

## AMPHIBIANS



Amphibians are thought to have been the first vertebrates on land. Many amphibians, such as this southern leopard frog (*Rana pipiens*), still live part or all of their life in water.

**SECTION 1** *Origin and Evolution of Amphibians*

**SECTION 2** *Characteristics of Amphibians*

**SECTION 3** *Reproduction in Amphibians*

# ORIGIN AND EVOLUTION OF AMPHIBIANS

*About 360 million years ago, amphibians became the first vertebrates to live on land. The name amphibian comes from the Greek words meaning “double” and “life” and reflects the fact that many amphibians spend part of their life on land and part in water.*

## ADAPTATION TO LAND

The first amphibians to spend a significant part of their life on land most likely evolved from lobe-finned fishes. Lobe-finned fishes had several preadaptations that allowed them to transition to life on land. **Preadaptations** are adaptations in an ancestral group that allow a shift to new functions which are later favored by natural selection.

Lobe-finned fishes ancestral to amphibians had a bone structure within their fins that worked as legs that could walk on land. Ancient lobe-finned fishes also had modified pouches in their digestive tracts, which evolved into the lungs of lungfish and swim bladders in most modern fishes. Some groups of ancient lobe-finned fishes also had internal nostrils that functioned in air breathing. In lobe-finned fishes ancestral to amphibians, these structures worked as a means of breathing on land.

Early amphibians required more oxygen than their fish ancestors. Because gravity makes movement on land more difficult than movement in water, early amphibians were likely to have had a higher metabolism than their fish ancestors. As a result, efficient hearts were an important adaptation that allowed oxygen to be delivered to the body more efficiently.

### Characteristics of Early Amphibians

Amphibians and lobe-finned fishes share many anatomical similarities, including features of the skull and vertebral column. Also, the bones in the fin of a lobe-finned fish are similar in shape and position to the bones in the limb of an amphibian. Figure 40-1 shows a sarcopterygian (sar-KOP-te-RIJ-ee-uhn), an extinct lobe-finned fish that is thought to be closely related to amphibians. This fish probably lived in shallow water and used its sturdy pelvic and pectoral fins to move along the bottom and to support its body while resting.

## OBJECTIVES

- **Describe** three preadaptations involved in the transition from aquatic to terrestrial life.
- **Describe** two similarities between amphibians and lobe-finned fishes.
- **List** five characteristics of living amphibians.
- **Name** the three orders of living amphibians, and give an example of each.

## VOCABULARY

preadaptation  
tadpole

**FIGURE 40-1**

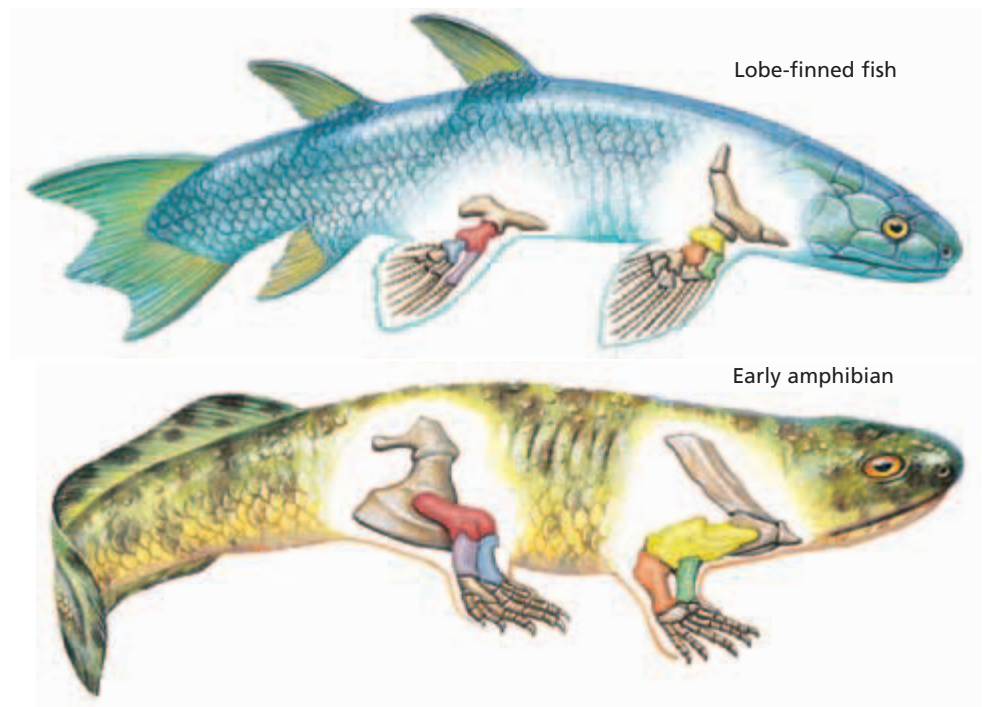
Early lobe-finned fishes, such as this sarcopterygian, are thought to be ancestors of the first land vertebrates.





**FIGURE 40-2**

Amphibians have similar bone structure to primitive lobe finned fishes. The colored bones in the figure are homologous structures between lobe-finned fish and amphibians. Homologous structures are anatomical structures that share a common ancestry.



