chapter 28 Fishes and Amphibians

section 1 Fishes

Before You Read

Have you ever watched a fish swim? On the lines below, describe how a fish's body moves as it swims. In this section you will learn how the bodies of fishes are well adapted for life in their watery world.

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MAIN Idea

Fishes are vertebrates that live and reproduce in water.

What You'll Learn

- the differences between vertebrates and invertebrates
- the characteristics common to most fishes
- how fishes are adapted to life in water

Read to Learn

Characteristics of Vertebrates

Recall that chordates have four main characteristics: a dorsal nerve cord, a notochord, pharyngeal pouches, and a postanal tail. Vertebrates are chordates that also have a vertebral, or spinal, column and specialized cells that develop from the nerve cord. These animals belong to the subphylum Vertebrata. Classes of vertebrates include fishes, amphibians, reptiles, birds, and mammals.

What are the functions of the vertebral column?

The vertebral column replaces the notochord as a vertebrate embryo develops. The vertebral column surrounds and protects the dorsal nerve cord. It also functions as a strong, flexible rod that muscles can pull against during movement. Separate vertebrae allow an animal to move quickly and easily.

Vertebrate skeletons are made of cartilage or a combination of bone and cartilage. **Cartilage** (KAR tuh lihj) is a tough, flexible material that makes up part or all of the skeleton of a vertebrate.

Mark the Text

Identify the Characteristics
Highlight each characteristic of vertebrates and fishes as you read. Underline the functions of each characteristic.

Reading Check

1. **Identify** the two main building materials in the skeletons of vertebrates.

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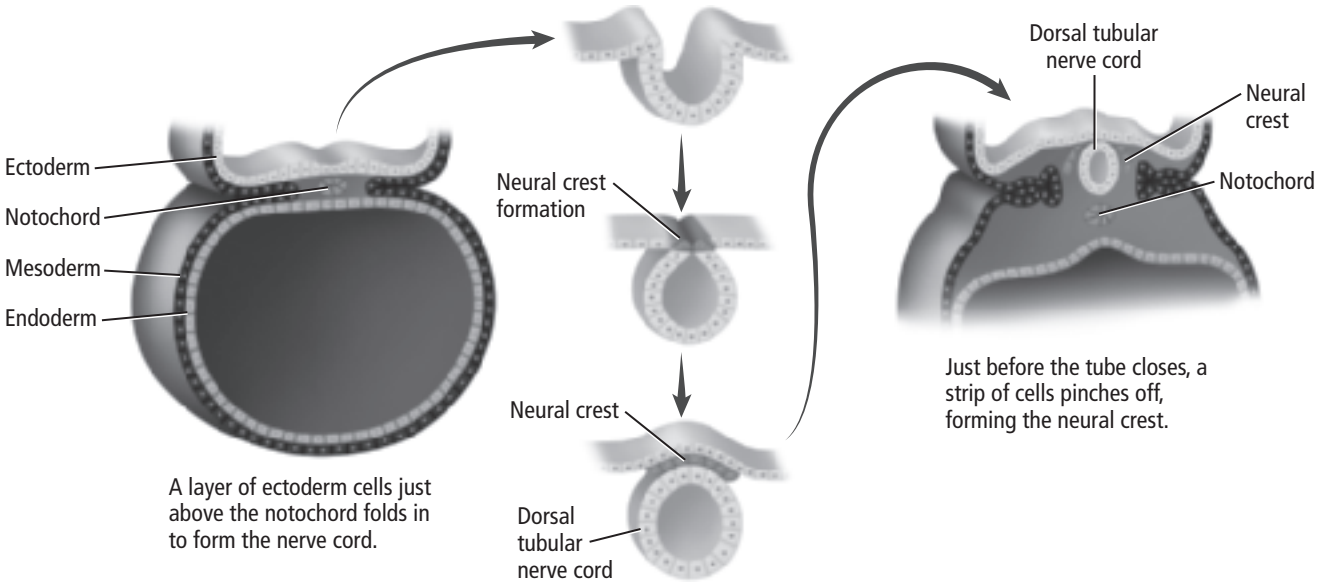
Neural Crest



Picture This

2. Describe the location of the neural crest

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What is a neural crest?

As vertebrate embryos develop and the nerve cord forms, a neural crest also forms. A **neural** (NOOR ul) **crest** is a small group of cells that develop from the nerve cord in vertebrates. The neural crest is located just above the nerve cord.

The figure above shows how the neural crest forms. Many important vertebrate features develop from the neural crest. These features include parts of the brain and skull, some sense organs, parts of pharyngeal pouches, some nerve fibers, insulation of nerve fibers, and some gland cells. Other vertebrate features are a heart, a closed circulatory system, and internal organs, such as kidneys.

Characteristics of Fishes

Fishes live in most aquatic habitats on Earth, including seas, lakes, ponds, streams, and marshes. Some fishes live in complete darkness at the bottom of the deep ocean. Others live in cold polar waters and have special proteins in their blood to keep them from freezing. They can range from 18 m long to the size of a human fingernail. There are more species of fish than all other vertebrates combined.

Most fishes have vertebral columns, jaws, paired fins, scales, gills, and single-loop circulation. They also cannot make certain amino acids. Some characteristics of fishes, including jaws and, in some fishes, lungs, provided the structural starting place for the development of land animals during evolution.

