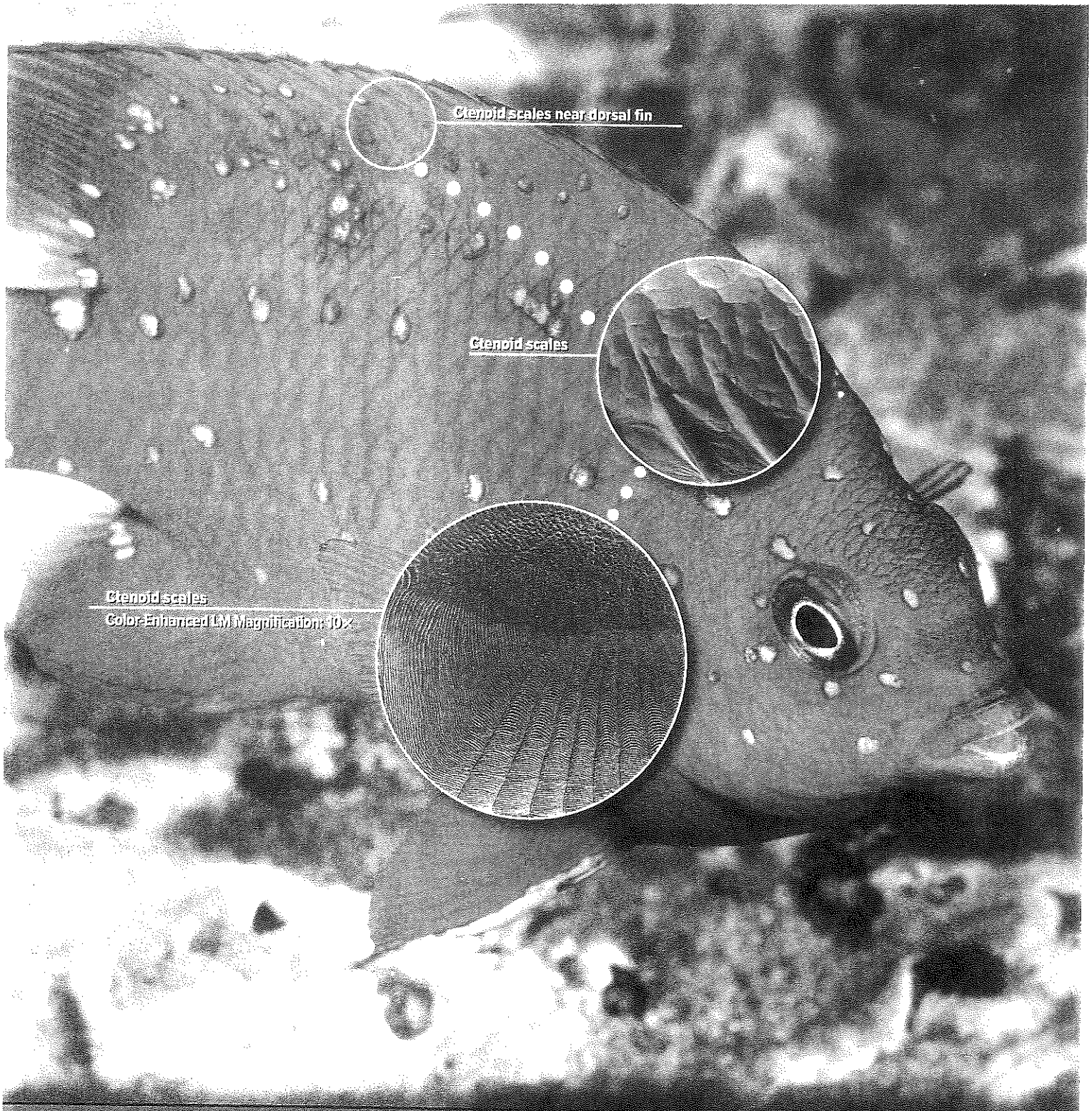


THEME FOCUS **Stability and Change**
Some amphibians go through a major change, called metamorphosis, in their lifetime.

Main Idea **Fishes have adaptations for living in aquatic environments. Most amphibians have adapted to living part of their lives on land.**

Reading Preview

Essential Questions

- What are the features of vertebrates that make them different from invertebrates?
- What are the characteristics that most fishes have in common?
- How are the characteristics of fishes adapted to aquatic life?

Review Vocabulary

notochord: a flexible, rodlike structure that extends the length of the body

New Vocabulary

cartilage
neural crest
fin
scale
operculum
atrium
ventricle
nephron
lateral line system
spawning
swim bladder

Multilingual eGlossary

BrainPOP

Fishes

MAIN Idea **Fishes are vertebrates that have characteristics allowing them to live and reproduce in water.**

Real-World Reading Link You might have seen an aquarium full of colorful fishes similar to the fish in the photo at the beginning of this chapter. What adaptations do fishes have for living in water? Fishes have unique characteristics that allow them to live and reproduce in water.

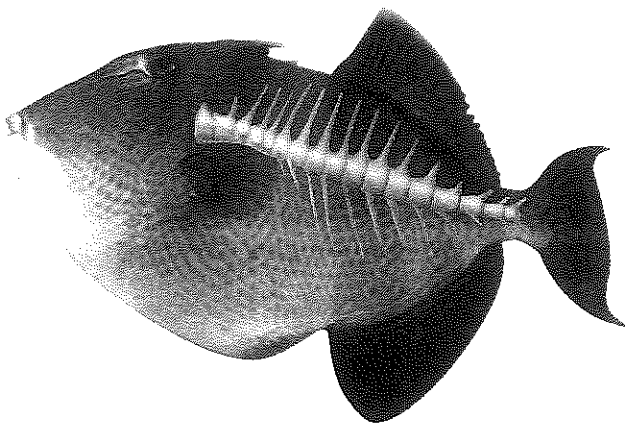
Characteristics of Vertebrates

You have studied sponges, worms, and sea stars, which are all invertebrates. Recall that the four main characteristics of chordates are that they have a dorsal nerve cord, a notochord, pharyngeal pouches, and a postanal tail. Animals belonging to subphylum Vertebrata are called vertebrates. Vertebrates have a vertebral column and specialized cells that develop from the nerve cord. The vertebral column, also called a spinal column, is the hallmark feature of vertebrates. Classes of vertebrates include fishes, amphibians, reptiles, birds, and mammals.

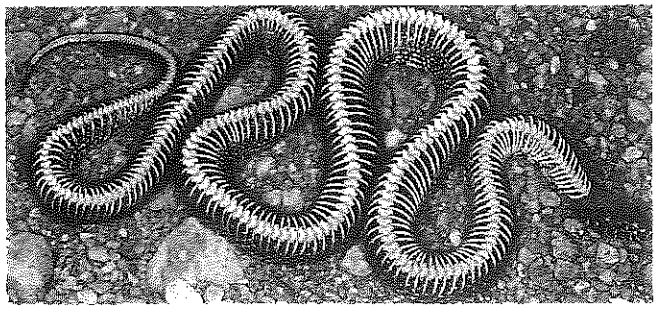
Vertebral column In most vertebrates, the notochord is replaced by a vertebral column that surrounds and protects the dorsal nerve cord. The replacement of the notochord happens during embryonic development. Cartilage or bone is the building material of most vertebrate endoskeletons. **Cartilage** (KAR tuh lihj) is a tough, flexible material making up the skeletons or parts of skeletons of vertebrates.

Vertebral columns, two of which are shown in **Figure 1,** are important structures in terms of the evolution of animals. The vertebral column functions as a strong, flexible rod that an animal's muscles can pull against during swimming or running. Separate vertebrae enhance an animal's ability to move quickly and easily. Bones enable forceful contraction of muscles, improving the strength of an animal.

Figure 1 The vertebral column is present in most vertebrates, including bony fishes and reptiles as shown by the art.



Triggerfish



Desert Kingsnake

(l)Antonio Martin/Alamy; (r)Design Pics/Jack Goldfarb

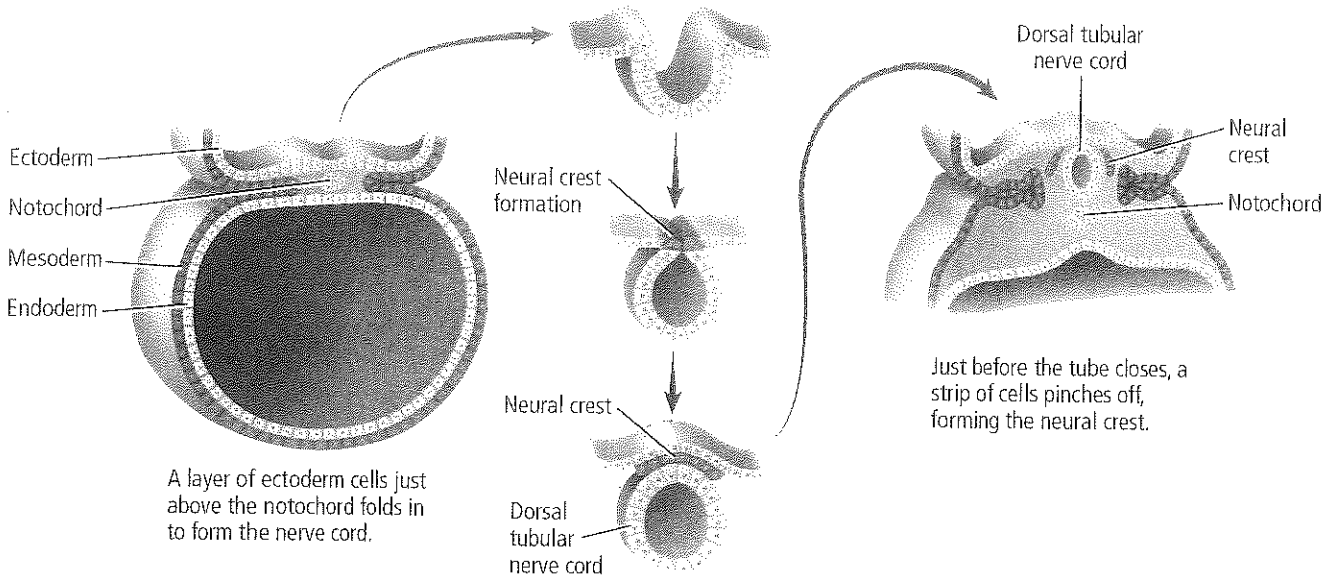


Figure 2 The neural crest of vertebrates develops from the ectoderm of the embryo.

Personal Tutor

Neural crest As the nerve cord forms during embryonic development in vertebrates, another important process occurs: a neural (NOOR ul) crest forms. A **neural crest** is a group of cells that develop from the nerve cord in vertebrates. The process of neural crest formation is shown in **Figure 2.** Even though this group of cells is small, it is significant in the development of vertebrates because many important vertebrate features develop from the neural crest. These features include portions of the brain and skull, certain sense organs, parts of pharyngeal pouches, some nerve fibers, insulation for nerve fibers, and certain gland cells.

Other features that are characteristic of vertebrates include internal organs, such as kidneys and a liver. A heart and closed circulatory system also are features of all vertebrates.

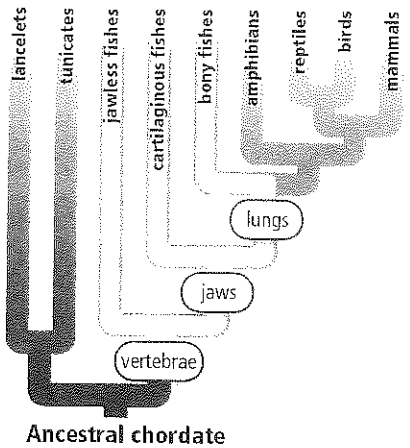
Reading Check **Explain** why the neural crest is an important vertebrate feature.

Characteristics of Fishes

Fishes live in most aquatic habitats on Earth–seas, lakes, ponds, streams, and marshes. Some fishes live in complete darkness at the bottom of the deep ocean. Others live in the freezing waters of the polar regions and have special proteins in their blood to keep the blood from freezing. There are about 24,600 species of living fishes, more than all other vertebrates combined. They range in size from whale sharks that can be 18 m long to tiny cichlids that are the size of a human fingernail.

The features of fishes provided the structural basis for the development of land animals during the course of evolution. Important characteristics of fishes include the development of jaws and, in some fishes, lungs. As shown in the evolutionary tree in **Figure 3,** there are three groups of fishes, all of which are vertebrates. Although fishes' body shapes and structures vary a great deal, they all have several characteristics in common. Most fishes have vertebral columns, jaws, paired fins, scales, gills, and single-loop blood circulation, and they are not able to synthesize certain amino acids.

Figure 3 The branches of the different groups of fishes are highlighted in this evolutionary tree.



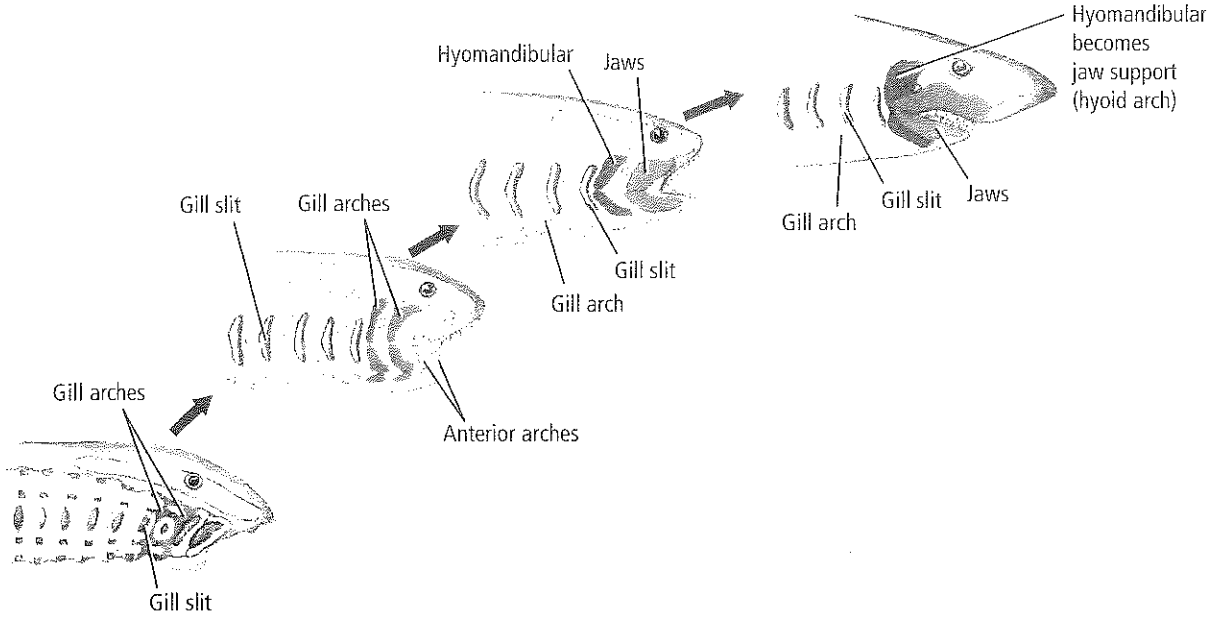


Figure 4 Anterior gill arches evolved into jaws in ancient fishes.

Jaws Most fishes have jaws. The evolution of jaws is shown in **Figure 4,** where you can see that the anterior gill arches evolved to form jaws in ancient fishes. The development of jaws allowed ancient fishes to prey on a larger range of animals. This included the ability to prey on fishes that were larger and more active. Fishes grasp prey with their teeth and quickly crush them using powerful jaw muscles. Jaws also allow for a biting defense against predators.