The oldest known amphibian fossils date from about 360 million years ago. All of the early amphibians had four strong limbs, which developed from the fins of their fish ancestors, as shown in Figure 40-2. The forelimbs of amphibians (and all other terrestrial vertebrates) are homologous to the pectoral fins of fishes, and the hind limbs are homologous to the pelvic fins. The early amphibians also breathed air with lungs. Lungs arose early in the history of fishes and are found in the descendants of these early fishes—including terrestrial vertebrates.

Although the early amphibians showed several adaptations for life on land, such as sense organs for detecting airborne scents and sounds, they probably spent most of their time in the water. For example, some of the first amphibians had a large tail fin and lateral-line canals on their head. Their teeth were large and sharp, indicating a diet of fish, not insects. In addition, some of the early amphibians appear to have had gills like those of fishes.

## Diversification of Amphibians

During the late Devonian period and the Carboniferous period (359 million to 299 million years ago), amphibians split into two main evolutionary lines. One line included the ancestors of modern amphibians, and the other line included the ancestors of reptiles. Amphibians have been a diverse, widespread, and abundant group since this early diversification.

Today there are about 4,500 species of amphibians, belonging to three orders. The largest order, with more than 3,900 species, is Anura, which includes the frogs and toads. The order Caudata contains about 400 species of salamanders. And the third order, Gymnophiona, consists of about 160 species of caecilians, which are legless tropical amphibians. Figure 40-3 on the following page shows hypotheses for the phylogenetic relationships between these three groups.



## Quick Lab

### Comparing Fish and Amphibian Skin

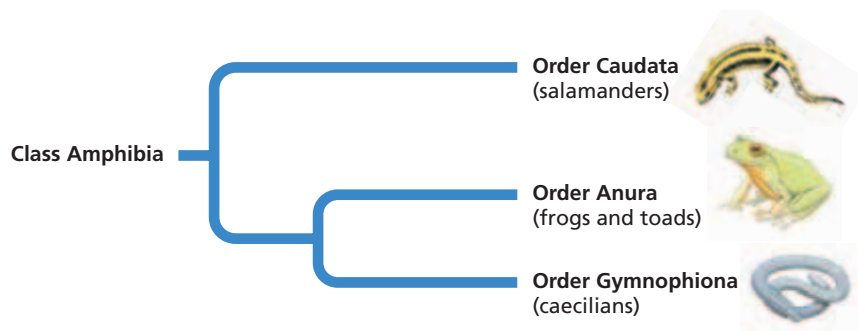
**Materials** disposable gloves, lab apron, safety goggles, paper, colored pencils, living or preserved specimens of a fish and a frog

#### Procedure



1. Put on your disposable gloves, lab apron, and safety goggles.
2. Handle living animals gently. Touch and examine the skin of the specimens provided by your teacher. Record your observations.
3. When you are finished with your observations, remove your disposable gloves, lab apron, and safety goggles. Wash your hands with soap and water.

**Analysis** Why can a frog use its skin as a respiratory membrane, while a fish cannot? What behaviors in amphibians enable them to maintain moist skin?



**FIGURE 40-3**

This phylogenetic diagram shows hypotheses of the evolutionary relationship among modern amphibian orders. For updates on phylogenetic information, visit [go.hrw.com](http://go.hrw.com) and enter the keyword **HM6 Phylo**.

## MODERN AMPHIBIANS

Modern amphibians are a very diverse group, but they do share several key characteristics:

- Most change from an aquatic larval stage to a terrestrial adult form. This transformation is called *metamorphosis*.
- Most have moist, thin skin with no scales.
- Feet, if present, lack claws and often are webbed.
- Most use gills, lungs, and skin in respiration.
- Eggs lack multicellular membranes or shells. They are usually laid in water or in moist places and are usually fertilized externally.

### Order Anura

Anurans (frogs and toads) are found worldwide except in polar climates and a few isolated oceanic islands. They live in a variety of habitats, from deserts and tundra to tropical rain forests. Many anurans spend at least part of their life in water, and some species are permanently aquatic. Many other species live and reproduce on land. Figure 40-4 shows two examples of anurans. The term *toad* is commonly used for any anuran that has rough, bumpy skin, as seen in Figure 40-4a. The term *frog* commonly refers to anurans having smooth, moist skin, such as in Figure 40-4b. These terms are general descriptions, however, and do not refer to any formal groups of anurans.



**FIGURE 40-4**

Anurans include toads and frogs such as the plains spadefoot toad (a), *Scaphiopus bombifrons*, which can be found throughout the United States, and the White's tree frog (b), *Litoria caerulea*, which is common in Australia.



(a)



(b)

## Word Roots and Origins

### caudata

from the Latin *cauda*,  
meaning "tail"

Anurans are characterized by a body adapted for jumping. Long, muscular legs provide power for the jump. The anuran body is compact, with a short, rigid spine and strong forelimbs that help absorb the shock of landing. The word *anuran* means "tailless" and reflects the fact that no adult anuran has a tail.