Think it Over

3. Name three characteristics that you share with fish.

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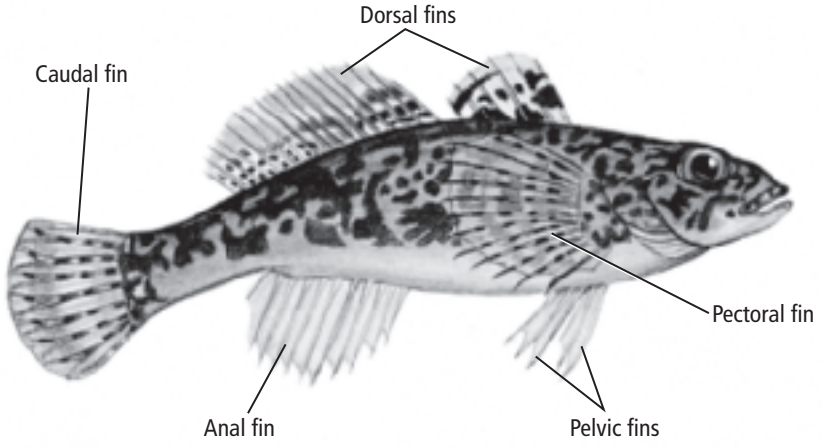
How did the development of jaws benefit fishes?

In ancient fishes, gill arches evolved to form jaws. Jaws enabled fishes to prey on more kinds of animals, including larger and more active fishes. Fishes grasp prey with their teeth and crush them with powerful jaw muscles. Fishes also use their jaws as a biting defense against predators.

What advantages do paired fins provide?

As jaws were evolving, paired fins—one on each side of the body—were also appearing in fishes. A **fin** is a paddle-shaped structure on a fish or other aquatic animal that is used to balance the body, control the direction of its movements, and move its body through the water.

A fish uses pelvic fins and pectoral fins, like those shown in the figure below, to keep its body steady as it moves. Paired fins, shown in the figure below, enable a fish to control the direction of its movements and keep its body from rolling to the side.



What types of scales do fishes have?

A **scale** is a small, flat, platelike structure near the surface of the skin of most fishes. There are four types of fish scales. Two types, ctenoid (TEH noyd) scales and cycloid (SY kloyd) scales, are made only of bone. These scales are thin and flexible. Sharks have rough and heavy placoid (PLA koyd) scales that are made of toothlike materials. Thick ganoid (GAN oyd) scales are diamond-shaped and made of both enamel and bone.

Picture This

4. Explain how a fish's movement might change if it had a pectoral fin on only one side.

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How do gills help fishes live in water?

Gills give fishes the ability to get oxygen from water. As water enters the mouth and flows across the gills, oxygen from the water diffuses into the blood. Gills are made of thin filaments that are covered with platelike lamellae (luh MEH lee). The lamellae are highly folded and have many blood vessels to take in oxygen and give off carbon dioxide.

In the gill, blood flows in the opposite direction of the flow of water on the gill's surface. This opposing flow helps fishes get up to 85 percent of the oxygen from the water. Some fishes have a moveable flap called an **operculum** (oh PUR kyuh lum) that covers and protects the gills. An operculum also helps to pump water coming in the mouth and over the gills.

Some fishes, such as lungfishes, can live out of water for a short time using structures similar to lungs. An eel can breathe through its moist skin when it is out of water.

Think it Over

5. Describe a situation in which having structures similar to lungs would benefit a lungfish.

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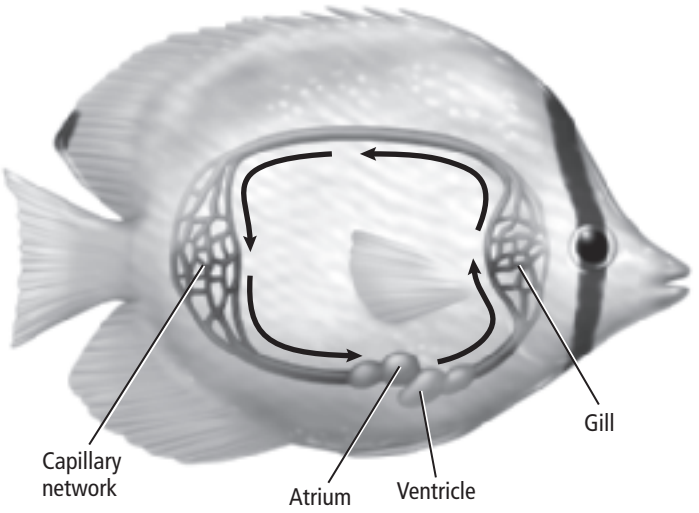
How does blood circulate in fishes?

Vertebrates have a closed circulatory system. This means that the heart pumps blood through blood vessels. In most fishes, blood flows in a one-way loop, as shown in the figure below.

The hearts of most fishes have two chambers—an atrium and a ventricle. The **atrium** receives blood from the body. After leaving the atrium, blood passes to the **ventricle**, which pumps blood from the heart to the gills. After flowing over the gills, blood travels to the rest of the body, delivering the oxygenated blood to tissues. The blood then goes back to the heart and cycles through again. Because this system is a complete circuit, it is called a single-loop circulatory system.