Reading Check **Describe** why the evolution of jaws in fishes was important.

Paired fins At the same time that jaws were evolving, paired fins were also appearing in fishes. A **fin** is a paddle-shaped structure on a fish or other aquatic animal that is used for balance, steering, and propulsion. Pelvic fins and pectoral fins, like the ones shown in **Figure 5,** give fishes stability. Most fishes have paired fins. Paired fins reduce the chance of rolling to the side and allow for precise steering during swimming.

While fishes in ancient seas moved with precision and skill, they also were able to use their jaws in new ways. Both jaws and paired fins contributed to the evolution of a predatory way of life for some fishes and also enabled them to live in new habitats and produce more offspring.

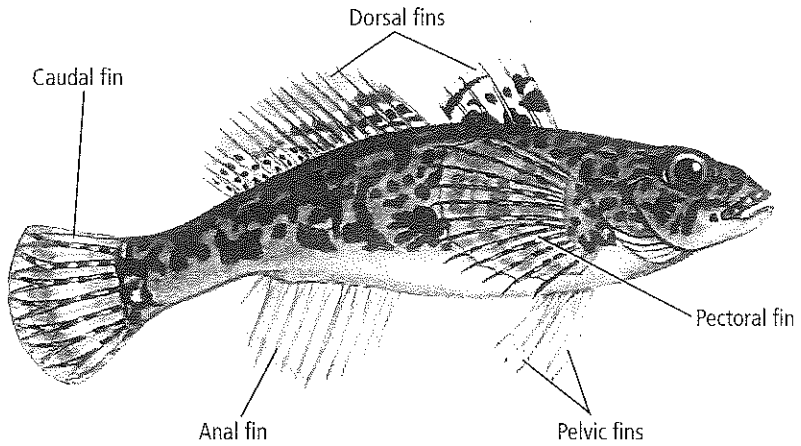


Figure 5 Paired fins, such as pelvic and pectoral fins, allow fishes to maintain balance and to steer in the water.

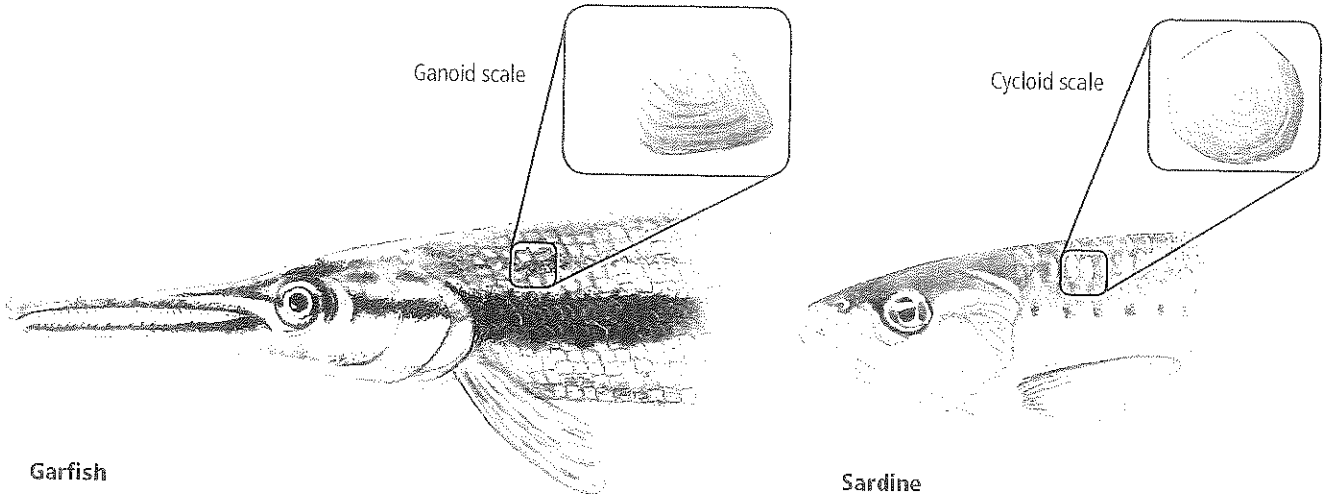


Figure 6 Two types of fishes' scales are shown here—ganoid scales and cycloid scales. **Describe** *the difference in the appearance of cycloid and ganoid scales.*

Scales Most fishes have at least one of four different types of scales. A **scale** is small, flat, platelike structure near the surface of the skin. There are four types of fish scales. Ctenoid (TEH noyd) scales, shown in the photos at the beginning of the chapter, and cycloid (SY kloyd) scales are made of bone and skin and are thin and flexible. Cycloid scales are shown in **Figure 6.** Placoid (PLA koyd) scales, which can be seen in **Figure 15** in Section 2, are made of toothlike materials and are rough and heavy. Ganoid (GAN oyd) scales, shown in **Figure 6,** are diamond-shaped and made of both enamel and bone.

Reading Check **Infer** why different fishes have different kinds of scales.

MiniLab 1

Observe a Fish

MiniLab

What inferences can you make about characteristics of fishes through observation? In this lab, you will observe a fish in its aquatic environment.

Procedure

1. Read and complete the lab safety form.
2. Observe the **fish(es)** in an **aquarium.**
3. Make a diagram of a fish and label the following applicable structures: dorsal fin, caudal fin, anal fin, pectoral fins, pelvic fins, scales, mouth, eye, and gill covering.
4. Observe how the fish moves through the water. Illustrate how the fish moves its body and its fins as it moves forward in the water.

Analysis

1. **Infer** A fish's body is divided into three regions: head, trunk, and tail. Label these regions on your diagram of the fish that you observed.
2. **Apply** Suppose a fish lost one of its pectoral fins when fighting off a predator. How might this affect its ability to move through the water?

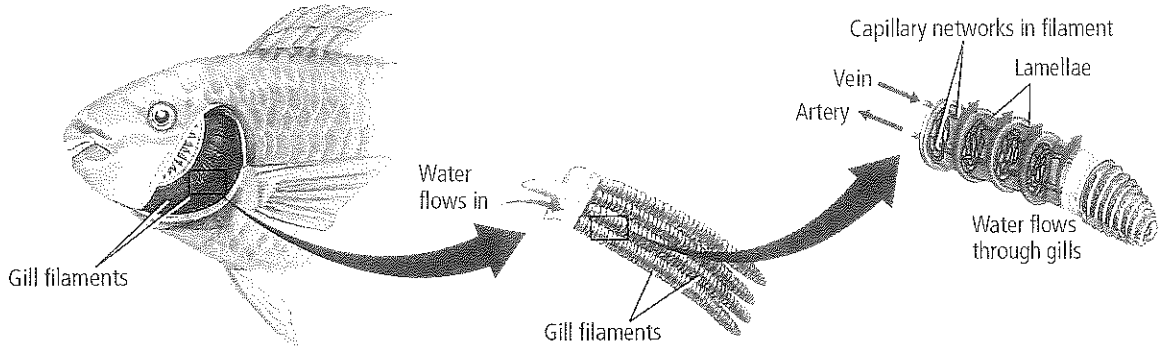


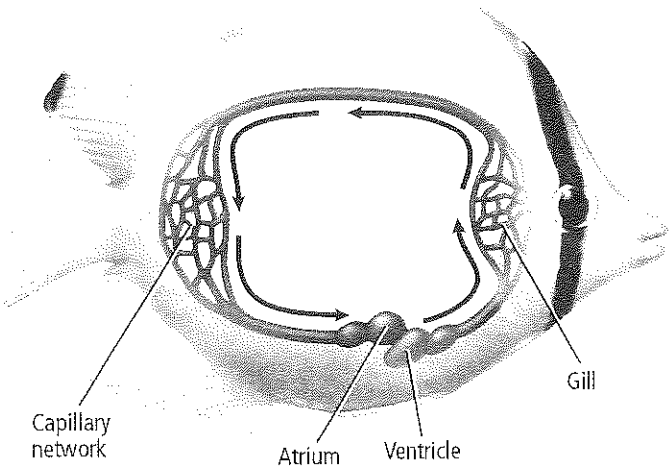
Figure 7 The lamellae in a fish's gills have many blood vessels. Infer *why the gills of fishes are made up of very thin tissue.*

VOCABULARY

Atrium
from the Latin word *atrium*, meaning *central hallway*

Figure 8 A fish's heart pumps blood through a closed circulatory system.

Animation



Gills Another adaptation that allows fishes to live in aquatic environments is their ability to get oxygen from the water. Fishes get oxygen when water that enters their mouths flows across their gills, where oxygen from the water diffuses into the blood. Gills are composed of thin filaments that are covered with highly folded, platelike lamellae (luh MEH lee). The gill structure of most fishes is shown in **Figure 7.** The lamellae have many blood vessels that can take in oxygen and give off carbon dioxide.

The flow of blood in the gill is opposite to the flow of water over the gill surface. This countercurrent flow is an efficient mechanism by which oxygen can be removed from water. Up to 85 percent of oxygen dissolved in water is removed as water flows over the gills in one direction and blood in the other. Some fishes have an **operculum** (oh PUR kyuh lum), a movable flap that covers the gills and protects them. An operculum also aids in pumping water coming in the mouth and over the gills. Some fishes, such as lungfishes, can live out of water for short times by using structures resembling lungs. Eels can breathe through their moist skin when they are not in water.

Circulation Vertebrates have a closed circulatory system in which the heart pumps blood through blood vessels. The circulatory system of fishes is shown in **Figure 8.** In most fishes, the blood is passed through the heart in a one-way loop. From the heart, the blood goes to the gills, and then through the body, delivering oxygenated blood to tissues. The blood then returns to the heart. From the heart, blood is pumped back to the gills and then to the body again. Because this system is a complete and uninterrupted circuit, it is called a single-loop circulatory system.

In most fishes, the heart consists of two main chambers that are analogous to parts of your own heart—an atrium and a ventricle. The **atrium** is the chamber of the heart that receives blood from the body. From there, blood is passed to the **ventricle,** a chamber of the heart that pumps blood from the heart to the gills. Once the blood passes over the gills, it travels to the rest of the body.

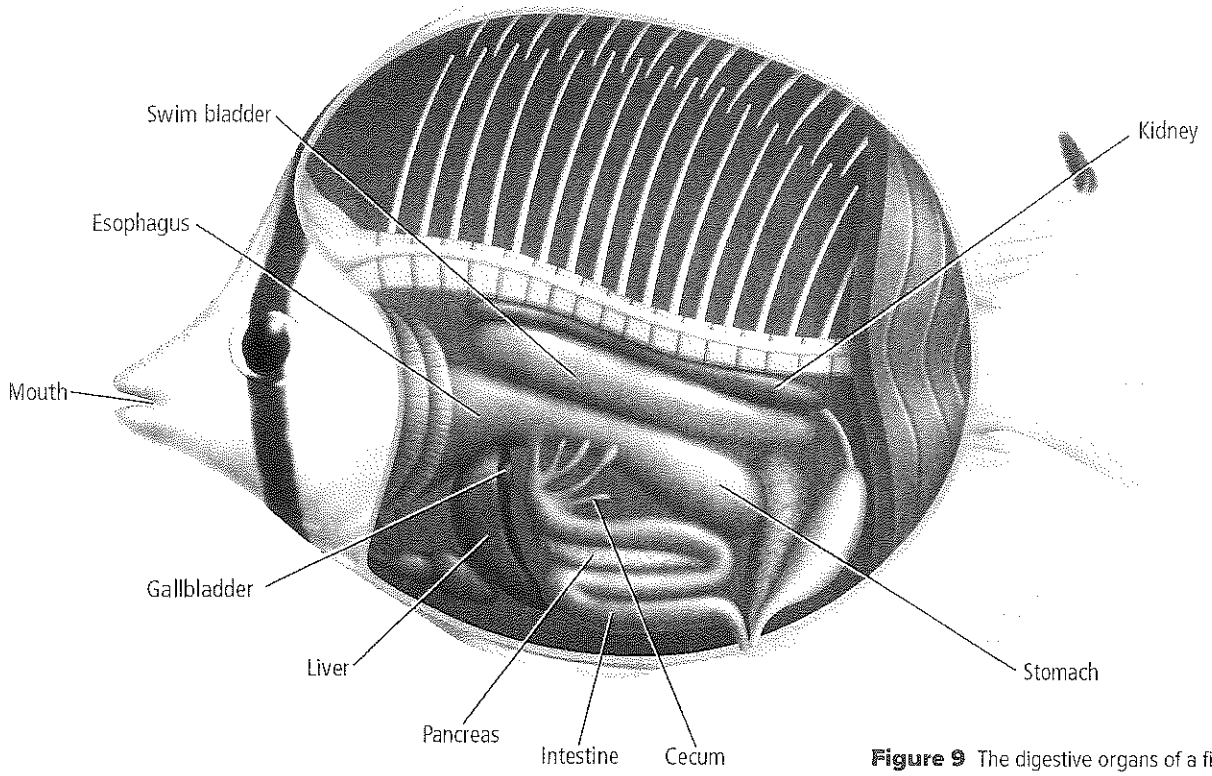


Figure 9 The digestive organs of a fish are similar to those of other vertebrates.
Identify ***the structures that food passes through as it is being digested.***

Feeding and digestion Ancient fishes most likely were filter feeders or scavengers, sucking up organic debris on the ocean floor. With the evolution of jaws, fishes became efficient predators, and the diets of fishes changed dramatically. The digestive tract of fishes, illustrated in **Figure 9,** consists of organs similar to those of other vertebrates.

Most fishes swallow their food whole, passing it 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 at the junction of the stomach and the intestine that secrete enzymes for digestion and absorb nutrients into the bloodstream. The liver, pancreas, and gallbladder add digestive juices that complete digestion.

Fishes are described not only by structures and their functions, but also by one important thing that they cannot do. They are not able to synthesize certain amino acids. Therefore, not only fishes, but also all the vertebrates that evolved from them, must get these amino acids from the foods they eat.

Excretion Cellular wastes are filtered from fishes' blood by organs called kidneys. The main functional unit of the kidney is the nephron. A **nephron** is a filtering unit within the kidney that helps to maintain the salt and water balance of the body and to remove cellular waste products from the blood. Some cellular wastes are excreted by the gills.

Connection to Chemistry The bodies of freshwater fishes take in water by osmosis because the surrounding water is hypotonic–the water contains more water molecules than the fishes' tissues. The opposite occurs in saltwater bony fishes. Because the surrounding water is hypertonic–the water contains fewer water molecules than their tissues–their bodies tend to lose water. Kidneys, gills, and other internal mechanisms adjust the water and salt balance in the bodies of freshwater and saltwater fishes.

CAREERS IN BIOLOGY

Ichthyologist Researching information about the behavior, ecology, and anatomy and physiology of fishes, both in the field and in the lab, is just one of the jobs an ichthyologist (ihk thee AHL uh jist) might have. Ichthyologists also manage aquariums, organize museum collections, teach at universities, and work to conserve fish populations.