Adult anurans are carnivores that feed on any animal they can capture. Some frogs have a sticky tongue that can be extended to catch prey. Many species of anurans return to water to reproduce. In nearly all species, eggs are fertilized externally. The fertilized eggs hatch into swimming, tailed larvae called **tadpoles**.

## Order Caudata

Salamanders have elongated bodies, long tails, and moist skin. Except for a few aquatic species, they have four limbs. The smallest salamanders are only a few centimeters long, while the largest reach lengths of 1.5 m (4.5 ft). Like anurans, salamander species range from fully aquatic to permanently terrestrial. Terrestrial salamanders usually live in moist places, such as under logs and stones. Larval and adult salamanders are carnivores. They are active mainly at night. Figure 40-5 shows two representative salamanders.

Most salamander species live in North America and Central America. There are very few species in Africa and South America, several species are found in Asia and in Europe, and there are no species found in Australia. With more than 300 species, the lungless salamanders (family Plethodontidae) are the largest group of salamanders. As their name suggests, these salamanders lack lungs. They absorb oxygen and release carbon dioxide through their skin.

Like most anurans, many salamanders lay their eggs in water, and the eggs hatch into swimming larval forms. Other species can reproduce in moist land environments. Eggs laid on land usually hatch into miniature adult salamanders and do not pass through a free-living larval stage. Most salamander species have a type of internal fertilization by which females pick up sperm packets deposited by males. In some terrestrial species, the female stays with the eggs until they hatch, which can take up to several weeks.



**FIGURE 40-5**

The flatwoods salamander (a), *Ambystoma cingulatum*, and the spotted salamander (b), *Ambystoma maculatum*, are members of the order Caudata. *A. cingulatum*, which lives only in Florida, is an endangered species; *A. maculatum* can be found from eastern Canada to eastern Texas.



(a)

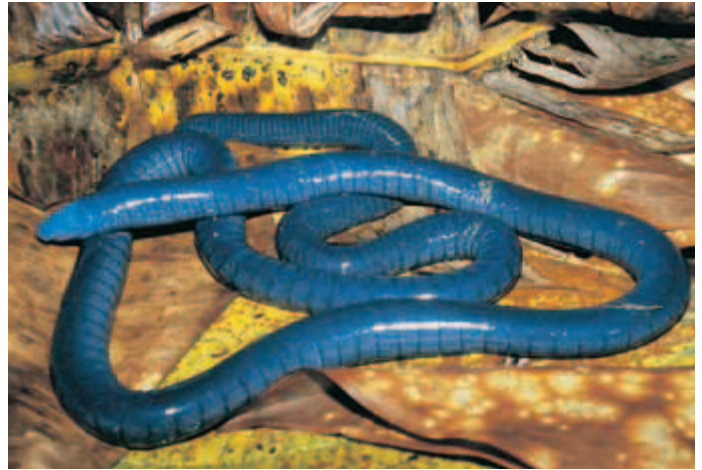


(b)





(a)



(b)

## Order Gymnophiona

The common name used to refer to members of the order Gymnophiona is caecilian (see-SIL-yuhn). Caecilians are a highly specialized group of legless amphibians that resemble small snakes, as you can see in Figure 40-6. Caecilians live in tropical areas of Asia, Africa, and South America. Caecilians average about 30 cm (12 in.) in length, but some species reach lengths of 1.5 m (4.5 ft). Because they have very small eyes that are located beneath the skin or even under bone, caecilians often are blind.

Caecilians are rarely seen, and little is known about their ecology and behavior. Most species burrow in the soil, but some species are aquatic. All species have teeth in their jawbones that enable them to catch and consume prey. They eat worms and other invertebrates, which they detect by means of a chemosensory tentacle located on the side of their head. All species are thought to have internal fertilization. Some species lay eggs, which the female guards until they hatch. In a few species, the young are born alive. These caecilians provide nutrition to their developing embryos. The young use their jaws and teeth to scrape secretions, called “uterine milk,” from the walls of the female’s reproductive tract.

**FIGURE 40-6**

Caecilians, such as *Ichthyophis kohtaoensis* (a) and *Caecilia nigricans* (b), are primarily carnivores. They are burrowing amphibians that are usually blind, and a few species have scales embedded in their skin.

## SECTION 1 REVIEW

1. Describe three adaptations that allowed early sarcopterygians to move onto land.
2. Identify two characteristics that amphibians share with modern lobe-finned fishes.
3. Name five key characteristics that are common to modern amphibians.
4. Differentiate each of the three living orders of amphibians.

### CRITICAL THINKING

5. **Applying Information** Early amphibian fossils do not indicate the presence of lungs. Why do scientists think that early amphibians had lungs?
6. **Forming Reasoned Opinions** Is the lack of legs a primitive characteristic for amphibians or a later amphibian adaptation? Support your answer.
7. **Analyzing Information** Why do modern amphibians not have a lateral line?

## SECTION 2

### OBJECTIVES

- **Relate** the structure of amphibian skin to the types of habitats in which amphibians can survive.
- **Identify** three adaptations for life on land shown by the skeleton of a frog.
- **Sequence** the flow of blood through an amphibian's heart.
- **Describe** how a frog fills its lungs with air.
- **Describe** the digestive and excretory systems of amphibians.
- **Discuss** an amphibian's nervous system.