Picture This

6. Circle the names of the chambers of a fish's heart.



How has feeding changed from ancient times?

Ancient fishes most likely were filter feeders or scavengers, sucking up organic matter on the ocean floor. The evolution of jaws enabled fishes to become predators. Most fishes today swallow their prey whole.

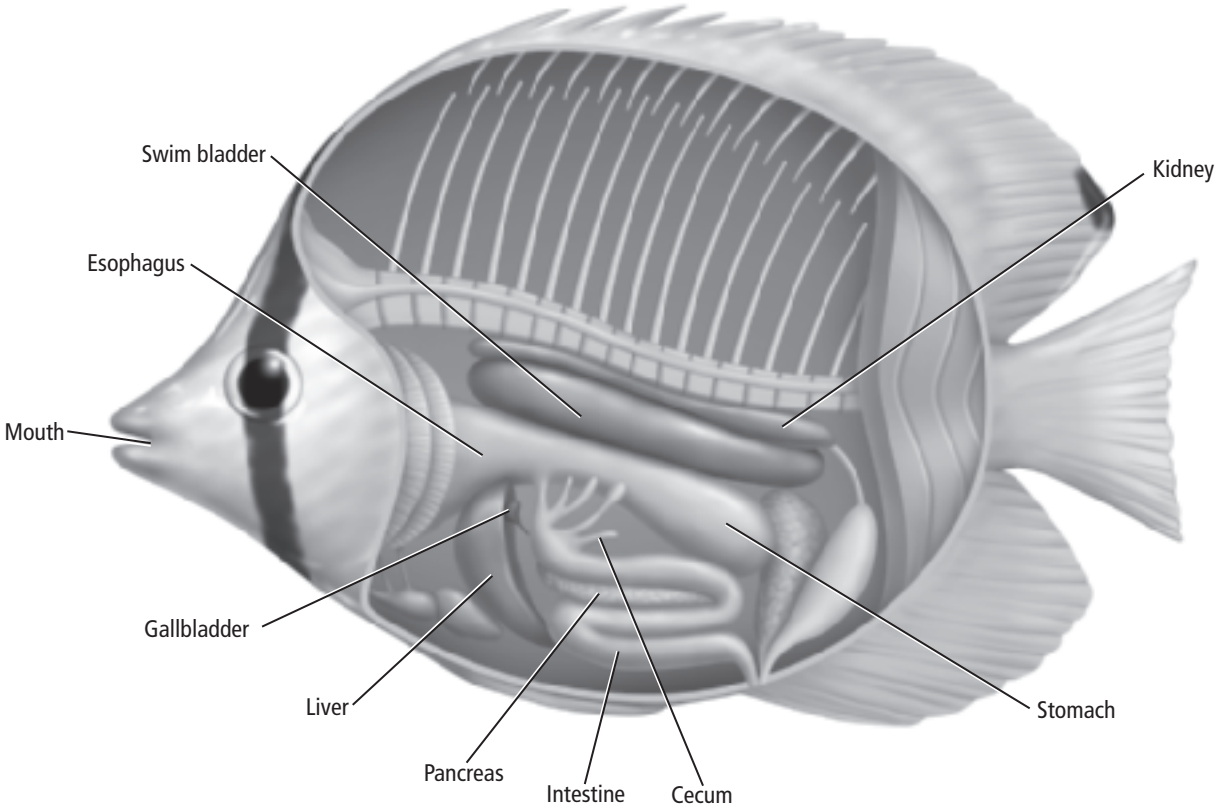
What are the structures of the digestive tract?

The digestive tract of a fish is illustrated in the figure below. After a fish swallows its prey, the food passes through a tube called the esophagus (ih SAH fuh gus) to the stomach, where digestion begins. Food then passes to the intestine, where most digestion occurs. Some fishes have pyloric (pi LOR ihk) ceca (SEE kuh) (singular, cecum), which are small pouches where the stomach and intestine meet. The pyloric ceca secrete enzymes for digestion and absorb nutrients into the bloodstream. Digestive juices from the liver, pancreas, and gallbladder complete digestion.

One important thing fishes cannot do is make certain amino acids. Therefore, fishes and all vertebrates that evolved from fishes must get these amino acids from foods they eat.

Picture This

7. Highlight in one color the structures where digestion occurs. Highlight in a different color the structures that produce digestive fluids.



What are the functions of the excretory system?

Kidneys filter cellular wastes from a fish's blood. A **nephron** is a filtering unit within the kidney that removes cellular wastes from the blood. Nephrons also help keep a balance between salt and water in the body. Some cellular wastes are excreted by the gills.

Reading Check

8. Name the excretory organ that contains filtering nephrons.

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What can fishes sense?