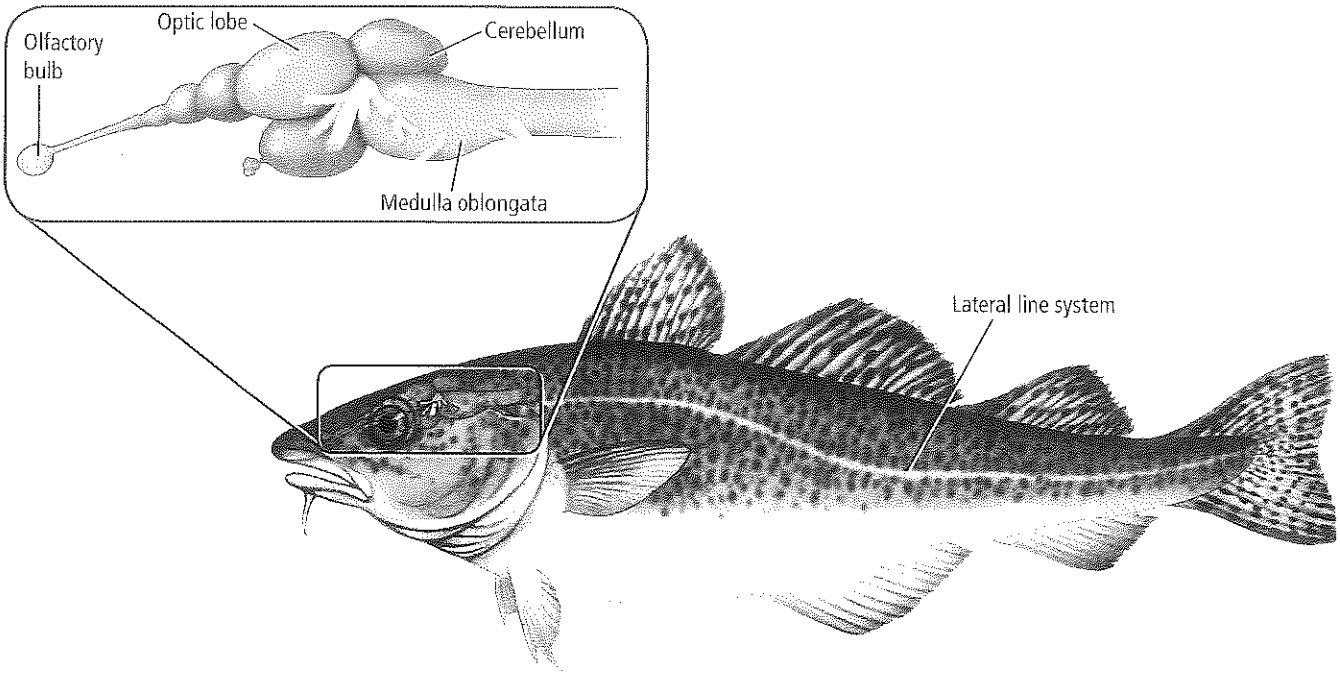


Figure 10 Fishes have a brain that enables them to carry out their life functions. ***Infer** in what way the brain of a fish that lives passively on the bottom of a pond feeding on organic debris would be different from a predatory fish that has to swim swiftly after prey.*

The brain and senses As in other vertebrates, the nervous system of fishes consists of a spinal cord and a brain. A fish brain is shown in **Figure 10.** The cerebellum is involved in coordinating movement and controlling balance. Fishes have receptors for the sense of smell that enable them to detect chemicals in the water. The olfactory (ohl FAK tree) bulbs record and respond to incoming chemical input. Fishes also have color vision. The optic lobes are responsible for visual input. The cerebrum coordinates input from other parts of the brain. Internal organs are under the control of the medulla oblongata.

If you have spent any time fishing, you know that fishes can detect the slightest movement in the water. Fishes can do this because they have special receptors called the lateral line system. The **lateral line system** enables fishes to detect movement in the water and also helps to keep them upright and balanced. You can see the lateral line system of a fish in **Figure 10.**

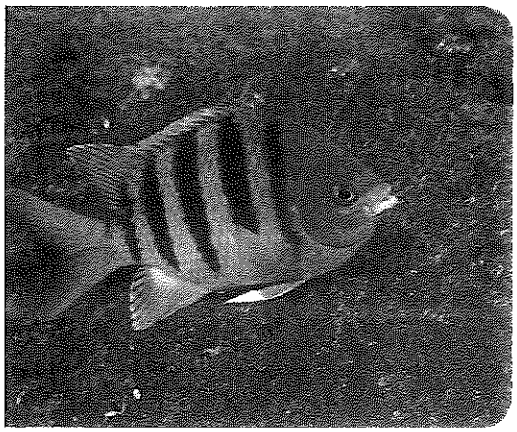


Figure 11 Most fishes do not care for their young; however, male sergeant majors guard the eggs as the embryos develop.

Reproduction The majority of fishes reproduce through external fertilization. Male and female fishes release their gametes near each other in the water in a process called **spawning.** Developing embryos get nutrition from food stored in the yolk of the egg. Some fishes, such as sharks, reproduce through internal fertilization. Although fertilization takes place internally, development of the embryo of some fish species might occur outside of the female's body when fertilized eggs are laid. Some species of fishes have internal fertilization as well as internal development of offspring. In these cases, the developing embryos get nutrition from the female's body.

Fishes that reproduce through external fertilization can produce millions of eggs in a single season. Most fishes do not protect or care for their eggs or offspring. As a result, many eggs and juvenile fishes are prey to other animals. The production of large numbers of eggs ensures that some offspring develop and survive to reproduce. One exception is the male sergeant major fish, shown in **Figure 11.** The male fish guards the fertilized eggs from predators until they hatch.

Andrew J. Martinez/Science Source

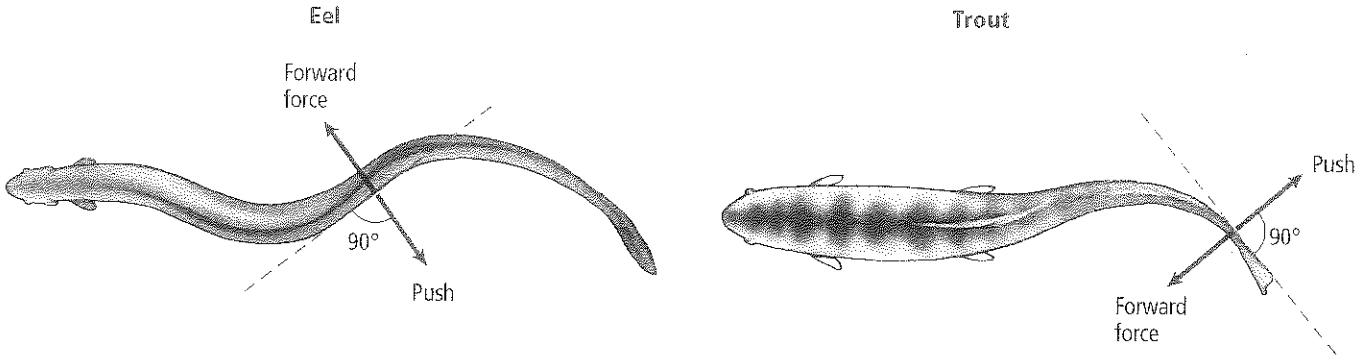


Figure 12 An eel moves its whole body in an S-shaped pattern. Other, faster moving fishes, such as trout, move only their tails as they push forward through the water.

Movement Fishes are well adapted to swimming in water. Most fishes have a streamlined shape. Most also have mucus that lubricates the body surface and reduces friction between the fish and the water. Fins enable fishes to steer and maneuver in a variety of ways. The buoyant force of water reduces the effect of gravity on fishes. In addition, the **swim bladder,** which is shown in **Figure 9,** is a gas-filled space, like a balloon, found in bony fishes that allows a fish to control its depth. When gases diffuse out of the swim bladder, a fish can sink. When gases from the blood diffuse into the swim bladder, a fish can rise in the water column.

Connection to Physics Examine **Figure 12.** Fishes move through the water by contracting muscle groups on either side of their bodies. The arrangement of muscle in a fish allows muscle contraction to bend a large portion of the fish's body. As the body of a fish bends, it pushes against the water, creating an opposing force that moves the fish forward, but at an angle. Alternate contraction of muscles, first on one side of the body and then on the other, keep the fish moving forward in an S-shaped pattern.

Section 1 Assessment

Section Summary

- Vertebrates include fishes, amphibians, reptiles, birds, and mammals.
- All vertebrates have a notochord. In most vertebrates, the notochord is replaced by a vertebral column during embryonic development.
- Fishes share certain characteristics and are therefore classified together.
- The bodies of fishes have unique adaptations that enable them to live their entire lives in water.

Understand Main Ideas

1. **Describe** the characteristics that fishes have that allow them to live and reproduce in water.
2. **Summarize** the features of vertebrates that make them different from invertebrates.
3. **Evaluate** the importance of the evolution of jaws in fishes.
4. **Identify** the characteristics that most fishes have in common.
5. **Explain** why freshwater and saltwater bony fishes have to adjust the balance of salt and water in their bodies.

Think Critically

6. **Hypothesize** Male three-spined stickleback fishes build nests using bright, shiny materials that are in limited supply and are chosen more frequently by females. Form a hypothesis about why this might ensure that a female is choosing a male that has strong traits of his species.
7. **Infer** How might an injury to a fish's lateral line system affect that fish's ability to escape predation?

Online Quiz

Reading Preview

Essential Questions

- What are the characteristics of different groups of fishes?
- What are similarities and differences between the key features of various types of fishes?
- How is the evolution of fishes explained?

Review Vocabulary

adaptive radiation: the process of evolution that produces many species from an ancestral species

New Vocabulary

tetrapod

Multilingual eGlossary

Diversity of Today's Fishes

MAIN Idea **Scientists classify fishes into three groups based on body structure.**

Real-World Reading Link You already know that the basic structures and their functions in fishes are similar. Now think about all the different types of fishes you have seen in aquariums, in photos, or on television.

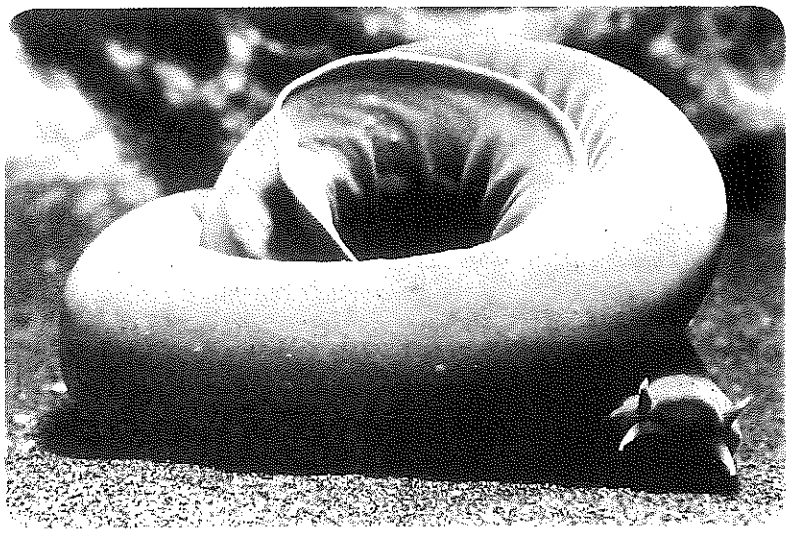
Classes of Fishes

You have read about jellyfish, crayfish, and various shellfish, but none of these are true fishes. True fishes belong to three groups based on their body structure. Hagfishes and lampreys are jawless fishes; sharks, skates, and rays are cartilaginous (kar tuh LAJ uh nus) fishes; and bony fishes include both ray-finned and lobe-finned fishes.

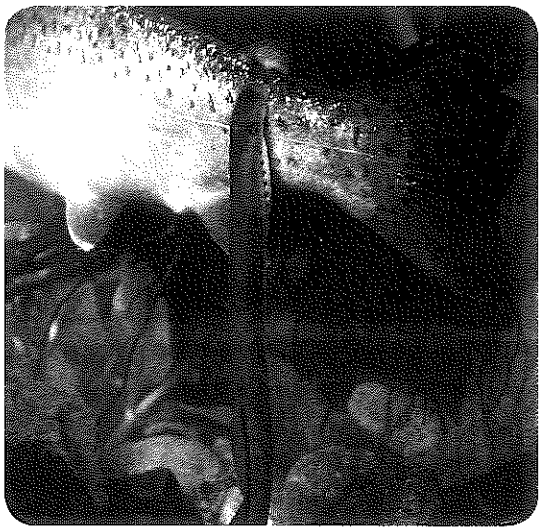
Jawless fishes Hagfishes, as shown in **Figure 13,** are jawless, eel-shaped fishes that do not have scales, paired fins, or a bony skeleton. Members of class Myxini (mik SEE nee), hagfishes have a notochord throughout life. Although they do not develop a vertebral column, they do have gills and many other characteristics of fishes. They live on the seafloor and feed on soft-bodied invertebrates and dead or dying fishes. Even though they are almost blind, their keen chemical sense enables them to locate food. Hagfishes either enter the body of the fish through the mouth or they scrape an opening into the fish with toothlike structures on their tongues. After eating the internal parts of the fish, the hagfish leaves only a sac of skin and bones.

Hagfishes are known for their ability to produce slime. If threatened, they secrete fluid from glands in their skin. When the fluid comes in contact with seawater, it forms a slime that is slippery enough to prevent the hagfishes from being caught by predators.

Figure 13 Hagfishes are jawless fishes that have toothlike structures on their tongues. Lampreys are parasites on other living fishes. Describe ***what adaptations for life on the seafloor you can see in the hagfish photo.***



Hagfish



Lamprey

(t)Sinclair Stammers/Photo Researchers; (r)Hans Reinhard/Photoshot

Lampreys, like hagfishes, also are jawless, eel-shaped fishes that lack scales, paired fins, or a bony skeleton. Lampreys, members of class Cephalaspidomorphi (ceh fah las pe doh MOR fee), retain a notochord throughout life, as do hagfishes. Lampreys have gills and other characteristics of fishes. An adult lamprey, as shown in **Figure 13,** is a parasite that feeds by attaching itself to other fishes. Lampreys use their suckerlike mouth and tongue with toothlike structures to feed on the blood and bodily fluids of their hosts.

Reading Check **List** the characteristics of jawless fishes.

Cartilaginous fishes When you hear the word *shark*, the first thing that might come to mind is a large fish with many sharp teeth. In spite of being famous for teeth, a shark's main distinguishing feature is its skeleton. The skeleton of a shark is made of cartilage, which gives the skeleton flexibility, and calcium carbonate, which gives it strength. All cartilaginous fishes have skeletons made of cartilage.

Sharks belong to class Chondrichthyes (kon DRIK thees). Some species of sharks have several rows of sharp teeth, as shown in **Figure 14.** As teeth are broken or lost, new ones move forward to replace them. Most sharks also have a streamlined shape, with a pointed head and a tail that turns up at the end, as shown in **Figure 15.**

These streamlining features, along with strong swimming muscles and sharp teeth, make sharks one of the top predators in the sea. They can sense chemicals in the water, allowing them to detect prey from a distance of one kilometer. As they move in closer, their lateral line systems can detect vibrations in the water. Finally, when they are in the last stages of pursuit, they use their vision and other receptors to detect the bioelectrical fields given off by all animals. An additional adaptation to a predatory life includes tough skin with placoid scales, shown in **Figure 15.**

Not all sharks have rows of teeth. Whale sharks, the largest living sharks, are filter feeders with specialized straining structures in their mouths. Other sharks have mouths adapted to feeding on shelled mollusks.