### VOCABULARY

mucous gland  
pulmonary circulation  
systemic circulation  
pulmonary respiration  
cutaneous respiration  
duodenum  
ileum  
mesentery  
vent  
nictitating membrane  
tympanic membrane  
columella

# CHARACTERISTICS OF AMPHIBIANS

*As you have already seen, terrestrial vertebrates face challenges that are far different from those faced by aquatic vertebrates. In this section, you will learn about some of the ways amphibians meet the challenges of living on land.*

## SKIN

The skin of an amphibian serves two important functions—respiration and protection. The skin is moist and permeable to gases and water, allowing rapid diffusion of oxygen, carbon dioxide, and water. Numerous **mucous glands** supply a lubricant that keeps the skin moist in air. This mucus is what makes a frog feel slimy. The skin also contains glands that secrete foul-tasting or poisonous substances that provide protection from predators.

However, the same features that allow efficient respiration also make amphibians vulnerable to dehydration, the loss of body water. Therefore, amphibians live mainly in wet or moist areas on land. Many species are active at night, when loss of water through evaporation is reduced. Although some species of frogs and toads survive in deserts, they spend most of their life in moist burrows deep in the soil. Only after heavy rains do these amphibians come to the surface to feed and reproduce.

Amphibians are affected by pollution. Chemicals present in water can be absorbed by amphibian skin. As a result, amphibians can serve as indicators of the health of an ecosystem.

## SKELETON

While water supports the body of an aquatic vertebrate against the force of gravity, terrestrial vertebrates must rely on the support of their strong internal skeleton. The vertebrae of the spine interlock and form a rigid structure that can bear the weight of the body. Strong limbs support the body during walking or standing. The forelimbs attach to the pectoral girdle (the shoulder and supporting bones), while the hind limbs attach to the pelvic girdle (the “hips”). The pectoral and pelvic girdles transfer the body's weight to the limbs. The cervical vertebra at the anterior end of the spine allows neck movement.

The frog skeleton in Figure 40-7 shows several specializations for jumping and landing. In frogs, the bones of the lower forelimb are fused into a single bone, the radio-ulna. The bones of the lower hind limb are fused into the tibiofibula. Frogs have few vertebrae, and the vertebrae at the posterior end of the spine are fused into a single bone called the urostyle. The pectoral girdle has thick bones that are braced to absorb the impact of landing.

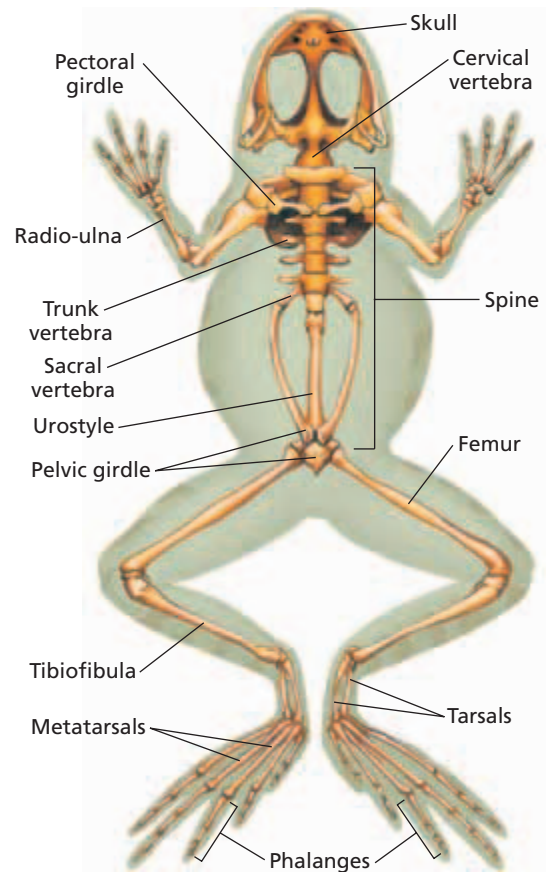
## CIRCULATORY SYSTEM

The circulatory system of an amphibian is divided into two separate loops. The **pulmonary circulation** carries deoxygenated blood from the heart to the lungs and back to the heart. The **systemic circulation** carries oxygenated blood from the heart to the body and back to the heart.

The three-chambered heart of an amphibian reflects the division of the circulatory system into pulmonary and systemic circulation. Deoxygenated blood from the body first enters the right side of the heart, as shown in step 1 of Figure 40-8. Blood moves into the right atrium. In step 2, oxygenated blood from the lungs enters the left atrium. In step 3, contraction of the atria forces the deoxygenated and oxygenated blood into the single ventricle, the main pumping chamber of the heart. Although the ventricle is not divided, its spongy interior surface and the coordinated contractions of the atria keep the oxygenated and deoxygenated blood from mixing. In step 4, ventricular contraction expels both kinds of blood into the conus arteriosus, which directs deoxygenated blood to the lungs and oxygenated blood to the body.