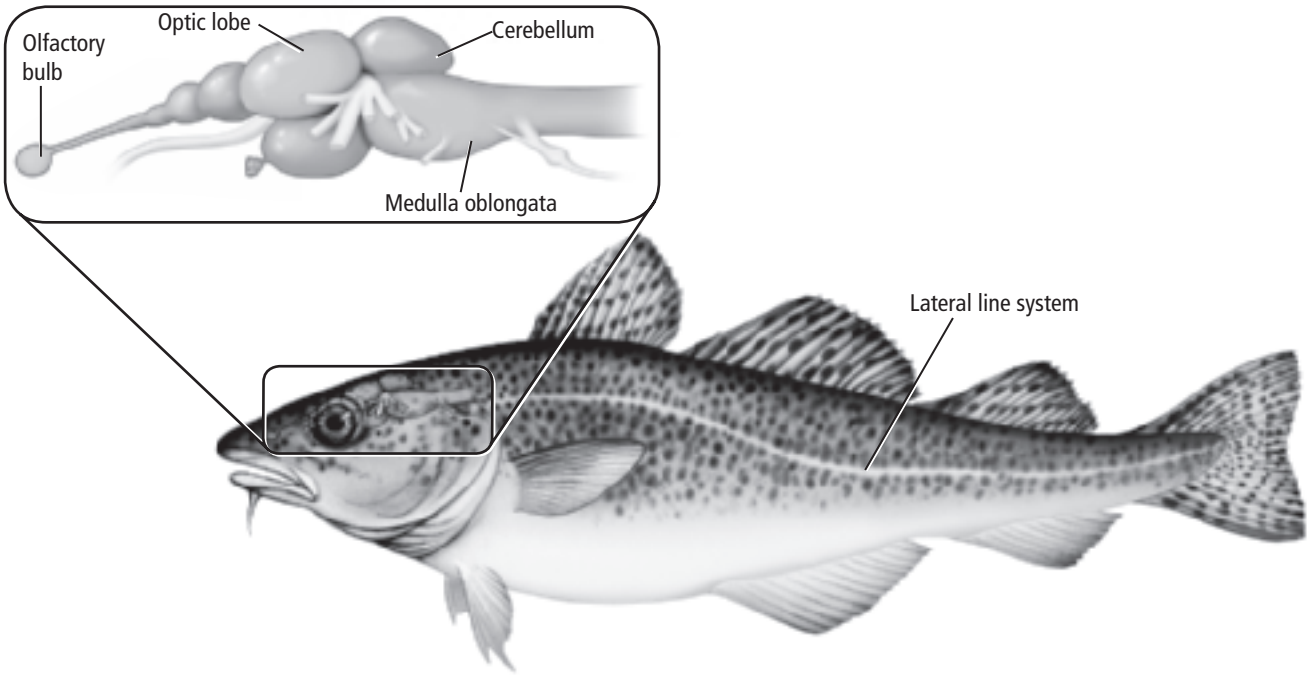
The nervous system of all vertebrates consists of a spinal cord and a brain. A fish brain is shown in the figure below. The cerebellum controls movement and balance. Receptors for the sense of smell detect chemicals in the water. In the brain, olfactory (ohl FAK tree) bulbs receive and process this chemical input. Fishes also have color vision. The optic lobes in the brain are responsible for visual input. The cerebrum coordinates input from the rest of the brain. The medulla oblongata controls internal organs.

What is the purpose of the lateral line system?

Fishes also have receptors called a lateral line system. The **lateral line system** enables a fish to detect movement in the water and helps keep it upright and balanced. The lateral line system is also shown in the figure below.

Picture This

9. Identify Circle the name of the brain structure that controls a fish's balance.



How do fishes reproduce?

For most fishes, fertilization occurs outside the body in a process called **spawning**. During spawning, male and female fishes release their gametes near each other in the water.

The yolk of the egg provides nutrition for the developing embryos. Some fishes, like sharks, reproduce through internal fertilization, with the offspring developing outside the body after the fertilized eggs are laid. Others reproduce through internal fertilization and internal development of the offspring. The developing offspring obtain nutrients from the female's body.

Why do most fishes produce large numbers of eggs?

Fishes that spawn can produce millions of eggs in a season. Most fishes do not protect or care for their eggs or their offspring. As a result, many eggs and young fishes become prey to other animals. The large number of eggs ensures that some will survive to develop and reproduce.

What features aid movement?

Most fishes have a streamlined shape. Most also have a mucous coating that reduces friction between the fish and the water for easier swimming. Fins enable fishes to control their movement through water. The buoyant force of water reduces the effect of gravity on fishes. Also, bony fishes have a **swim bladder**, which is a gas-filled space that allows a fish to control its depth in the water. When gases diffuse out of the swim bladder, the fish can sink. When gases from the blood diffuse into the swim bladder, the fish can rise.

A fish moves by contracting muscles on either side of its body. As muscles on one side contract, the fish bends, pushing against the water. The water pulses and the fish moves forward at an angle. Alternating contractions of muscles from side to side move the fish forward in an *s*-shaped pattern, as shown in the figure below.

Reading Check

10. Summarize the survival strategy of reproduction by spawning.

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Picture This

11. Name What is the shape of the pattern of a moving fish?

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chapter 28 Fishes and Amphibians

section 2 Diversity of Today's Fishes

MAIN Idea

Fishes belong to one of three groups based on body structure.

What You'll Learn

- characteristics of different groups of fishes
- key features of various types of fishes
- how fishes evolved

Before You Read

When you hear the word *shark*, what image comes to mind? On the lines below, describe a shark. In this section you will learn the features of sharks that make them successful hunters.

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Study Coach

Create a Quiz As you read this section, write quiz questions based on what you have learned. After you write the questions, answer them.