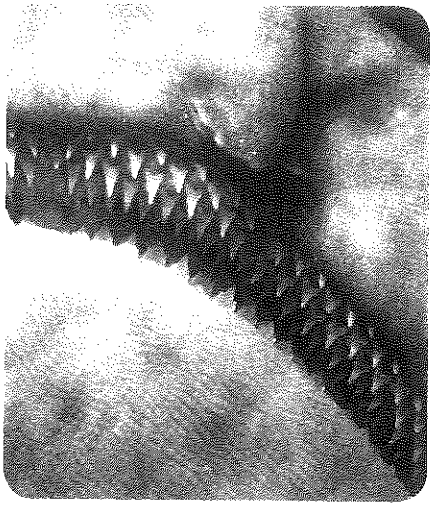
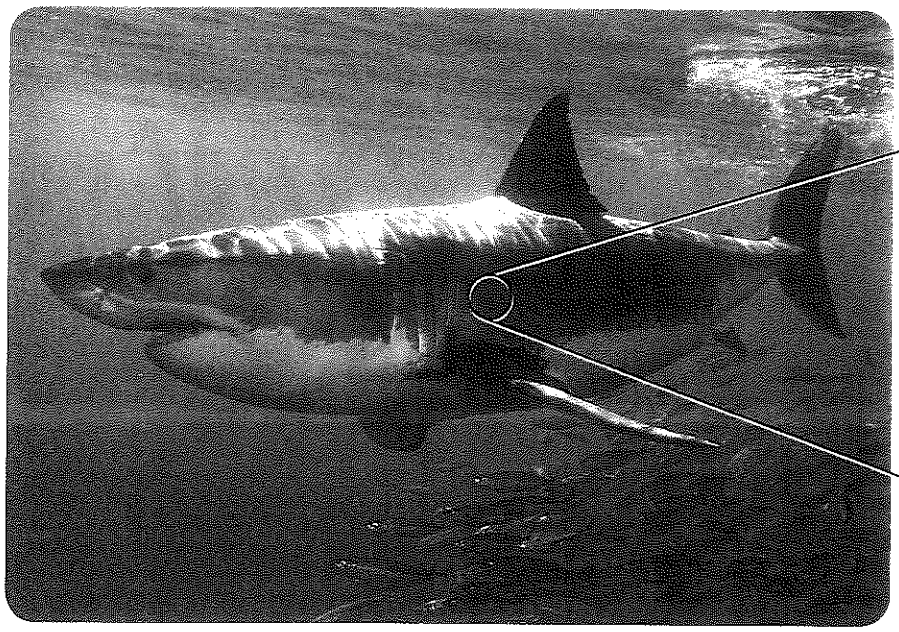


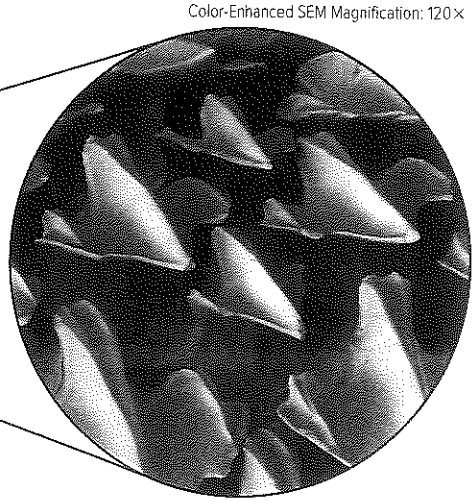
Figure 14 Some sharks have several rows of teeth. As teeth in the front row fall or are pulled out, teeth from the row behind them move up to take their place.



Great white shark

Figure 15 Great white sharks have streamlined bodies and are covered with tough placoid scales.
Infer ***what a shark's skin would feel like if you touched it.***

Color-Enhanced SEM Magnification: 120×



Placoid scales

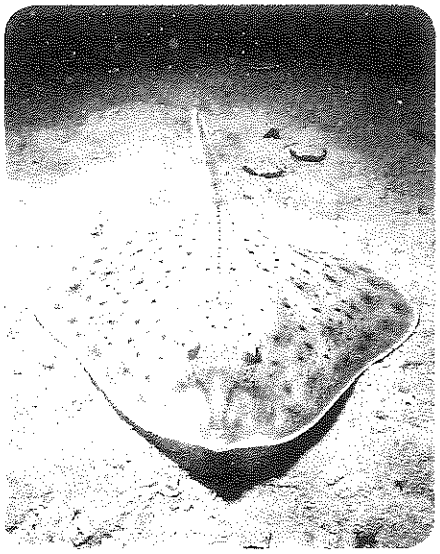


Figure 16 Skates have flattened bodies that are adapted for living on the ocean floor.

Skates and rays are cartilaginous fishes adapted to life on the bottom of the sea. In addition to their flattened bodies, their pectoral fins, shown in **Figure 16,** are enlarged and attached to their heads. Their winglike fins flap slowly as they swim along the seafloor in search of mollusks and crustaceans, which they crush with their teeth.

Bony fishes Class Osteichthyes (ahs tee IHK theez) contains two groups of bony fishes: the ray-finned fishes, belonging to subclass Actinopterygii (AK tihn ahp TUR ee jee i), and the lobe-finned fishes, belonging to the subclass Sarcopterygii (SAR kahp TUR ee jee i). Modern ray-finned fishes have a bony skeleton, ctenoid or cycloid scales, an operculum covering the gills, and a swim bladder. The most distinguishing feature of ray-finned fishes is suggested by their name. The thin membranes of these fishes' fins are supported by thin, spinelike rays, which are shown in **Figure 17.** Most fishes alive today, including salmon and trout, are ray-finned fishes.

There are only eight species of lobe-finned fishes living today. Their fins, shown in **Figure 17,** have muscular lobes and joints similar to those of land vertebrates. This makes the fins more flexible than those of ray-finned fishes. Lobe-finned fishes, such as the lungfish, usually have lungs for gas exchange. When drought occurs, a lungfish can burrow with its fleshy fins into the mud and breathe air. When rain returns, lungfishes come out of their burrows.

Coelacanths (SEE luh kanths) are another small group of lobe-finned fishes that many people thought had become extinct about 70 million years ago. However, in 1938, some people fishing off the coast of South Africa caught a coelacanth. Since that time, other coelacanths have been caught. A third group of lobe-finned fishes, now extinct, is thought to be the ancestor of tetrapods. A **tetrapod,** shown in **Figure 17,** is a four-footed animal with legs that have feet and toes that have joints.

DATA ANALYSIS LAB 1

Based on Real Data*

Analyze Data

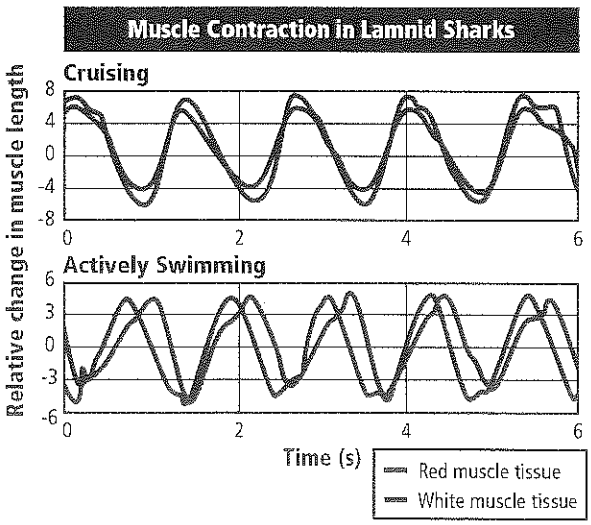
How do sharks' muscles function? Lamnid sharks have two types of muscles. Red muscle tissue does not tire easily and is used more during cruising. White muscle tissue is used more during short bursts of speed. Both muscles, however, are always used at the same time.

Data and Observations

The peaks of the graph represent when each muscle type contracts.

Think Critically

1. **Evaluate** Does the timing of the contractions of the two types of muscle differ when the sharks are cruising?
2. **Compare** How does the timing of the contractions between the two muscle types change when the sharks are actively swimming?



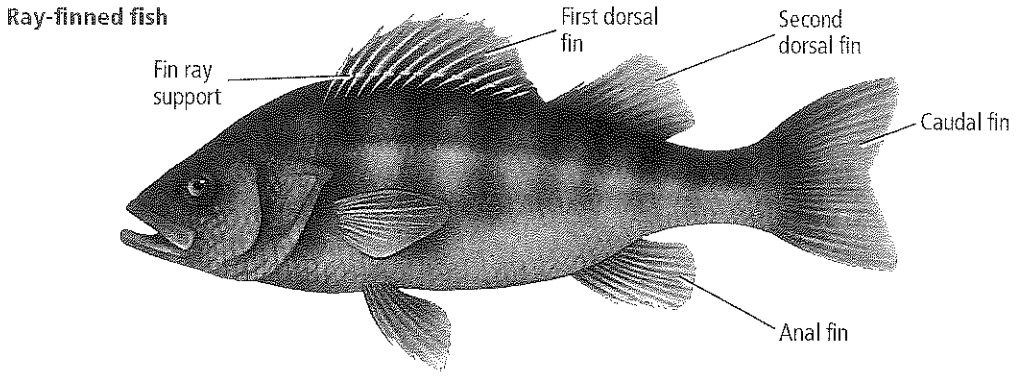
*Data obtained from: Donley, J., et al. 2004 Convergent evolution in mechanical design of lamnid sharks and tunas. *Nature* 429: 61-65.

Jeff Rotman/Photo Researchers

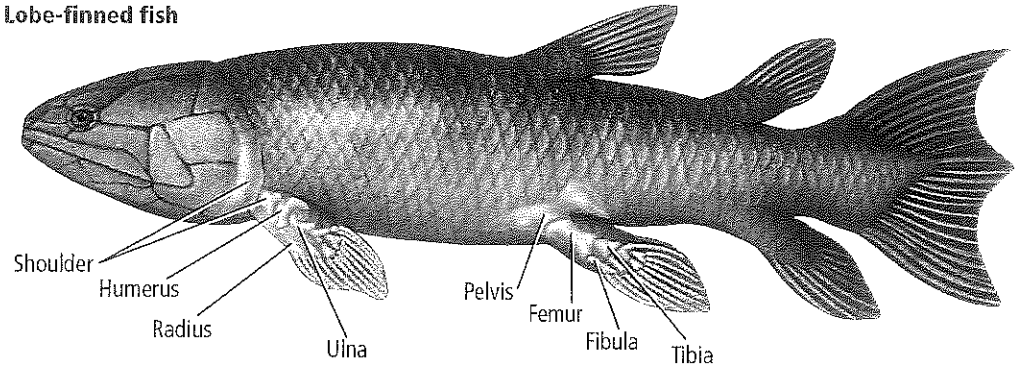
Visualizing Bony Fishes

Figure 17

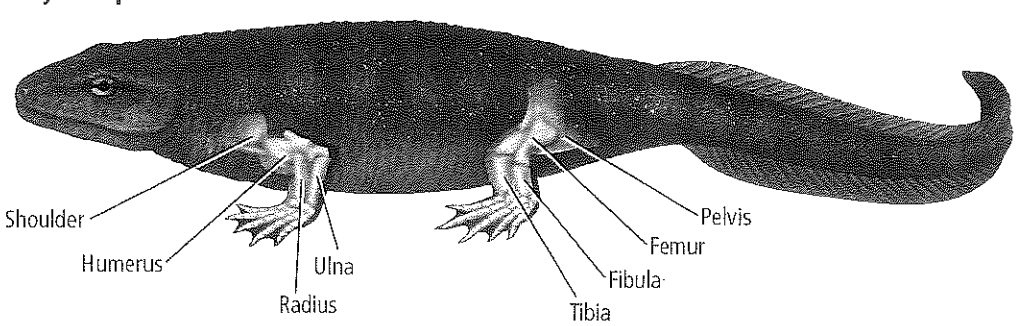
Class Osteichthyes consists of the bony fishes. It can be divided into two subclasses—ray-finned fishes and lobe-finned fishes. An extinct lobe-finned fish is thought to be the ancestor of modern tetrapods.



Ray-finned fishes have thin, spinelike rays that support the membranes of their fins.



Lobe-finned fishes have muscular lobes and joints similar to those of tetrapods.



The limbs of tetrapods evolved from the fins of lobe-finned fishes. *Ichthyostega* was a tetrapod that lived about 325 million years ago, had fully formed limbs, and walked on land.

Animation

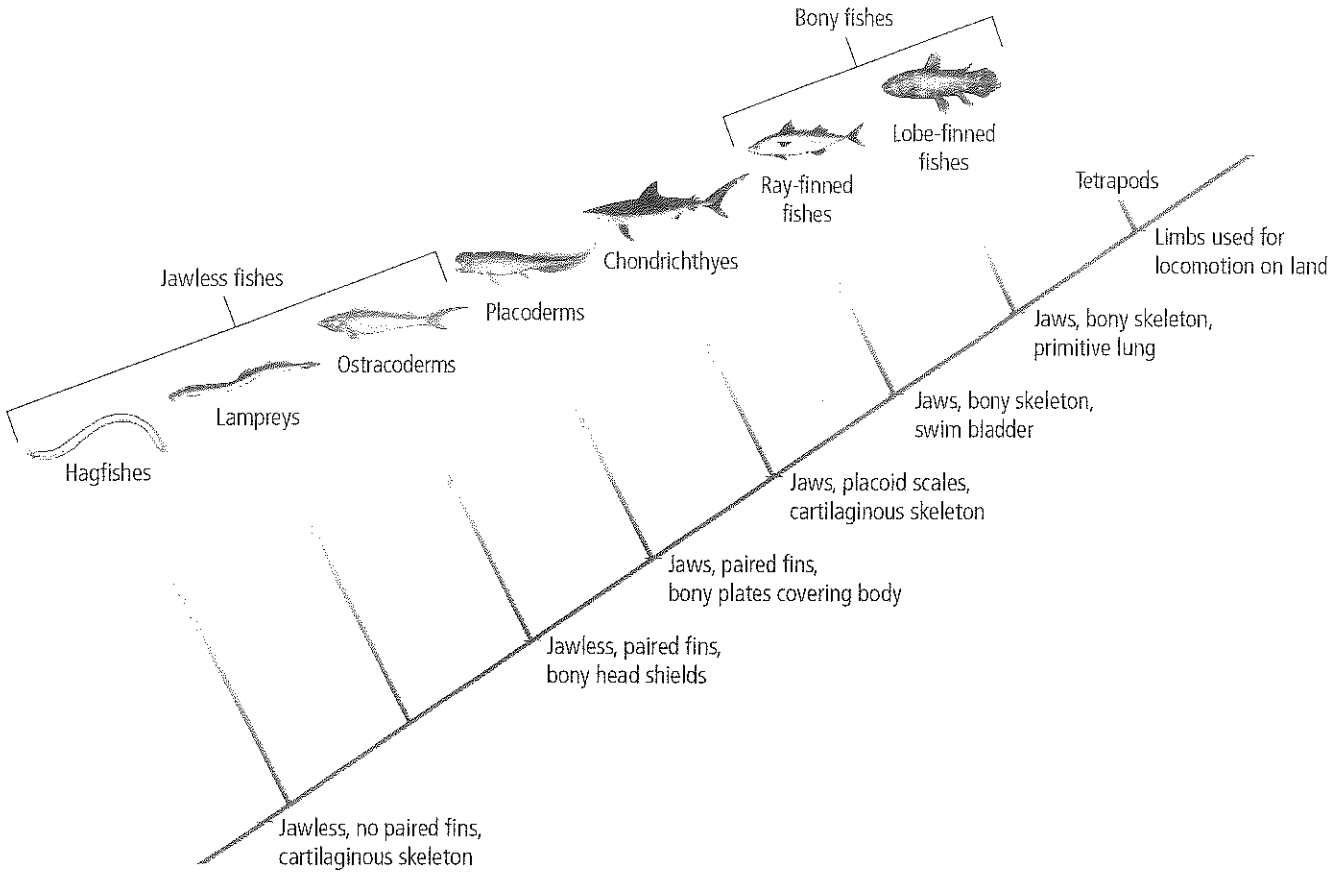


Figure 18 The cladogram shows one interpretation of the phylogeny of fishes. **Identify *which fishes did not have jaws, according to the cladogram.***

Evolution of Fishes

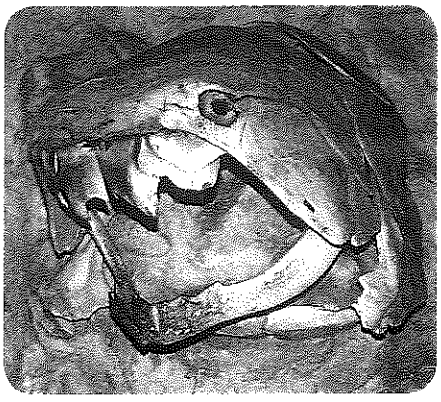
In the ancient seas of the Cambrian period, the first vertebrates wriggled through the water. They were jawless and toothless, but they did have gills, heads, and tails that moved them through the water. The cladogram shown in **Figure 18** is one interpretation of the phylogeny of fishes. As you examine the cladogram, notice the characteristics of fishes that developed during the course of their evolution.