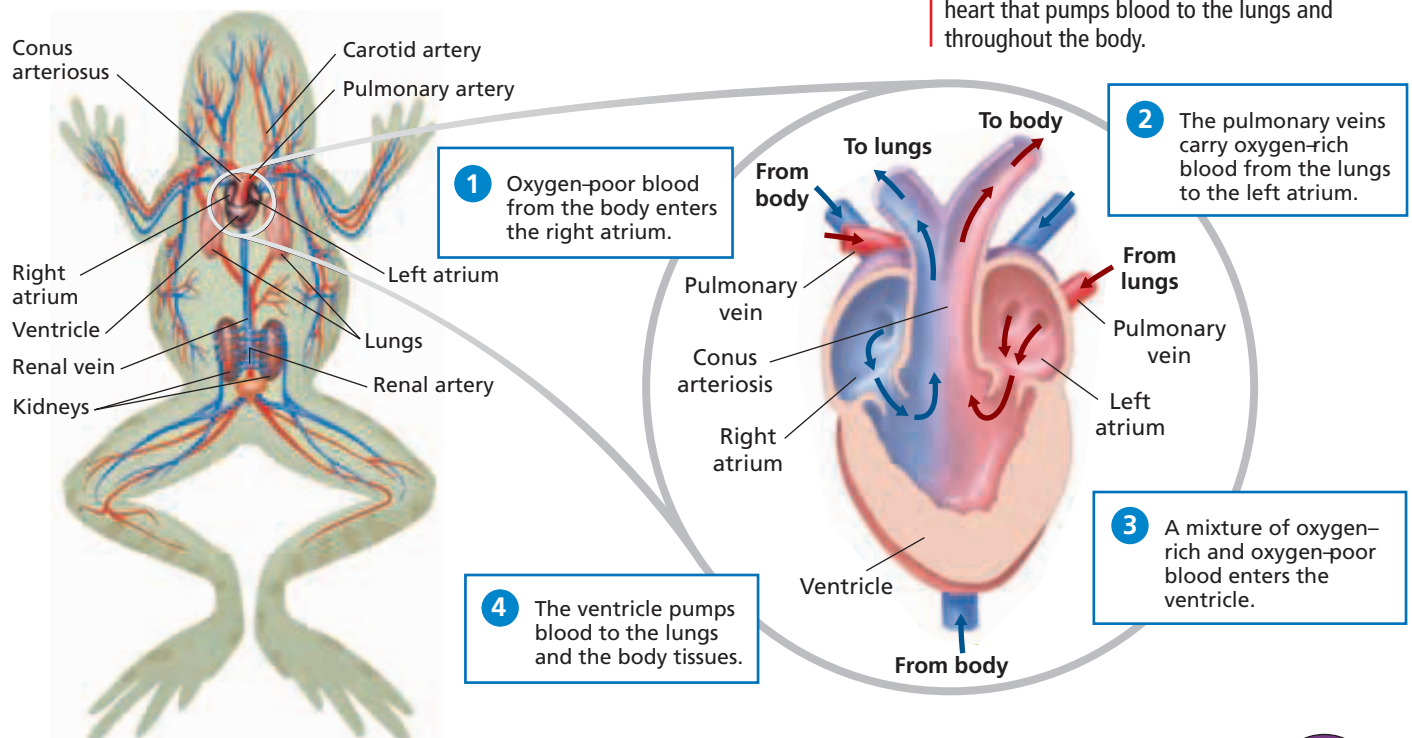
**FIGURE 40-7**

The skeleton of the frog has adapted to absorb shocks when the frog jumps and lands.



**FIGURE 40-8**

Amphibians have a three chambered heart that pumps blood to the lungs and throughout the body.