Reading Check

1. **Name** the parts of a fish that hagfish do not eat.

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Read to Learn

Classes of Fishes

Fishes are grouped into three classes based on body structure. The classes are jawless fishes, bony fishes, and cartilaginous (kar tuh LAJ uh nus) fishes.

What are the characteristics of jawless fishes?

Hagfishes belong to class Myxini (mik SEE nee). They are jawless, eel-shaped fishes that do not have scales, paired fins, or a bony skeleton. Hagfishes have a notochord throughout life. They do not develop a vertebral column. However, they do have gills and many other characteristics of fishes. They live on the ocean floor and are scavengers, which means that they feed on dead or dying fishes.

Because they are almost blind, hagfishes locate their food with their highly sensitive chemical senses. A hagfish enters the body of a dead or dying fish through the mouth or by scraping an opening into the fish with toothlike structures on its tongue. After eating the internal parts of the fish, the hagfish leaves only a sac of skin and bones. If threatened, a hagfish secretes fluid from glands in its skin that forms a slippery coating to prevent a predator from catching it.

Are there other jawless fishes?

Class Cephalaspidomorphi (ceh fah las pe doh MOR fee) includes another jawless, eel-shaped fish—the lamprey. Like hagfishes, lampreys do not have scales, paired fins, or bony skeletons. Lampreys also keep a notochord through life. They have gills and other features of fishes. Adult lampreys are parasites. They attach to other fishes with a suckerlike mouth and scrape away scales and skin to feed on the blood and body fluids of their hosts.

What features do cartilaginous fishes share?

Sharks are members of class Chondrichthyes (kon DRIK thees) and have several rows of sharp teeth. As teeth are broken or lost, new ones move forward to replace them. The main feature that sets sharks apart from other fishes, however, is their skeleton. Sharks are cartilaginous fishes. All cartilaginous fishes have skeletons made of flexible cartilage and calcium carbonate for strength.

Most sharks have a streamlined shape with a pointed head and a tail that turns up at the end, as shown below. Their skin is covered with tough placoid scales. These features, along with strong swimming muscles and sharp teeth, make sharks effective predators.

A shark's chemical sensors enable it to detect prey from a distance of 1 km. As it moves closer, its lateral line system detects movement in the water. In the final chase, a shark uses vision and receptors that detect electricity given off by the prey.

The largest sharks—whale sharks—do not have rows of teeth. They are filter-feeders. Their mouth structures are adapted for straining food from the water.

Skates and rays are also cartilaginous fishes. Their flattened bodies are adapted for life on the bottom of the ocean. Their pectoral fins are enlarged and attached to their heads. These winglike fins flap slowly as they search for mollusks and crustaceans, which they crush with their teeth.

Reading Check

2. **Contrast** Lampreys differ from hagfishes in what main way?

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Picture This

3. **Name** one feature shown in the figure that helps make a shark an effective predator.

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What are the characteristics of ray-finned bony fishes?

Class Osteichthyes (ahs tee IHK theez) contains the bony fishes, which are separated into two groups: ray-finned fishes and lobe-finned fishes. The fins of ray-finned fishes are thin membranes supported by thin, spinelike rays. These fishes also have a bony skeleton, ctenoid or cycloid scales, an operculum covering the gills, and a swim bladder. Most fishes alive today, such as salmon and trout, are ray-finned fishes.

What are the characteristics of lobe-finned bony fishes?

Only eight species of lobe-finned fishes are alive today. Their fins have muscular lobes and joints similar to those of land vertebrates. Most lobe-finned fishes, such as lungfishes, have structures similar to lungs. During droughts, lungfish burrow into the mud with their fins and breathe air. When rain returns, they come out of their burrows.

Coelacanths (SEE luh kanths), another small group of lobe-finned fishes, were thought to be extinct until one was caught in 1938. Others have been caught since then.

A third group of lobe-finned fishes is now extinct. It is thought to be the ancestor of tetrapods. A **tetrapod** is a four-footed animal with legs that have feet and toes with joints. Tetrapods walked on land. Their limbs might have evolved from the fins of lobe-finned fishes.

Think it Over

4. Draw Conclusions
The first vertebrates to live on land probably evolved from which class of fishes? (Circle your answer.)
a. bony fishes
b. cartilaginous fishes
c. jawless fishes