First fishes These first jawless, toothless fishes sucked up organic materials from the ocean floor as if they were miniature vacuum cleaners. Ostracoderms (OS tra koh dermz) were the next group of fishes to appear in the fossil record, in the Ordovician period. Ostracoderms had head shields made of bone, a bony outer covering, and paired fins. They were jawless filter feeders, many of which rested on the bottom of ancient seas.

The bony armor of ostracoderms was an evolutionary milestone in the development of vertebrates. Stronger movement is possible when muscle is attached to bone. Even though ostracoderms became extinct, scientists hypothesize that modern fishes share an ancestry with ostracoderms.

Age of fishes During the Devonian period, modern fishes had their beginnings. Some were jawless, while some, such as the placoderms, had jaws, a covering of bony plates, paired fins, and an internal skeleton. A fossil of a placoderm fish is shown in **Figure 19.** Recall that three of these features are characteristics of the fishes that eventually replaced the placoderms as they became extinct. The Devonian period often is referred to as the Age of Fishes because of the adaptive radiation of fishes that occurred at that time.

Figure 19 *Dinichthys,* also called *Dunkleosteus,* was a placoderm that had armor plating around its head.



Sabena Jane Blackbird/Alamy

Ecology of Fishes

Fishes are an important source of food in all aquatic ecosystems. Yet their freshwater habitats and saltwater habitats are being changed by human activities, such as the damming of rivers and pollution. Fishes are good bioindicators of the environmental health of an aquatic system. When noncommercial fish populations decrease, the main cause often is habitat alteration. When fishes decline in numbers, not only are there negative human economic impacts, but also, ecosystems can become unbalanced.

Habitat alteration Some fishes, such as salmon, migrate. Salmon spend their adult lives in the ocean but return to freshwater to spawn in the streams where they hatched. In the Pacific Northwest, river and stream habitats have been changed by the construction of dams. Dams interfere with the upstream and downstream migration of salmon, as shown in **Figure 20.** The end result in the Pacific Northwest, for example, is that the number of salmon swimming upstream now is only about three percent of the 10 to 16 million salmon that swam up the rivers 150 years ago.

Pollution The habitats of fishes can be changed by pollution, which can reduce the quality of water in lakes, rivers, and streams. This can result in a decline in both the number and diversity of fishes in an area. In some cases, when the cause of habitat alteration is stopped and suitable conditions return, fishes also return. For example, Atlantic salmon were not observed in the Penobscot River in Maine for ten years during a time when intense pollution altered water quality. When the pollution was stopped, the salmon returned.

Figure 20 Not all salmon are able to get over the dams used to generate hydroelectricity. To spawn, salmon must return to the streams where they hatched.

Launch Lab

Review Based on what you have read about different fishes, how would you now answer the analysis questions?

Section 2 Assessment

Section Summary

- Fishes can be placed into one of three main groups—jawless, cartilaginous, and bony.
- Hagfishes and lampreys are examples of jawless fishes.
- Sharks, rays, and skates are examples of cartilaginous fishes.
- Bony fishes consist of two subclasses—ray-finned fishes and lobe-finned fishes.
- Ancient extinct fishes had features that enabled them to evolve into modern fishes.
- Habitat alteration and pollution can negatively affect fish populations.

Understand Main Ideas

1. MAIN Idea **Compare and contrast** the structures of jawless fishes, cartilaginous fishes, and bony fishes.
2. **Identify** the characteristics of the two subclasses of bony fishes.
3. **Sketch** the basic shape that represents each of the three main groups of fishes.
4. **Describe** the evolutionary sequence of the different groups of fishes.
5. **Hypothesize** Bony fishes have either cycloid or ctenoid scales. Form a hypothesis that explains how scale type is related to diversity.

Think Critically

MATH in Biology

6. The number of fish species often decreases as latitude increases. In fact, the number of fish species in tropical lakes is much greater than the number of fish species in temperate lakes. Suggest a hypothesis that accounts for this mathematical phenomenon.

Online Quiz

Reading Preview

Essential Questions

- What were the kinds of adaptations that were important as animals moved to the land?
- What are the characteristics of amphibians?
- What are the differences between the orders of amphibians?

Review Vocabulary

metamorphosis: a series of developmental changes in the form or structure of an organism

New Vocabulary

cloaca
nictitating membrane
tympanic membrane
ectotherm

Multilingual eGlossary

Amphibians

Most amphibians begin life as aquatic organisms and then live on land as adults.

Real-World Reading Link Think about the last time you went swimming. How is moving in water different from moving on land? Just as fishes have adaptations for living in water, tetrapods have adaptations for living on land.

Evolution of Tetrapods

Tetrapods are four-legged vertebrates that first appeared on Earth 360 million years ago. Modern amphibians are descendants of these early tetrapods. Examine the evolutionary tree in **Figure 21** to see how amphibians are related to other vertebrates. As millions of years passed, animals adapted to the conditions of life on land.

The move to land Animals faced several physical challenges in the move from water to land. **Table 1** lists some of the differences between conditions of life in the water and life on land. These differences include buoyancy, oxygen concentration, and temperature. **Table 1** also gives examples of how terrestrial vertebrates adapted to life on land.

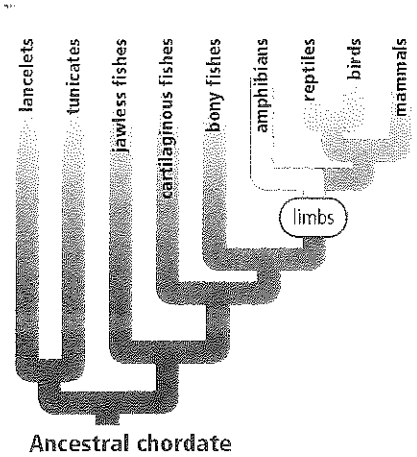


Figure 21 The evolutionary tree shows how amphibians are related to other vertebrates.

Table 1 Adaptations to Land — Interactive Table

Conditions in Water	Conditions on Land	Terrestrial Vertebrate Adaptations
Water exerts a buoyant force that counters the force of gravity.	• Air is about 1000 times less buoyant than water. • Animals must move against gravity.	Limbs develop and the skeletal and muscular systems of terrestrial animals become stronger.
Oxygen is dissolved in water and must be removed by gills through countercurrent circulation.	• Oxygen is at least 20 times more available in air than in water.	With lungs, terrestrial animals can get oxygen from air more efficiently than from water.
Water retains heat, so the temperature of water does not change quickly.	• Air temperature changes more easily than water temperature. • Daily temperatures can change by 10°C between day and night.	Terrestrial animals develop behavioral and physical adaptations to protect themselves from extreme temperatures.

In addition to the differences listed in **Table 1**, another difference between conditions in water and on land is that sound travels more quickly through water. Fishes use lateral line systems to sense vibrations, or sound waves, in water. A lateral line system is not effective in air. The ears of terrestrial vertebrates evolved to sense sound waves traveling through air.

Terrestrial habitats In spite of the challenges associated with terrestrial life, there are many habitats available to animals on land. The different biomes on land, including tropical rain forests, temperate forests, grasslands, deserts, taiga, and tundra, provide suitable habitats for animals with appropriate adaptations.

Characteristics of Amphibians

Have you ever watched a tadpole in a jar of pond water? Examine and describe the tadpole in **Figure 22.** A tadpole is the limbless, gill-breathing, fishlike larva of a frog. Day by day, the tadpole undergoes metamorphosis (me tuh MOR fuh sihs)–hind legs form and grow lon-ger, the tail shortens, gills are replaced by lungs, and forelimbs sprout. In just a few weeks or months, depending on the species, the tadpole becomes an adult frog. Most amphibians begin life as aquatic organisms. After metamorphosis, they are equipped to live life on land.

Modern amphibians include frogs, toads, salamanders, newts, and legless caecilians. Most amphibians are characterized by having four legs, moist skin with no scales, gas exchange through the skin, lungs, a double-loop circulatory system, and aquatic larvae.

Feeding and digestion Most frog larvae are herbivores, whereas salamander larvae are carnivores. However, as adults, their diets are similar as both groups become predators and feed on a variety of invertebrates and small vertebrates. Some salamanders and legless amphibians use just their jaws to catch prey. Others, such as frogs and toads, can flick out their long, sticky tongues with great speed and accuracy to catch flying prey.

Food moves from the mouth through the esophagus to the stomach, where digestion begins. From the stomach, food moves to the small intestine, which receives enzymes from the pancreas to digest food. From the intestine, food is absorbed into the bloodstream and delivered to body cells. Food moves from the small intestine into the large intestine before waste material is eliminated. At the end of the intestine is a chamber called the cloaca. The **cloaca** (kloh AY kuh) is a chamber that receives the digestive wastes, urinary waste, and eggs or sperm before they leave the body.

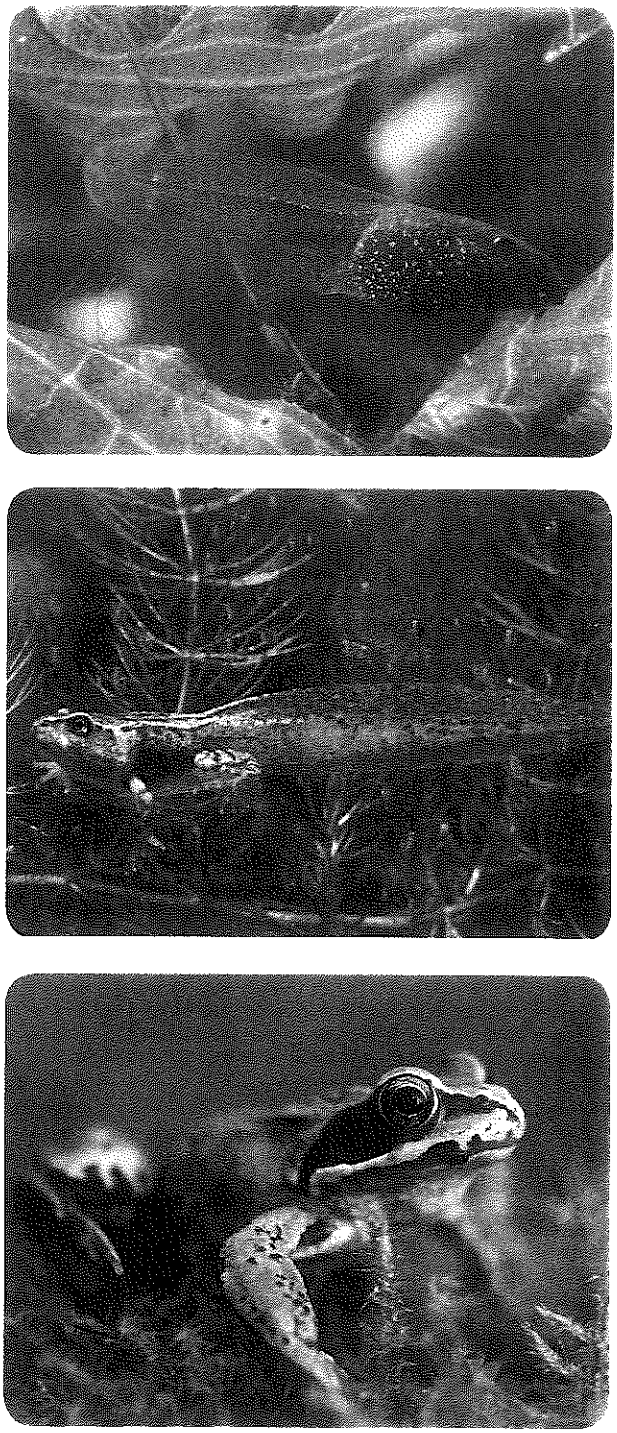


Figure 22 This common frog undergoes metamorphosis. As an adult it lives on land.
Top: A tadpole is limbless.
Middle: The tadpole is undergoing metamorphosis to become an adult frog. Notice the development of limbs.
Bottom: An adult frog has fully developed limbs and lacks a tail.

Animation

Excretion Amphibians filter wastes from the blood through their kidneys and excrete either ammonia or urea as the waste product of cellular metabolism. Ammonia is the end product of protein metabolism and is excreted by amphibians that live in water. Amphibians that live on land excrete urea that is made from ammonia in the liver. Unlike ammonia, urea is stored in the urinary bladder until it is eliminated from the body through the cloaca.

Respiration and circulation As larvae, most amphibians exchange gases through their skin and gills. As adults, most breathe through lungs, through their thin, moist skin, and through the lining of the mouth cavities. Frogs can breathe through their skin either in or out of water. This ability enables them to spend the winter protected from the cold in the mud at the bottom of a pond.

The circulatory system of amphibians is shown in **Figure 23.** It consists of a double loop instead of the single loop you learned about in fishes. The first loop moves oxygen-poor blood from the heart to pick up oxygen in the lungs and skin, and then moves the oxygen-filled blood back to the heart. During circulation in the second loop, blood filled with oxygen moves from the heart through vessels to the body, where the oxygen diffuses into cells.

Amphibians have three-chambered hearts. The atrium is completely separated into two atria by tissue. The right atrium receives deoxygenated blood from the body, while the left atrium receives oxygenated blood from the lungs. The ventricle of amphibians remains undivided.