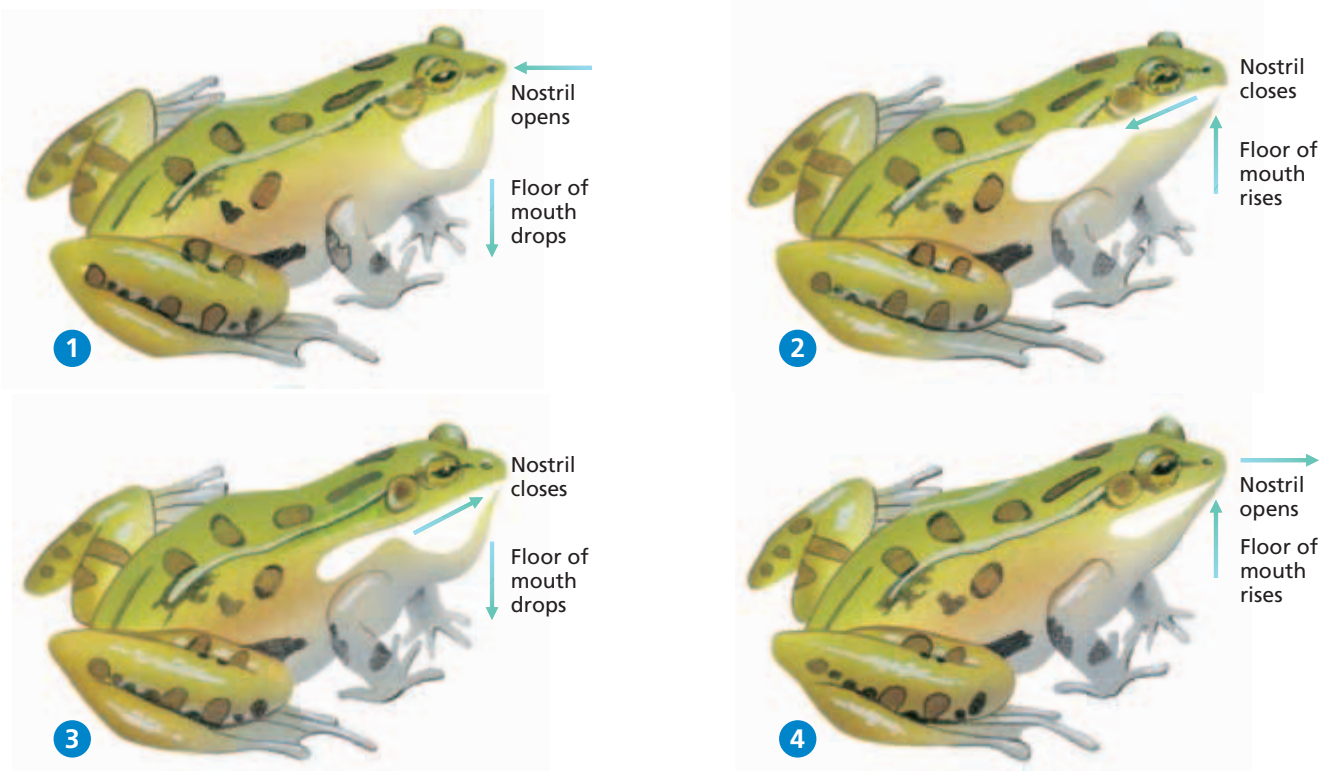
All other terrestrial vertebrates also have a “double-loop” circulatory pattern. This pattern of circulation provides a significant advantage over the “single-loop” circulation of a fish—faster blood flow to the body. In a fish, the blood loses some of its force as it passes through the narrow capillaries of the gills, and blood flow slows as a result. The lungs of an amphibian also contain narrow capillaries that slow blood flow. But after passing through the capillaries of the lung, blood returns to the heart to be pumped a second time before circulating to the body.

## RESPIRATION

Larval amphibians respire, or exchange carbon dioxide and oxygen, through their gills and skin. Most adult amphibians lose their gills during metamorphosis, but they can respire in two ways: through the lungs and through the skin. Respiration through the lungs is called **pulmonary respiration**. Amphibians ventilate their lungs with a unique mechanism that pumps air into the lungs; this is called *positive-pressure breathing*. For example, a frog breathes by changing the volume and pressure of air in its mouth while either opening or closing its nostrils, as shown in Figure 40-9. Both inhalation and exhalation involve a two-step process during which the floor of the frog’s mouth is raised and lowered. The frog controls the direction of air flow by opening or closing its nostrils. Because amphibians have a small surface area in the lungs for gas exchange, respiration through the skin, or **cutaneous respiration**, is very important to most aquatic and terrestrial amphibians.

**FIGURE 40-9**

Frogs breathe by creating pressure that forces air into their lungs. ❶ When the floor of the frog’s mouth drops, air capacity increases in the frog’s mouth, and air rushes in. ❷ When the nostril is closed and the mouth floor rises, the air is forced into the lungs of the frog. ❸ The mouth floor lowers and air is forced out of the lungs. ❹ Then the nostril opens and the mouth floor rises again, forcing air out the nostril.



# DIGESTIVE SYSTEM

All adult amphibians are carnivorous. Because most amphibians are small, insects and other arthropods are their most commonly consumed prey. Larger amphibians sometimes eat mice, snakes, fish, other amphibians, and even sometimes birds. Many amphibian larvae, such as those of frogs, are herbivorous, feeding on algae, bacteria, or plants. The larvae of some species, such as those of salamanders, are carnivorous, and some feed on the larvae of other species.

The amphibian digestive system includes the pharynx, esophagus, stomach, liver, gallbladder, small intestine, large intestine, and cloaca. Figure 40-10 shows a ventral view of the digestive system of a frog.

The elastic esophagus and stomach allow an amphibian to swallow large amounts of food. Once food reaches the stomach, tiny glands in the stomach walls secrete gastric juices that help break down, or digest, the food. A muscle called the pyloric sphincter at the lower end of the stomach relaxes, which allows digested food to move into the small intestine. The upper portion of the small intestine is called the **duodenum** (DOO-oh-DEE-nuhm). The coiled middle portion of the small intestine is the **ileum** (IL-ee-uhm). A membrane resembling plastic wrap, called the **mesentery**, holds the small intestine in place. Inside the small intestine, digestion is completed and the released nutrients pass through capillary walls into the bloodstream, which carries them to all parts of the body.