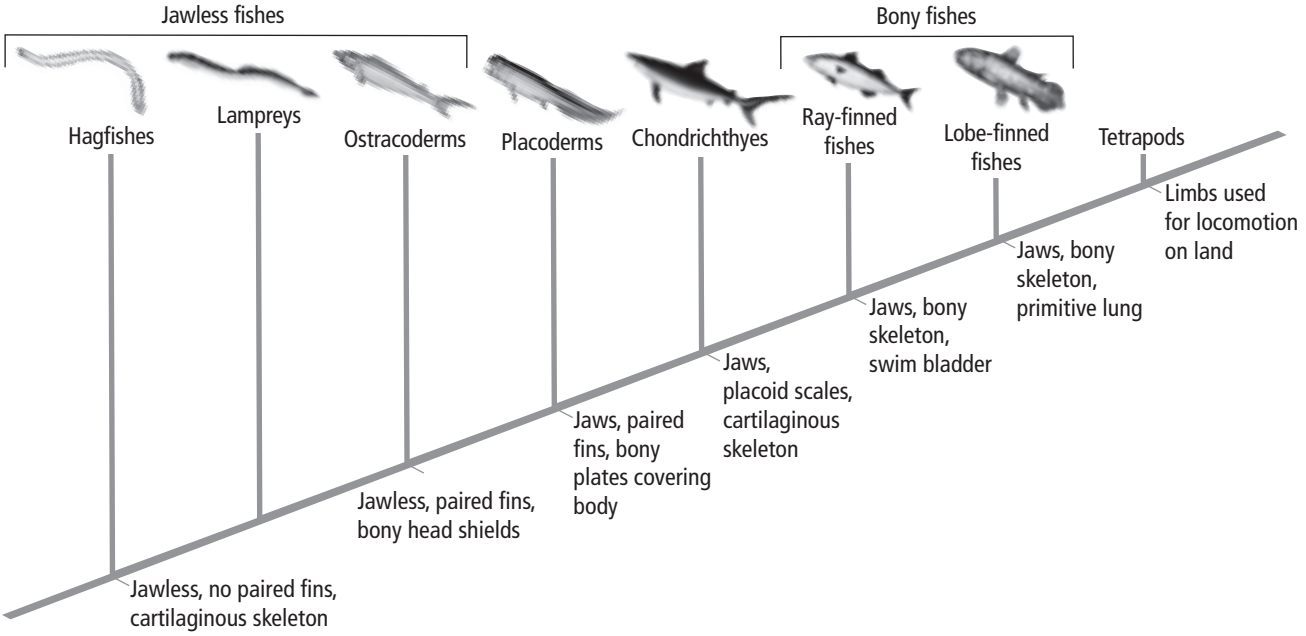
Evolution of Fishes

The cladogram on the next page shows how fishes might have evolved. Notice the features that developed during the course of evolution.

What were the characteristics of the first fishes?

The first fishes appeared in the Cambrian period. These jawless, toothless fishes sucked up organic matter from the ocean floor. Ostracoderms (OS tra koh dermz) were the next group of fishes that appeared in the Ordovician period. Their bony head shield, bony outer covering, and paired fins marked a milestone in vertebrate evolution. Stronger movement was possible with muscle attached to bone. Scientists hypothesize that present-day fishes share a common ancestor with ostracoderms.

Cladogram of Fishes



What period is called the Age of Fishes?

Many adaptations appeared during the Devonian period, also called the Age of Fishes. During this time period, now-extinct placoderms had three features of modern fishes: jaws, paired fins, and an internal skeleton.

Ecology of Fishes

Fishes are an important source of food in aquatic ecosystems. Human activities such as damming rivers and dumping pollutants in waterways are changing fishes' freshwater and saltwater habitats. When the numbers of fishes decline, people that make their living from fishing and related industries will be negatively affected. In addition, ecosystems can become unbalanced.

How have dams affected salmon?

Each year, salmon return to spawn in the freshwater stream where they hatched. Dams on rivers interfere with this migration. As a result, the salmon population is smaller in these areas.

How does pollution affect aquatic ecosystems?

Pollution of lakes and streams can reduce the quality of water in lakes, rivers, and streams. This can result in a decline of both number and diversity of fishes in an area. Sometimes fish return when the pollution stops.

Picture This

5. Identify which fishes did not have jaws.

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Reading Check

6. List two ways in which humans have altered ecosystems, causing the number and diversity of fishes to decline in the affected area.

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chapter 28 Fishes and Amphibians

section 3 Amphibians

MAIN Idea

Most amphibians are born in the water but live on land as adults.

What You'll Learn

- adaptations as animals moved to the land
- characteristics of amphibians
- the differences among the orders of amphibians

Before You Read

On the lines below, describe the changes that occur as a tadpole becomes an adult frog. In this section you will learn how amphibians adapted to life on land.

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Mark the Text

Identify Main Ideas As you read, highlight the main ideas in each paragraph.

Read to Learn

Evolution of Tetrapods

Tetrapods first appeared on Earth approximately 360 million years ago. The amphibians evolved as they adapted to life on land.

How did vertebrates adapt to life on land?

Conditions are much different on land than in water. The table below compares conditions in water and on land. It also lists some important adaptations that enabled vertebrates to live on land.

Picture This

1. **Highlight** the adaptation that occurred in response to more available oxygen.

Conditions in Water	Conditions on Land	Adaptations for Life on Land
Water has buoyancy. That is, it has an upward force that works against gravity.	• Air is less buoyant. • Movement is against gravity.	Limbs develop and skeletal and muscular systems become stronger.
Oxygen is dissolved in water and must be removed by gills.	• Oxygen is more available in air than in water.	Lungs enable animals to get oxygen from air more efficiently.
Water holds heat, so the temperature of water does not change quickly.	• Temperature changes occur more rapidly in air. • Temperatures vary between day and night.	Animals develop behaviors, such as migration, and physical adaptations that protect them from extreme temperatures.
Sound waves travel more quickly through water.	• A lateral line system cannot detect sound in air.	Animals develop ears that detect sound waves in the air.

What land habitats do animals occupy?

Land provides many habitats for animals. With proper adaptations, animals can occupy tropical rain forests, temperate forests, grasslands, deserts, taiga, and tundra.