Reading Check **Describe** how the amphibian circulatory system is adapted to life on land.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

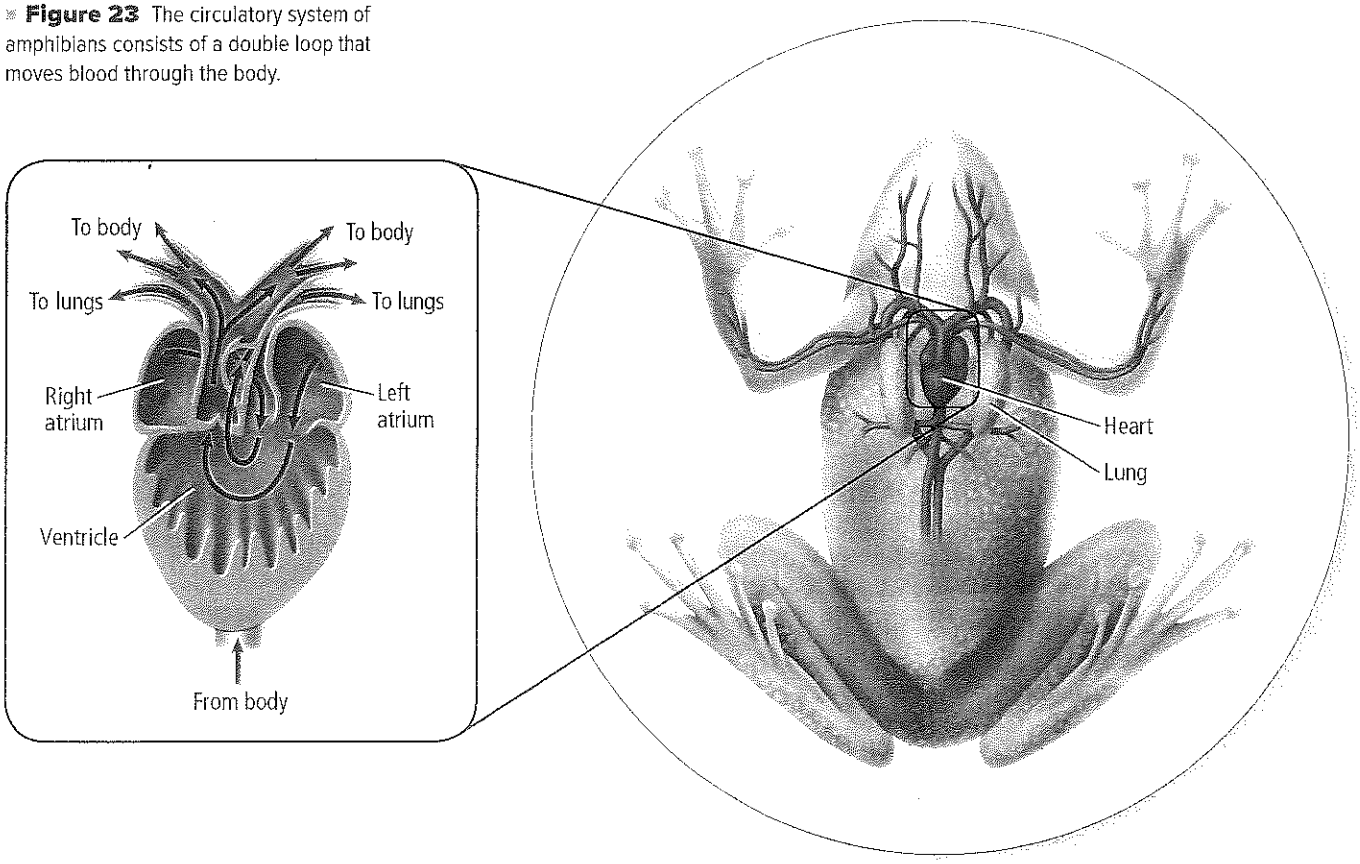
Amphibian

Science usage: any organism that is a member of class Amphibia; most spend part of their lives in water and part on land
A frog is an amphibian.

Common usage: an airplane designed to take off from and land on either land or water
The amphibian landed smoothly on the lake.

Interactive Dissection

Figure 23 The circulatory system of amphibians consists of a double loop that moves blood through the body.



The brain and senses Like fishes, the nervous systems of amphibians are well developed. The differences in conditions between life in the water and life on land are reflected in the differences between the brains of fishes and those of amphibians. For example, the forebrain of frogs contains an area that is involved with the detection of odors in the air. The cerebellum, which is important in maintaining balance in fishes, is not as well developed in terrestrial amphibians that stay close to the ground.

Vision is an important sense for most amphibians. They use sight to locate and capture prey that fly at high speeds and to escape predators. Frogs' eyes have structures called nictitating (NIK tuh tayt ing) membranes. The **nictitating membrane** is a transparent eyelid that can move across the eye to protect it underwater and keep it from drying out on land.

The amphibian ear also shows adaptation to life on land. The **tympanic** (tihm PA nihk) **membrane** is an eardrum. In frogs, it is a thin external membrane on the side of the head, as shown in **Figure 24.** Frogs use their tympanic membrane to hear high-pitched sounds and to amplify sounds from the vocal cords. Other senses in amphibians include touch, chemical receptors in the skin, taste buds on the tongue, and sense of smell in the nasal cavity.

It is important for amphibians to sense the temperature of their environment because they are ectotherms. **Ectotherms** are animals that obtain their body heat from the external environment. Ectotherms cannot regulate their body temperatures through their metabolism, so they must be able to sense where they can go to get warm or to cool down. For example, if it is cold, a toad can find a warm rock on which to bask and warm itself.

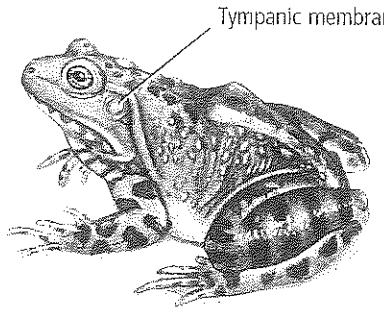


Figure 24 The tympanic membrane is an adaptation for life on land.

Animation

DATA ANALYSIS LAB 2

Based on Real Data*

Interpret a Graph

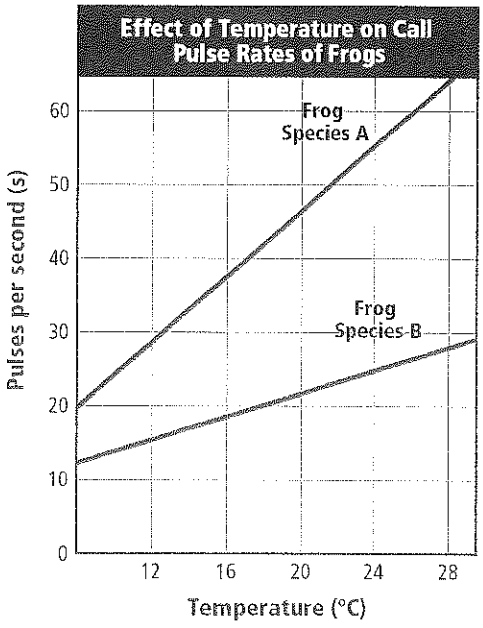
How does temperature affect the pulse rate of calling in tree frogs? Male tree frogs make calls that females can identify easily based on the rate of the sound pulses in the call.

Data and Observations

The graph shows the pulse rate of two species of frogs versus temperature.

Think Critically

1. **Interpret Data** What is the relationship between sound pulses and temperature?
2. **Compare** How did temperature affect the rate of pulses in species A and in species B?
3. **Infer** Why is it important that the two species of frogs do not have the same pulse rate in their calls at the same temperature?



*Data obtained from: Gerhardt, H.C. 1978. Temperature coupling in the vocal communication system in the grey treefrog *Hyla versicolor*. *Science* 199: 992–994.

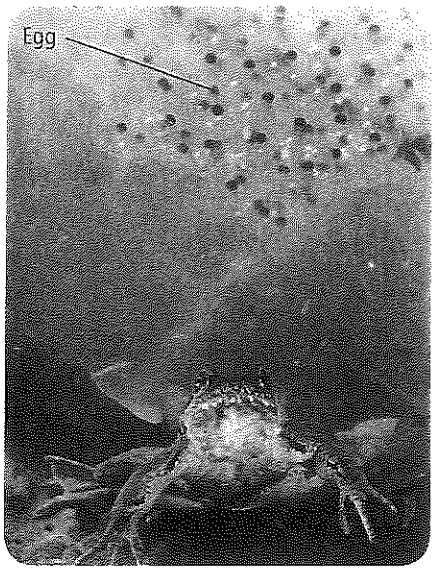


Figure 25 Amphibian eggs do not have shells that would protect them from drying out. **Infer** *what adaptation ensures that amphibian eggs do not dry out.*

Reproduction and development Like many amphibians, female frogs lay eggs in the water to be fertilized by males. The eggs do not have shells or protective coverings to keep them from drying out. The eggs, like the ones shown in **Figure 25,** are covered with a sticky, jellylike substance that helps them stay anchored to vegetation in the water. After fertilization, the developing embryo uses the yolk in the egg for nourishment until it hatches into a tadpole. A tadpole, like the one shown in **Figure 22,** changes from a gill-breathing, legless herbivore with fins and a two-chambered heart into a lung-breathing, four-legged carnivore with a three-chambered heart. The stages of metamorphosis are primarily under the control of chemicals released within the tadpole's body.

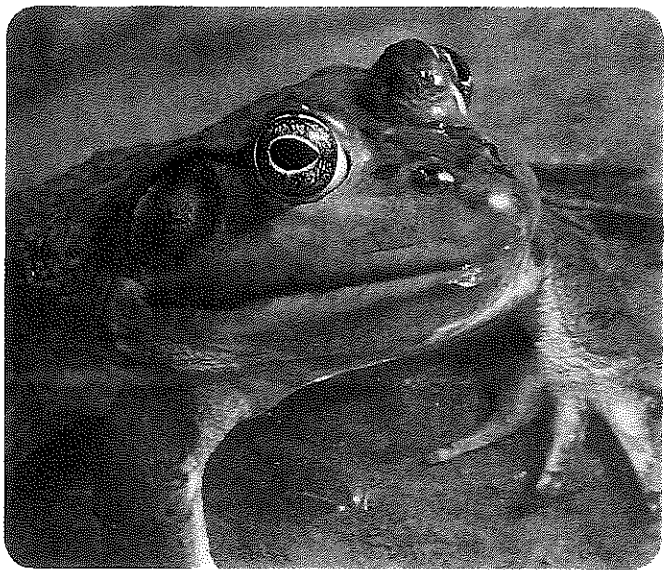
Amphibian Diversity

Biologists classify modern amphibians into three orders. Order Anura (a NOOR ah) contains 4200 species of frogs and toads. Order Caudata (kaw DAY tah) has about 400 species of salamanders and newts. One hundred and fifty species of wormlike caecilians make up order Gymnophiona (JIHM noh fee oh nah). Frogs, toads, and salamanders live in moist areas in a variety of habitats, while newts are aquatic. Caecilians are tropical burrowing animals.

Frogs and toads Frogs and toads, shown in **Figure 26,** lack tails and have long legs, enabling them to jump. Frogs have longer and more powerful legs than toads and are able to make more powerful jumps than the small hops of toads. Frogs have moist, smooth skin, while the skin of toads tends to be bumpy and dry. Although both need to be near water to carry out reproduction, toads generally live farther away from water than do frogs. Another difference between frogs and toads is that toads have kidney-bean-shaped glands near the back of their heads that release a foul-tasting poison. The poison discourages predators from eating them.

Reading Check **Compare and contrast** the characteristics of frogs and toads.

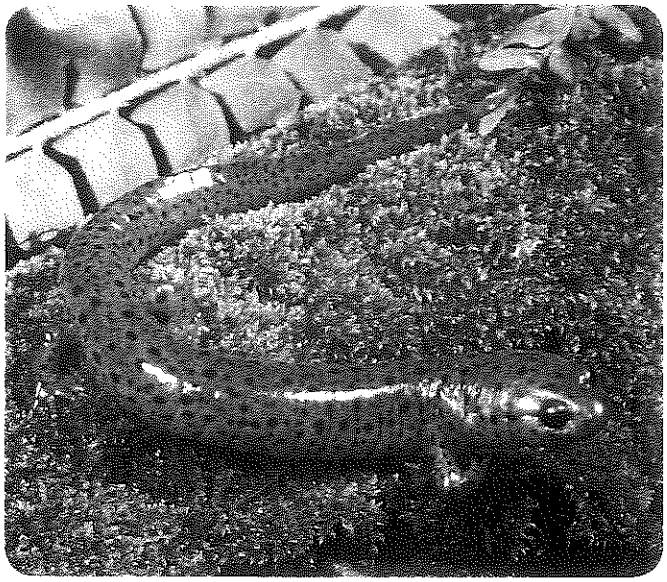
Figure 26 The bullfrog has moist, smooth skin compared to the skin of the American toad, which is dry and bumpy.



Bullfrog

American toad

(t)FLPA/Fabio Pupin/age fotostock; (b)Dazz DeLaMorte/Cutcaster; (br)altrendo nature/Getty Images



Red salamander

Warty newt

Figure 27 The red salamander is found in the eastern United States. The warty newt breeds in deep ponds that contain aquatic vegetation.

Salamanders and Newts Unlike frogs and toads, salamanders and newts have long, slim bodies with necks and tails, as shown in **Figure 27.** Most salamanders have four legs and thin, moist skin, and they cannot live far from water. Like frogs, most salamanders lay their eggs in water. The larvae look like miniature salamanders, except that they have gills. Newts, like the one in **Figure 27,** generally are aquatic throughout their lives, while most salamanders, as adults, live in moist areas such as under logs or in leaf litter. Salamanders range in size from about 15 cm long to the giant salamander that is 1.5 m long. An adult salamander's diet consists of worms, frog eggs, insects, and other invertebrates.

Caecilians Caecilians (si SILH yenz) are different from other amphibians because they are legless and wormlike, as shown in **Figure 28.** They burrow in the soil and feed on worms and other invertebrates. Skin covers the eyes of many caecilians, so they might be nearly blind. All caecilians have internal fertilization. They lay their eggs in moist soil located near water. Caecilians can be found in the tropical forests of South America, Africa, and Asia.

CAREERS IN BIOLOGY

Animal Curator An animal curator works at a zoo, managing some part of the zoo's animal collection, such as the amphibian exhibit. Curators work together to decide the best way to maintain an animal's habitat in the zoo.

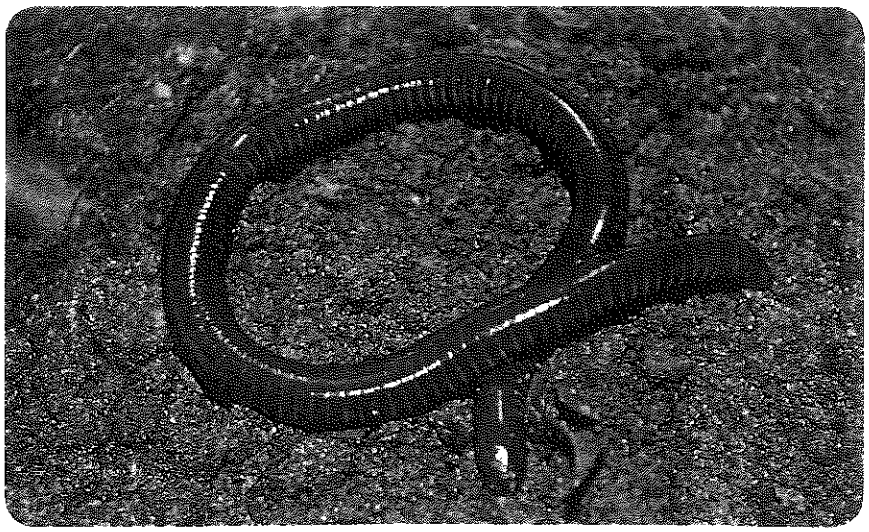


Figure 28 Caecilians do not have ear openings. It is not known if, or how, they can hear sounds.