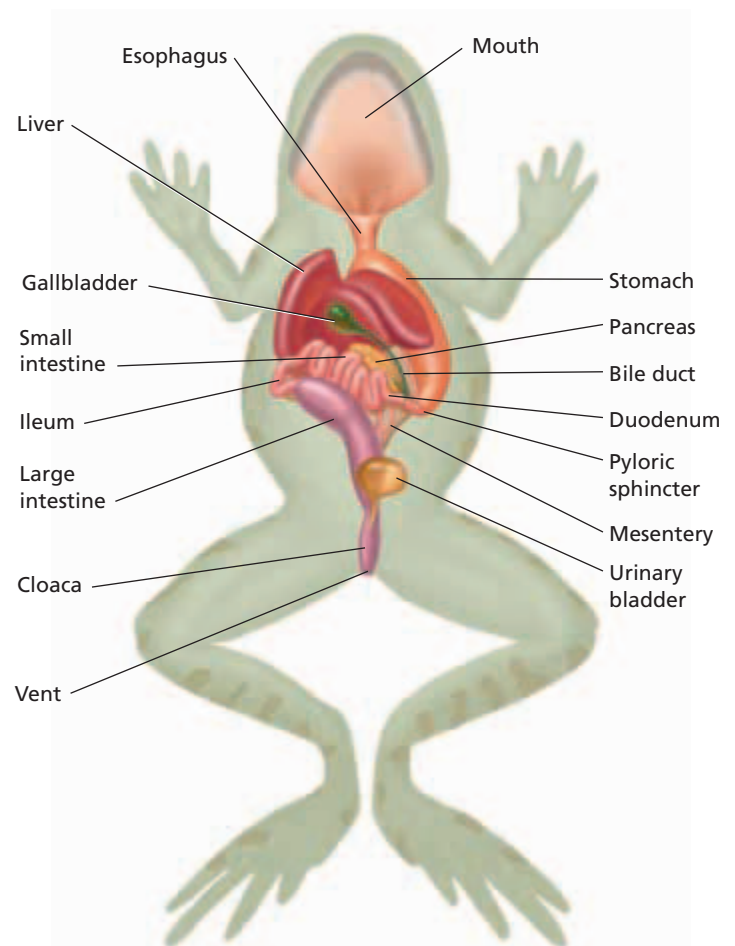
The lower end of the small intestine leads into the large intestine. Here indigestible wastes are collected and pushed by muscle action into a cavity called the *cloaca* (kloh-AY-kuh). Waste from the kidneys and urinary bladder, as well as either eggs or sperm from the gonads, also passes into the cloaca. Waste materials exit the body through the **vent**.

## Accessory Glands

Other glands and organs aid in the digestion process. The liver produces bile, which is stored in the gallbladder. Bile helps break down fat into tiny globules that can be further digested and absorbed. A gland called the pancreas, located near the stomach, secretes enzymes that enter the small intestine and help break down food into products that can be absorbed by the blood.

**FIGURE 40-10**

The frog digestive system is shown in ventral view. Notice how the short small intestine is an adaptation for a carnivorous diet.





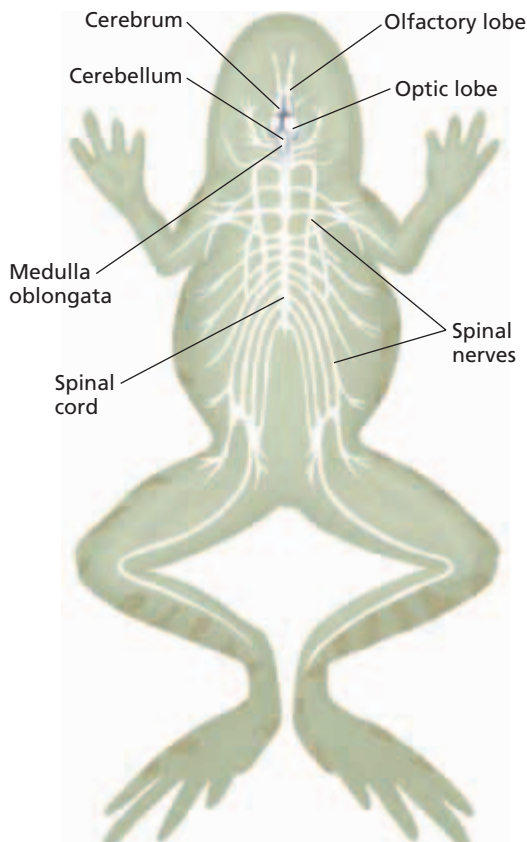
## EXCRETORY SYSTEM

The kidneys are the primary excretory organs. One kidney lies on either side of the spine against the dorsal body wall. The kidneys filter nitrogenous wastes from the blood. These wastes, flushed from the body with water, are known as urine. Urine flows from the kidneys to the cloaca through tiny tubes called urinary ducts. From the cloaca, it flows into the urinary bladder, which branches from the ventral wall of the cloaca. For many terrestrial amphibians, the urinary bladder serves as a water-storage organ. During dry periods, water can be reabsorbed from the urine in the bladder.

Like the larvae of fishes, most amphibian larvae excrete the nitrogen-containing wastes as ammonia. Because ammonia is very toxic, it must be removed from the body quickly or diluted with large amounts of water in the urine. To conserve water, adult amphibians transform ammonia into urea, a less-toxic substance that can be excreted without using as much water. Although this transformation uses energy, it helps save water. During metamorphosis, larval amphibians change from excreting ammonia to excreting urea.