Characteristics of Amphibians

Most amphibians begin life as aquatic organisms. After undergoing metamorphosis (me tuh MOR fuh sihs), they are equipped to live on land.

A frog begins life as a limbless, gill-breathing tadpole. The tadpole undergoes metamorphosis daily. Hind legs form and grow longer, and forelimbs sprout. The tail shortens. Lungs replace gills. Soon the tadpole becomes an adult frog.

Most amphibians have four legs, moist skin with no scales, a double-loop circulatory system, and aquatic larvae. They exchange gases through both their skin and lungs.

How do amphibians feed and digest?

Frog larvae are herbivores. Salamander larvae are carnivores. As adults, both frogs and salamanders are predators. They feed on a variety of invertebrates and small vertebrates. Some salamanders and legless amphibians catch prey in their jaws. Frogs flick out their long, sticky tongues to catch flying prey.

Food moves from the mouth through the esophagus to the stomach, where digestion begins. The food moves to the small intestine, which receives enzymes from the pancreas to digest food. From the intestine, food is also absorbed into the bloodstream. From the small intestine, food moves to the large intestine before waste is eliminated.

At the end of the intestine is a chamber called the cloaca. (kloh AY kuh). The **cloaca** receives digestive and urinary wastes as well as eggs or sperm before they leave the body.

How are wastes removed from the body?

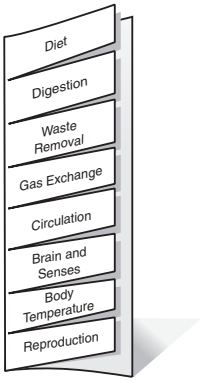
The kidneys filter wastes from the blood. Amphibians that live in water excrete waste as ammonia. Amphibians that live on land excrete urea. Urea is made from ammonia in the liver. Unlike ammonia, urea is stored in the urinary bladder until it leaves the body through the cloaca.

What structures are used for gas exchange?

As larvae, most amphibians exchange gases through their skin and gills. As adults, most amphibians breathe through their lungs, mouths, and thin, moist skin.

FOLDABLES™

Take Notes Make a vocabulary Foldable and label as shown. As you read, record information about the characteristics of amphibians under the tabs.



Think it Over

2. **Explain** how the method of gas exchange reflects the difference in habitat between larvae and adult amphibians.

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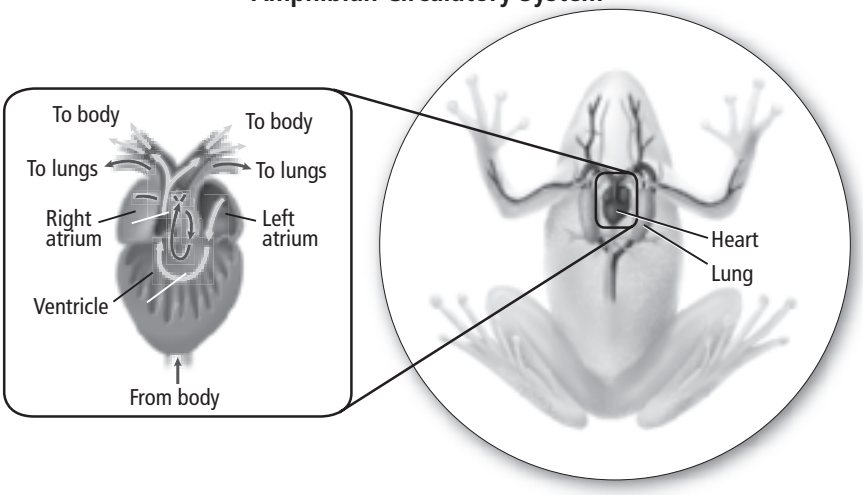
Amphibian Circulatory System



Picture This

3. Highlight in one color the segments of the circulatory loops in which the blood is oxygen-poor. Highlight in another color the segments in which the blood is oxygen-filled.

How does blood circulate through the body?

Amphibians have a double-loop circulatory system, as shown in the figure above. In the first loop, oxygen-poor blood moves from the heart to pick up oxygen in the lungs and skin. Oxygen-filled blood then moves back to the heart. In the second loop, oxygen-filled blood moves from the heart through vessels to the body, where oxygen diffuses into cells.

The amphibian heart has three chambers. The right atrium receives oxygen-poor blood from the body. The left atrium receives oxygen-filled blood from the lungs. The ventricle remains undivided.

How have the brain and senses adapted?

The amphibian brain is adapted for life on land. A frog's forebrain can detect odors in air. The cerebellum, important for balance to fishes, is not well developed in amphibians that live on land.

Vision is important to amphibians for catching prey and escaping predators. A **nictitating** (NIK tuh tayt ing) **membrane** is a transparent eyelid that covers a frog's eye. It protects the eye underwater and keeps it from drying out on land.

Amphibians have developed a **tympanic** (tihm PA nihk) **membrane**, or eardrum. In frogs, it is a thin external membrane on the side of the head. It is used to hear high-pitched sounds, such as mating calls.

How do amphibians control body temperature?

Amphibians are ectotherms. **Ectotherms** are animals that get their body heat from the external environment. Because they cannot control their body temperature internally, they must be able to sense where to go to get warmer or cooler.