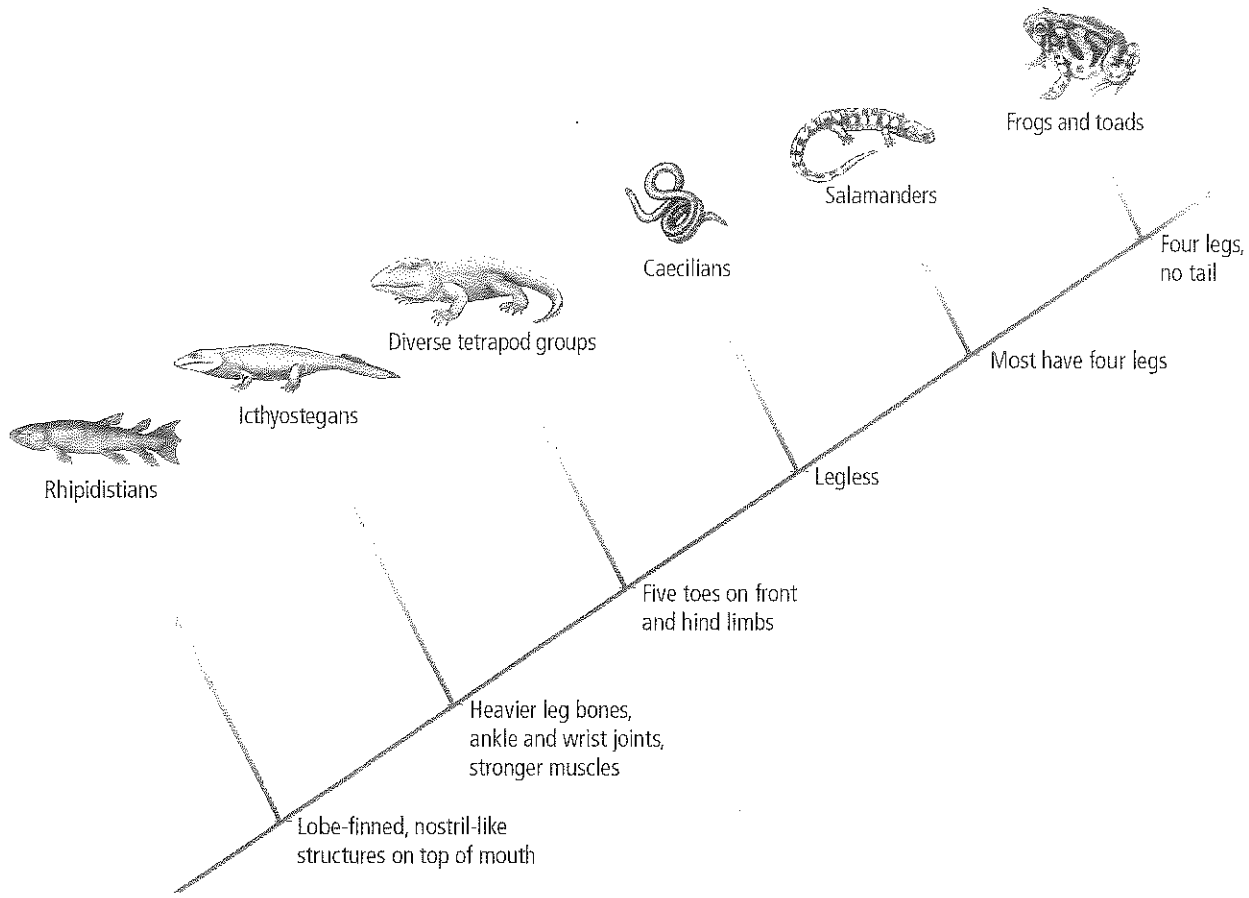


Figure 29 The cladogram shows one interpretation of amphibian evolution.
Interpret ***which modern amphibians are more closely related to the first tetrapods.***

Virtual Lab

VOCABULARY

ACADEMIC VOCABULARY

Diversify
to produce variety
The bakery diversified the flavors of doughnuts it made, giving customers more choices.

Evolution of Amphibians

Fossil evidence shows that the first tetrapods evolved limbs in water before they moved to land. Many adaptations that are useful on land first evolved in water. For example, legs with feet and toes could be helpful in moving through bottom vegetation. Ankles and wrists might have increased maneuverability. The attachment of hip bones to the vertebral column might have helped predators attack prey more easily.

The cladogram shown in **Figure 29** is one interpretation of the evolution of amphibians. Many scientists think that early tetrapods are most closely related to a group of now extinct, lobe-finned fishes called rhipidistians (RI pih dihs tee unz). Characteristics that both early tetrapods and rhipidistians share include similar bone structure in the skull and limbs, nostril-like openings in the tops of their mouths, and a similar tooth structure.

Early tetrapods had defined legs with feet, but the construction of the legs was too weak for these animals to walk easily on land. Ichthyostegans, as shown in **Figure 17,** had more support in the shoulder bones, heavier leg bones, and more muscular features that enabled them to pull themselves onto land and move a little more easily. The skull had the same general shape as the skulls of lobe-finned fishes. Tetrapod groups branched out to produce the three major groups of amphibians alive today, as well as reptiles, birds, and mammals.

Reading Check **Explain** why scientists think that tetrapods evolved from rhipidistians.

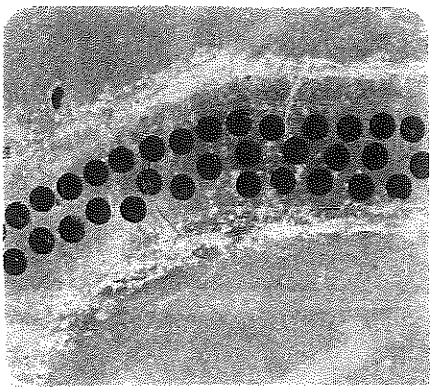
Ecology of Amphibians

In recent decades, amphibian populations have been declining worldwide. Scientists have been collecting data to determine possible causes for the decline. The results have varied. In some cases, the cause can be isolated to a local condition. In other cases, the cause might be the result of several factors occurring on a large scale.

Local factors In some cases, such as that of the California red-legged frog, the decline is due to habitat destruction. When wetlands are drained and buildings are built in the areas instead, these areas of water are no longer available to amphibians that must lay eggs in or near water to reproduce successfully. In other areas, the introduction of exotic species–species that are not found in that area naturally–has affected amphibian populations. The exotic species compete with the amphibians for food and habitat space, or they are predators of amphibians. The introduction of trout, which prey on tadpoles, into the high-altitude lakes of Califor-nia's Sierra Nevada Mountains is thought to have contributed to the near extinction of the mountain yellow-legged frog found in that region.

Global factors In addition to local factors, various global factors might be causing amphibian decline. Aspects of global climate change, such as increased temperature, decreased soil moisture, increased length of the dry season, and changes in rainfall can cause either death or stress to the bodies of amphibians, making them more susceptible to disease.

Figure 30 compares healthy toad eggs with eggs infected by a fungus. Some scientists think that global climate changes that have led to a decreased amount of rainfall leave developing amphibians' eggs in shallow pond water. Because the depth of the water is reduced, the eggs are exposed to more ultraviolet light. Laboratory experiments have shown that increased exposure to UV light leads to an increased risk of fungal infection in amphibian eggs.



Healthy toad eggs

Fungus-infected toad eggs

Figure 30 Healthy toad eggs are laid in single file in the water. Infected toad eggs are covered by fungus; fungal infection might account for a decrease in some toad populations.

Section 3 Assessment

Section Summary

- The transition of animals to land required a variety of adaptations.
- The bodies of amphibians have unique adaptations that enable them to live on land.
- Amphibians belong to three orders based on structural similarities.
- Ancient tetrapods evolved aquatic adaptations that they eventually used on land.
- Amphibian populations are declining worldwide for a variety of reasons.

Understand Main Ideas

1. **Summarize** the adaptations of amphibians that make them adapted to life on land.
2. **Compare** the conditions of a land environment to that of an aquatic environment.
3. **Analyze** the kinds of adaptations that were important as animals moved to land.
4. **Summarize** the characteristics of each order of amphibians.

Think Critically

5. **Interpret Scientific Illustrations** Examine **Figure 29** and explain which of the three groups of amphibians is the most recent and which is the most ancient.

WRITING in Biology

6. On a hike in a marshy area near your home, you find a dead frog with deformed limbs. Hypothesize possible reasons why these deformities might have occurred.

Online Quiz

BioDiscoveries

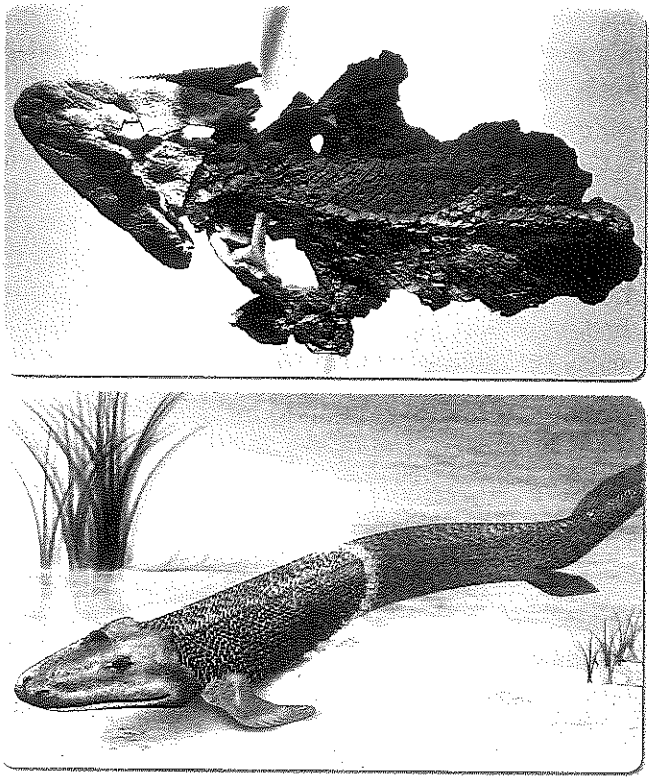
A Fish... with Legs?

Millions of years ago, a fish braced itself on its fins, pushed its head above water, took a deep breath—and vaulted into evolutionary history. Many scientists hypothesize the "fishapod" (*Tiktaalik roseae*) is a link between fish and the first tetrapods. The fishapod was first discovered in 2004, embedded in a rock formation on Ellesmere Island, a Canadian island in the Arctic Circle. To date, scientists have unearthed 10 separate fishapod fossils.

Why move onto land? At the time of the fishapods, around 375 million years ago, Ellesmere Island was part of a landmass located near the equator. Scientists think the danger of predators and fierce competition for food in deep-water environments favored adaptations that allowed animals to live in shallow water and, eventually, on land.

Not really a fish Although it has fish characteristics, *Tiktaalik roseae* also has a number of features that differentiate it from fish. First, its pectoral fins contain a wrist-like, jointed bone structure and five digit bones. Scientists hypothesize that the fishapod used its strong fins to move through the shallow waters. It also used its fins to push itself above the surface of the water to look for food and to breathe air.

Like many primitive fish, the fishapod had both gills and lungs and it used them both to breathe. It also had a big, strong rib cage that suggests two things: the rib cage made room for and protected lungs, and it supported the fishapod's body when it pushed up on its fins. The fishapod's eyes were located on top of its large, broad head, much like a crocodile. Its head was separated from its shoulders by a neck, while the skulls of fish are connected directly to their shoulders. These characteristics enabled the fishapod to turn and lift its head.



Scientists think that *Tiktaalik roseae* is the evolutionary link between fish and the first tetrapods. The top image shows part of a fishapod fossil. The lower image is an artist's interpretation of how a fishapod may have looked and lived.

Filling in the gaps The discovery of the fishapod has been enormously helpful in detailing the evolution of tetrapods from primitive fish. Scientists hope that in the future, more fossils of other previously unknown species will help answer questions about evolutionary history.

CAREERS IN BIOLOGY

Job Description Research a career in paleontology, which is the study of fossils. What skills does a paleontologist need? What tasks does he or she perform? Write a job description for a paleontology job that you would like. Include where you would travel, what fossils you would like to discover, and what hypothesis you would hope to confirm.

WebQuest

BIOLAB

HOW DO SOME ECTOTHERMS REGULATE BODY TEMPERATURE?

Background: **Recall that amphibians are ectotherms. Many ectotherms live in habitats where the temperature may fluctuate by 10 or 15°C throughout each day. In this lab, you will investigate the strategies some ectothermic animals use to maintain a suitable body temperature.**

Question: *How do ectotherms maintain their body temperature within a specific range?*

Materials

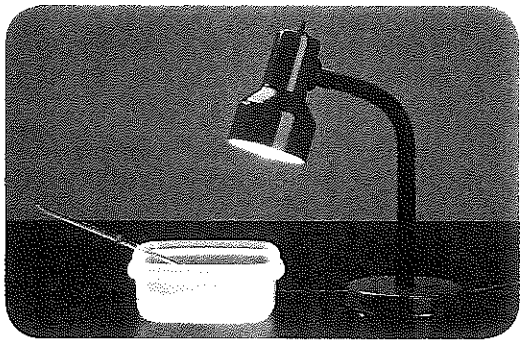
thermometers (2)
plastic containers (2)
metric ruler
room-temperature water
paper towels
sand
soil
high-wattage light bulb and lamp

Safety Precautions

WARNING: ***Lamps may become hot when the light bulb is lit.***

Procedure

1. Read and complete the lab safety form.
2. Obtain two thermometers. These will be a model of an ectotherm animal. Record the temperature of each thermometer. Place one thermometer in a plastic container. Place the other thermometer in another container and fill the container so that the thermometer is covered by at least 5 cm of water.
3. Place each container under a lit light bulb. Monitor the temperature of the thermometers. You must maintain the temperature of each thermometer within a range of 36–39°C for the next 15 min. Decide how often you will measure the temperature of the thermometers and record the data in a table. Record what actions you took to maintain the temperature of the thermometers within the given range.



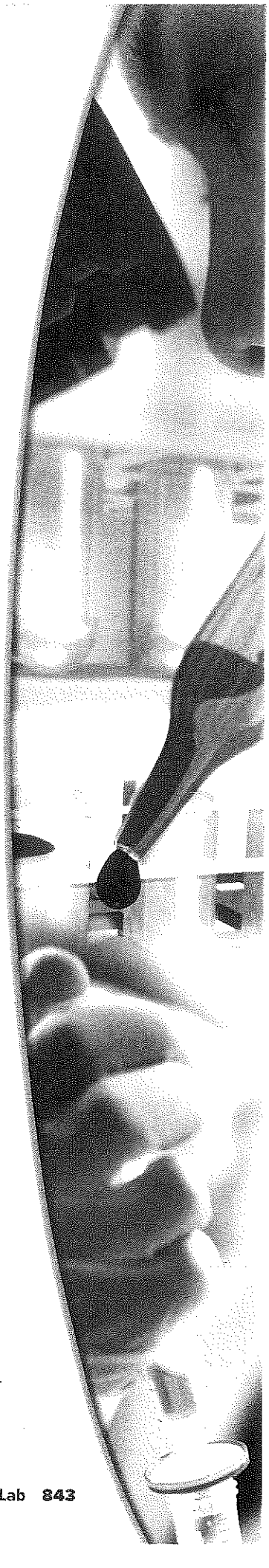
4. Pour the water out of the container and dry the container thoroughly. Allow the thermometers to return to room temperature.
5. Place one thermometer in a container and fill the container with soil so that the thermometer is covered by at least 5 cm of soil. Place the other thermometer in a container and cover it with at least 5 cm of sand.
6. Repeat Step 3.

Analyze and Conclude

1. **Summarize** Did you successfully maintain the temperature within a given range for all steps of the experiment? How did you do this?
2. **Analyze** Were there differences in how you maintained the temperature of the thermometers in water, soil, and sand? In which substance was it easiest to maintain the temperature range? Why?
3. **Draw Conclusions** What are the challenges associated with being an ectothermic animal? Explain.
4. **Think Critically** How do real ectotherms, such as amphibians and reptiles, keep their body temperatures within a specific range?

APPLY YOUR SKILL

Poster Research ectotherms and make a poster that describes the adaptations they require to survive in cold temperatures.



Chapter 28 Study Guide

THEME FOCUS Stability and Change A tadpole is a fishlike larva that goes through change, called metamorphosis, to become an adult frog.

Big Idea Fishes have adaptations for living in aquatic environments. Most amphibians have adaptations for living part of their lives on land.

Section 1 Fishes

cartilage (p. 820)
neural crest (p. 821)
fin (p. 822)
scale (p. 823)
operculum (p. 824)
atrium (p. 824)
ventricle (p. 824)
nephron (p. 825)
lateral line system (p. 826)
spawning (p. 826)
swim bladder (p. 827)

Key Idea Fishes are vertebrates that have characteristics allowing them to live and reproduce in water.

