shown in **Figure 30–20.** 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.

▲ **Figure 30–20** Adult salmon return from the sea to reproduce 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?***

30–2 Section Assessment

1. **Key Concept** Identify the main characteristics of fishes.
2. **Key Concept** What adaptive 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. **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.

Focus on the BIG Idea

Structure and Function
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?

Ecology of Fishes

Make Connections

Environmental Science Explain that the construction of dams across many rivers in the northwestern U.S. has affected the population of salmon. Ask: **Why would dams cause a reduction in the population of salmon?** *(Dams prevent the salmon from swimming upriver to spawn.)* Explain that some dams have "fish ladders" to help salmon swim upstream of the dams. L2

3 ASSESS

Evaluate Understanding

Have students write a sentence that describes the characteristics used to classify fishes. Then, instruct them to make a table in which they list the three main groups of fishes, examples of each, and the key characteristics of each group.

Reteach

Have students create a concept map that shows at least four different ways in which fishes are adapted to live in water.

Focus on the BIG Idea

Students' diagrams should note that the circulatory systems of an annelid and a fish are similar in that both are closed and consist of a single loop. The fish has a true heart; the annelid does not. The fish's blood picks up oxygen from gills; the annelid's does not.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 30–2.

30–2 Section Assessment

1. Aquatic vertebrates with fins, scales, and gills
2. Jaws: defense, can manipulate materials and therefore eat a wider variety of food; fins: more controlled movements, move faster
3. Answers include various modes of feeding; gills; paired fins; kidneys that control water balance; lateral line system; and swim bladder.
4. Jawless fishes: lampreys or hagfishes; cartilaginous fishes: sharks, rays, skates, sawfishes; bony fishes: guppies, groupers, salmon, eels, lungfishes, coelacanths
5. Fish get oxygen from the water. Water that is unclean and not ventilated is low in oxygen, causing the fish to suffocate.

Answers to . . .

Figure 30–19 *Answers include color, body shape, and structure of the fins and mouth.*

Figure 30–20 *Sense of smell*