Think it Over

4. Apply Why might a salamander lie on a rock on a sunny morning?

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How do amphibians reproduce and develop?

A frog's reproduction cycle is typical of many amphibians. Female frogs lay eggs to be fertilized by males in the water. The eggs do not have shells and can dry out if not kept in water. The eggs are covered in a jelly-like substance that helps them stick to plants in the water. After fertilization, the embryo uses the egg yolk for nutrition until it hatches into a tadpole. Chemicals in the tadpole's body control its metamorphosis into an adult frog. During metamorphosis, the tadpole changes from gill-breathing to lung-breathing. The legless herbivore becomes a four-legged carnivore. Its two-chambered heart changes to a heart with three chambers.

Reading Check

5. Explain Why do frog eggs need to be laid in water?

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Amphibian Diversity

Biologists group amphibians into three orders. Frogs and toads belong to order Anura (a NOOR ah). Salamanders and newts belong to order Caudata (KAW day tah). Caecilians make up order Gymnophiona (JIHM noh fee oh nah).

What features distinguish frogs from toads?

Frogs have longer and more powerful legs and can make more powerful jumps than toads. Frogs have moist, smooth skin, while toads have bumpy, dry skin. Both need to be near water for reproduction. However, toads generally live farther from water than do frogs. Unlike frogs, toads have glands near the back of their heads. These glands release poison to discourage predators from eating them.

What are features of salamanders and newts?

Salamanders and newts have long, slim bodies with necks and tails. Most salamanders have four legs; thin, moist skin; and lay their eggs in water. Their larvae look like small salamanders with gills. Salamanders must live near water. They live in moist areas, such as under logs or in leaf litter. They feed on worms, frog eggs, and insects. Newts are aquatic throughout their lives.

Reading Check

6. Contrast the habitat of adult salamanders with the habitat of newts.

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How do caecilians differ from other amphibians?

Unlike other amphibians, caecilians (si SILH yenz) have no legs. They are wormlike. They burrow in the soil and feed on worms. Skin covers their eyes, so they might be nearly blind. They have internal fertilization and lay their eggs in moist soil near water. Caecilians live in tropical forests.

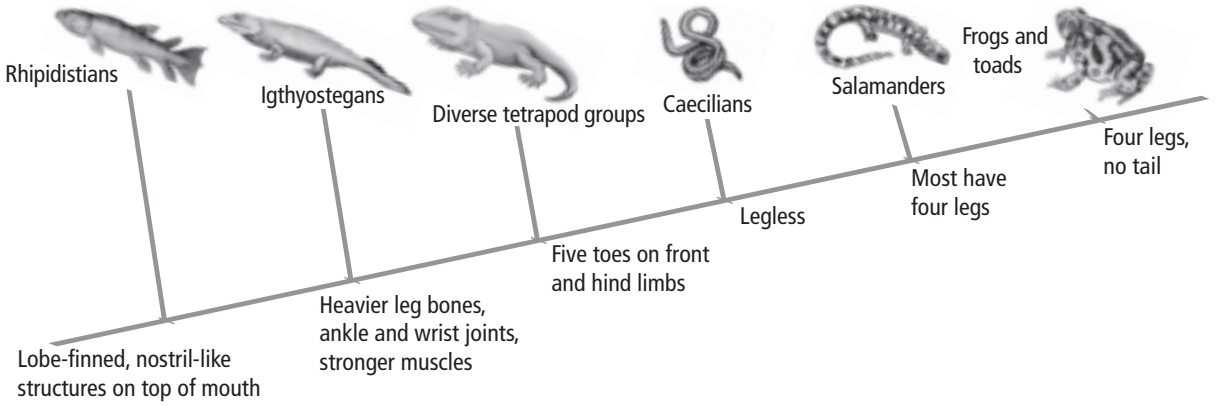
Evolution of Amphibians

Fossils show that the first tetrapods evolved limbs in water before they moved to land. Many adaptations that are useful on land first evolved in water. The cladogram below shows one interpretation of amphibian evolution. Many scientists believe that early tetrapods are more closely related to extinct lobe-finned fishes called rhipidistians (RI pih dihs tee unz). They share similar skull and limb bone structure, nostril-like openings in the tops of their mouths, and tooth structure.

Early tetrapods had legs with feet, but the legs were too weak for walking on land. Ichthyostegans had stronger shoulders, heavier leg bones, and more muscular features. These features enabled their movement on land. Tetrapods branched out to produce the three major groups of amphibians alive today, as well as reptiles, birds, and mammals.

Picture This

7. **Highlight** the groups of amphibians alive today that branched out from tetrapods.



Ecology of Amphibians

Amphibian populations have been declining worldwide. Scientists are collecting data to find possible causes.

What local factors contribute to their decline?

Habitat destruction is a cause of the decline of some amphibians. Wetlands are drained to provide land for new buildings. Without water, amphibians cannot reproduce. The introduction of species not naturally found in an area also adds to the decline. These species might prey on amphibians or compete with them for food and space.

Reading Check

8. **Explain** why draining wetlands might result in the decline of amphibians.

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What global factors contribute to their decline?

Global climate change, such as warmer temperatures and less rainfall, can cause death or disease among amphibians. Increased exposure to UV light might increase the risk of fungal infection that damages amphibian eggs.