- Vertebrates include fishes, amphibians, reptiles, birds, and mammals.
- All vertebrates have a notochord. In most vertebrates, the notochord is replaced by a vertebral column during embryonic development.
- Fishes share certain characteristics and are therefore classified together.
- The bodies of fishes have unique adaptations that enable them to live their entire lives in water.

Section 2 Diversity of Today's Fishes

tetrapod (p. 830)

Key Idea Scientists classify fishes into three groups based on body structure.

- Fishes can be placed into one of three main groups–jawless, cartilaginous, and bony.
- Hagfishes and lampreys are examples of jawless fishes.
- Sharks, rays, and skates are examples of cartilaginous fishes.
- Bony fishes consist of two subclasses–ray-finned fishes and lobe-finned fishes.
- Ancient extinct fishes had features that enabled them to evolve into modern fishes.
- Habitat alteration and pollution can negatively affect fish populations.

Section 3 Amphibians

cloaca (p. 835)
nictitating membrane (p. 837)
tympanic membrane (p. 837)
ectotherm (p. 837)

Key Idea Most amphibians begin life as aquatic organisms and then live on land as adults.

- The transition of animals to land required a variety of adaptations.
- The bodies of amphibians have unique adaptations that enable them to live on land.
- Amphibians belong to three orders based on structural similarities.
- Ancient tetrapods evolved aquatic adaptations that they eventually used on land.
- Amphibian populations are declining worldwide for a variety of reasons.

Vocabulary eGames

Chapter 28 Assessment

Section 1

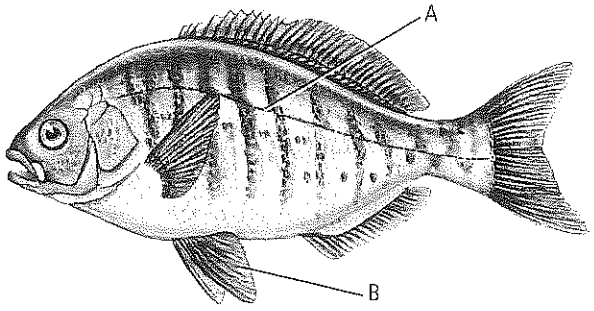
Vocabulary Review

Complete each sentence by providing the missing vocabulary term from the Study Guide page.

1. The process by which male and female fishes release their gametes near each other in the water is called _____.
2. The _____ is the chamber of the heart that receives blood from the body.
3. A group of cells that develop from the nerve cord in vertebrates is called a _____.

Understand Main Ideas

Use the diagram below to answer questions 4 and 5.



4. Which is the structure labeled A?
   A. ctenoid scales **C.** neural crest
   B. lateral line system **D.** operculum
5. Which is the structure labeled B?
   A. gills
   B. swim bladder
   C. ventricle
   D. pelvic fins
6. Which structure allows fishes to control their depth in an aquatic environment?
   A. operculum
   B. swim bladder
   C. lateral line system
   D. jaws
7. Which adaptation allows fishes to be predators?
   A. paired fins
   B. placoid scales
   C. jaws
   D. gills

Constructed Response

8. **THINK** There are more species of vertebrates living in the ocean than there are on land. Form a hypothesis to explain why this is true.
9. **CAREERS IN BIOLOGY** After ichthyologists discovered a new species of deep-sea predatory dragonfish, they were curious about the function of a long, thin, luminescent protrusion called a barbel that was attached under its chin and trailed below its body. Design an experiment that could determine the function of the dragonfish's barbel.

Think Critically

10. **Draw Conclusions** Bluegill males make a nest and protect the eggs and newly hatched offspring. Sometimes intruding males are able to fertilize some of the eggs. The bluegill fathers can identify their biological offspring and will care only for them and not others that might hatch from the same nest. Why is it important for male bluegills to identify their own offspring and care only for them?

Section 2

Vocabulary Review

Complete the sentence by providing the missing vocabulary term from the Study Guide page.

11. A _____ is a four-footed animal with legs that have feet and toes that have joints.

Understand Main Ideas

12. Which illustration shows an external parasite?

A.


C.


B.


D.


13. Which ancient extinct fishes are ancestors to modern fishes?
   A. ostracoderms
   B. ray-finned fishes
   C. coelacanths
   D. jawless fishes

14. Which are characteristics of sharks?
   A. jawless, cartilaginous skeleton, lateral line
   B. jawless, cartilaginous skeleton, ray-finned
   C. jaws, bony skeleton, swim bladder
   D. jaws, cartilaginous skeleton, lateral line

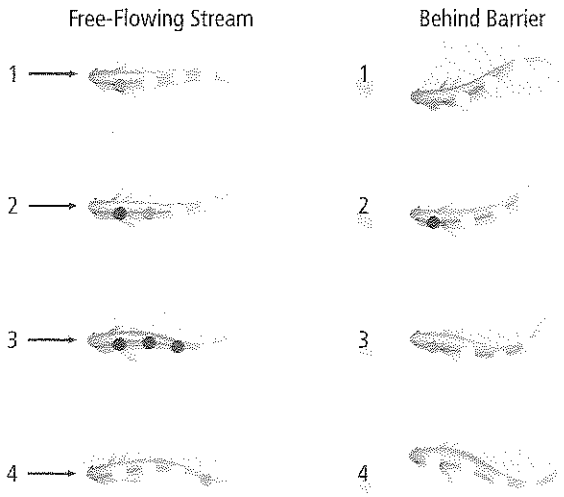
Constructed Response

15. THINK Sketch the body forms of each of the main groups of fishes. Include and explain external adaptations of fishes to their environment.

Think Critically

Use the diagram below to answer questions 16 and 17.

Biologists have studied muscle activity in trout swimming in a free stream flow compared to trout behind a barrier during the same stream movement. The red dots indicate the most intense muscle activity, orange dots indicates moderate muscle activity, while white dots indicates no muscle activity.



16. **Evaluate** In which situation does the trout use the most energy?

17. **Infer** Based on this experiment, if trout are trying to conserve energy, in which part of the stream would they be found?

Section 3

Vocabulary Review

Each of the following sentences is false. Make the sentence true by replacing the italicized word with a vocabulary term from the Study Guide page.

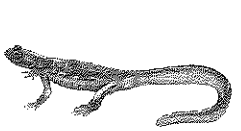
18. The *atrium* is a chamber that receives the digestive wastes, urinary waste, and eggs or sperm before they leave the body.

19. The *nictitating membrane* enables amphibians to hear sounds.

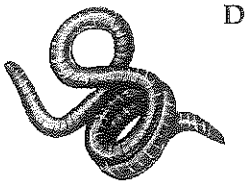
20. Amphibians have *tympanic membranes* to protect their eyes from drying out.

Understand Main Ideas

21. Which is a caecilian?

A.


C.


B.


D.


22. THEME FOCUS Stability and Change What does the phylogeny of tetrapods indicate about lobe-finned fishes?
   A. Lobe-finned fishes are the ancestors of amphibians.
   B. Lobe-finned fishes are similar to amphibians because they both have fins.
   C. Lobe-finned fishes are most closely related to hagfishes.
   D. Lobe-finned fishes are similar to amphibians because they both have lateral lines as adults.

23. What structures do amphibians use to maintain homeostatic water balance?
   A. nictitating membranes
   B. tympanic membranes
   C. kidneys
   D. swim bladders

Online Test Practice

24. Which is not associated with a tadpole?
A. lungs C. gills
B. tail D. herbivorous feeding

Constructed Response

25. **Open Ended** Draw a picture that would illustrate how amphibians could be affected by increased exposure to ultraviolet light.

26. **Open Ended** Describe how the structure and physiology of amphibians, presently adapted to temperate and tropical climates, might be modified to enable them to live in colder climates.

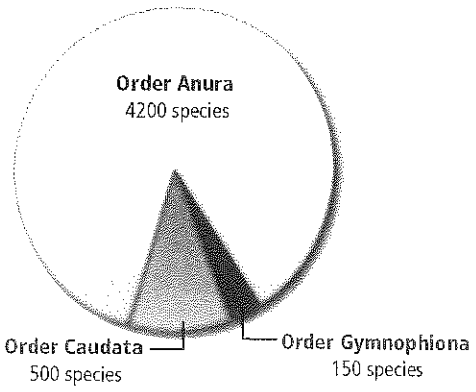
27. BIG Idea Describe how the senses of amphibians are adapted to life on land.

Think Critically

28. **Design an Experiment** Tadpole larvae of certain frogs gather in clusters so close together that the group looks like a moving football in the water. Design an experiment that could test a hypothesis about why the tadpoles exhibit this behavior.

29. **Create** Read homes-for-sale ads in the newspaper to see how they are written. Write an ad for an amphibian home site based on what you know about the habitat, nutrition, and other needs of frogs.

Use the diagram below to answer question 30.



30. **Calculate** Determine the percent that each order of amphibians contributes to the total amount of amphibians.

Summative Assessment

31. BIG Idea Fishes have adaptations for living in aquatic environments. Most amphibians have adaptations for living part of their lives in water and part on land. Citing specific characteristics of fishes and amphibians, explain how the organisms are similar to each other and how they are different.

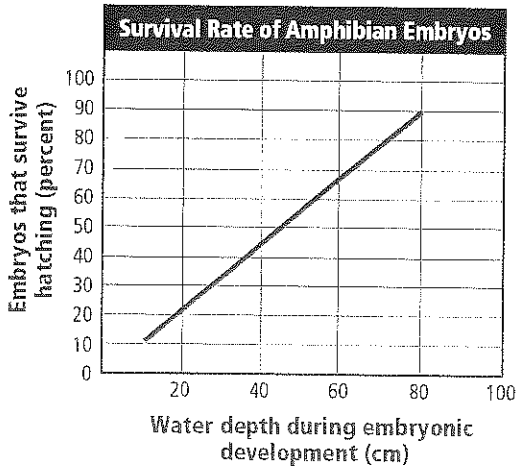
32. How did walking change the circulatory needs of an amphibian?

33. WRITING in Biology Research what efforts are being made by scientists to preserve amphibians. Write a newspaper article summarizing what you learned.

Document-Based Questions

Scientists are trying to determine the cause or causes for the decline in amphibian populations over the past few decades. The graph below shows the results of one study in which the survival rate of amphibian embryos was measured against the depth of the water in which they developed.

Data obtained from: Kiesecker, J., et al. 2001. Complex causes of amphibian population declines. *Nature* 410: 681-683.



34. Describe the relationship between water depth during development and the survival rate of embryos.

35. Form a hypothesis about the decline of amphibian populations in relation to changes in climate.

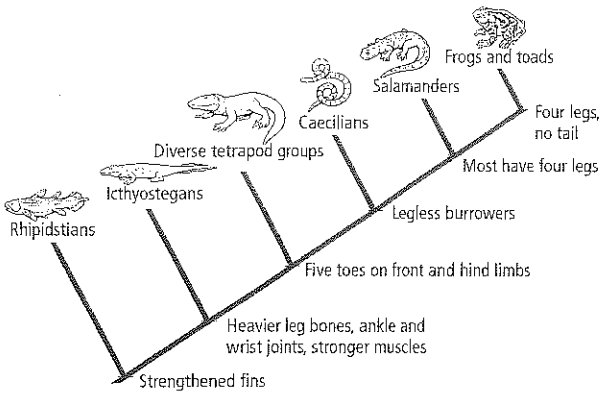
Online Test Practice

Standardized Test Practice

Cumulative

Multiple Choice

Use the diagram below to answer question 1.



1. According to the cladogram, which is the earliest relative of the amphibians?
   A. ichthyostegans
   B. rhipidstians
   C. rays
   D. sharks

2. What describes the symmetry of echinoderms in their larval and adult stages?
   A. bilateral in larval stage, bilateral in adult stage
   B. bilateral in larval stage, radial in adult stage
   C. radial in larval stage, bilateral in adult stage
   D. radial in larval stage, radial in adult stage

3. Which is the role of the Malpighian tubules in arthropods?
   A. adding digestive enzymes to the intestines
   B. allowing oxygen into the body
   C. maintaining homeostatic water balance
   D. transporting blood to body tissues

4. Which method of communication does a honeybee use to tell others in the hive about the location of food?
   A. chemical pheromones
   B. complex dances
   C. quiet buzzing sounds
   D. rapid wing beating

5. What is the function of the simple eye in arthropods?
   A. to analyze landscapes during flight
   B. to detect colors
   C. to distinguish light from dark
   D. to see movement

Use the chart below to answer question 6.

Row	Group	Characteristics
1	Invertebrate chordates	Lack a backbone
2	Jawless fishes	Lack a notochord
3	Bony fishes	Have a skeleton made of bone
4	Cartilaginous fishes	Have a skeleton made of cartilage

6. Which row in the chart contains incorrect information?
   A. 1
   B. 2
   C. 3
   D. 4

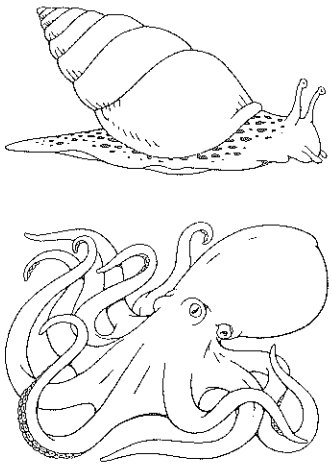
7. Which statement describes the most reasonable way to prevent the disease of trichinosis in humans?
   A. Cook pork thoroughly before eating it.
   B. Treat infected pigs for trichinosis worms.
   C. Vaccinate the population against trichinosis.
   D. Wash pork properly before cooking it.

8. Which statement is NOT true about amphibians?
   A. Many lack legs during part of their life cycles.
   B. Many spend part of their life cycles in the water and part on land.
   C. Most depend on outside water sources to keep their bodies moist.
   D. Most have developed a lateral line system.

9. Which mutation is often caused by the addition or deletion of a single base pair?
   A. frame shift
   B. missense
   C. substitution
   D. tandem repeat

Short Answer

Use the diagrams below to answer question 10.



10. Describe a body structure from each of the mollusks shown above, and explain how these structures are related.

11. Sequence the energy transitions that have to take place for the Sun's energy to be used by a heterotroph.

12. Evaluate why the notochord is considered an evolutionary advancement.

13. Analyze which characteristics of a shark enable it to be a fast swimmer. Explain your answer.

14. Name two groups of invertebrate chordates and describe how they feed. Relate their feeding patterns to their way of life.

15. Compare three characteristics of fishes to three characteristics of another group of animals that you have already studied.

Extended Response

16. Create a Venn diagram to organize information about endoderm and ectoderm tissues that form during embryonic development. Then explain how endoderm and ectoderm tissues are similar and different.

17. Explain how energy is converted in photosynthesis and in cellular respiration.

18. Contrast the circulatory systems of lancelets and tunicates. Justify the classification of both kinds of organisms as invertebrate chordates.

19. Hypothesize whether incomplete metamorphosis or complete metamorphosis in insects is more primitive. Explain your reasoning.

Essay Question

Most of the invertebrate animal groups living today trace their evolutionary history back more than 500 million years. Every other group of invertebrates living today expanded from the oceans to freshwater and, in many cases, to land. The fossil record for echinoderms shows that they have changed radically throughout their evolutionary history. Today, there are many diverse forms of echinoderms, yet none have ever left the ocean.

Using the information in the paragraph above, answer the following question in essay format.

20. Hypothesize why echinoderms have continued living only in the ocean while other invertebrate groups have migrated to freshwater and land.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Review Section . . .	28.3	27.1	26.1	26.3	26.1	28.2	25.2	28.3	12.4	25.4	8.2, 8.3,	27.2	28.2	27.2	28.1	24.1	14.2	27.2	26.3	27.1