**FIGURE 40-11**

This diagram shows the frog's nervous system in ventral view. The brain of the frog is sufficiently developed to cope with both land and water environments.



## NERVOUS SYSTEM

Use the diagram in Figure 40-11 to find the main components of the amphibian nervous system. An amphibian's brain is about the same size as that of a fish of similar size. The olfactory lobes, which are the center of the sense of smell, are larger in amphibians than in fish, and they lie at the anterior end of the brain. Behind the olfactory lobes are the long lobes of the cerebrum, the area of the brain that integrates behavior and is responsible for learning.

The optic lobes, which process information from the eyes, lie behind the cerebrum. The cerebellum, a small band of tissue that lies at a right angle to the long axis of the brain, is the center of muscular coordination and is not as well developed in amphibians as it is in other tetrapods. The medulla oblongata lies at the back of the brain and joins the spinal cord. It controls some organ functions, such as heart rate and respiration rate.

There is continuous communication among most areas of the brain. Ten pairs of cranial nerves extend directly from the brain. The spinal cord conducts signals from all parts of the body to the brain and from the brain back to the body. Encased in protective bony vertebrae, the spinal cord extends down the back. As in fishes, the spinal nerves branch from the spinal cord to various parts of the body.



**FIGURE 40-12**

Frogs have a well-developed sense of sight, which is necessary for locating prey and avoiding predators. Frogs also have good hearing. Note the tympanic membrane (the circle below and to the left of the eye), which transmits sound to the inner ear.

## Sense Organs

Some sense organs work as well in air as in water, but others do not. For example, the lateral line system, used by fishes to detect disturbances in the water, works only in water. Thus, while larval amphibians have a lateral line, it is usually lost during metamorphosis. Only a few species of aquatic amphibians have a lateral line as adults.

The senses of sight, smell, and hearing are well developed in most amphibians. Visual information is often important in hunting and in avoiding predators. The eyes are covered by a transparent, movable membrane called a **nictitating** (nik-ti-tayt-eeng) **membrane**.

Sound is detected by the inner ear, which is embedded within the skull. Sounds are transmitted to this organ by the **tympanic** (tim-PAN-ik) **membrane**, or eardrum, and the **columella** (CAHL-yoo-mel-uh), a small bone that extends between the tympanic membrane and the inner ear. Sounds first strike the tympanic membrane, which is usually located on the side of the head, just behind the eye as shown in Figure 40-12. Vibrations of the tympanic membrane cause small movements in the columella that are transmitted to the fluid-filled inner ear. In the inner ear, the sound vibrations are converted to nervous impulses by sensitive hair cells. These impulses are transmitted to the brain through a nerve.

### Word Roots and Origins

#### *nictitating*

from the Latin *nictare*,  
meaning "to wink"

## SECTION 2 REVIEW

1. Identify an advantage and a disadvantage to the permeability of amphibian skin.
2. Explain three ways in which a frog's skeleton is adapted for jumping.
3. Identify the relationship between the structure of a frog's heart and "double-loop" circulation.
4. Explain how a frog uses positive pressure to move air into and out of its lungs.
5. What feature do the digestive and excretory systems in frogs have in common?

### CRITICAL THINKING

6. **Applying Information** Which are the two largest features of an amphibian's brain? Why do you think these lobes are the largest?
7. **Making Comparisons** Which sense organ of a terrestrial amphibian resembles the fish's lateral line in function? Explain your answer.
8. **Recognizing Relationships** Why are the skeletal bones in a frog's shoulders thicker than the bones in a frog's pelvic girdle?



## SECTION 3

### OBJECTIVES

- **Explain** how a male frog attracts a female of the same species.
- **Discuss** the reproductive system of a frog.
- **Describe** the life cycle of a frog.
- **Describe** the changes that occur during metamorphosis in frogs.
- **Identify** two examples of parental care in amphibians.

### VOCABULARY

amplexus

# REPRODUCTION IN AMPHIBIANS

*One of the biggest differences between aquatic and terrestrial life-forms is their method of reproduction. Most amphibians depend on water for reproduction. They lay their eggs in water and spend the early part of their lives as aquatic larvae.*

## COURTSHIP AND FERTILIZATION

In the first warm days of spring in the temperate zones, frogs emerge from hibernation. They migrate in great numbers to ponds and slow-moving streams. Males call to attract females of their own species and to warn off other males, as shown in Figure 40-13. Each species has its own mating call. The frog's croak is produced by air that is driven back and forth between the mouth and the lungs, vibrating the vocal folds. Male frogs have vocal sacs that amplify their calls. The female responds only to the call from a male of the same species.

When a female approaches, the male frog climbs onto her back. He grasps her firmly in an embrace called **amplexus** (am-PLEKS-uhs). The male clings to the female until she lays her eggs. When the female finally releases her eggs into the water, the male frog discharges his sperm over them, and direct external fertilization takes place. The frogs then separate and resume their solitary lives. Courtship behavior and fertilization often differ between species.

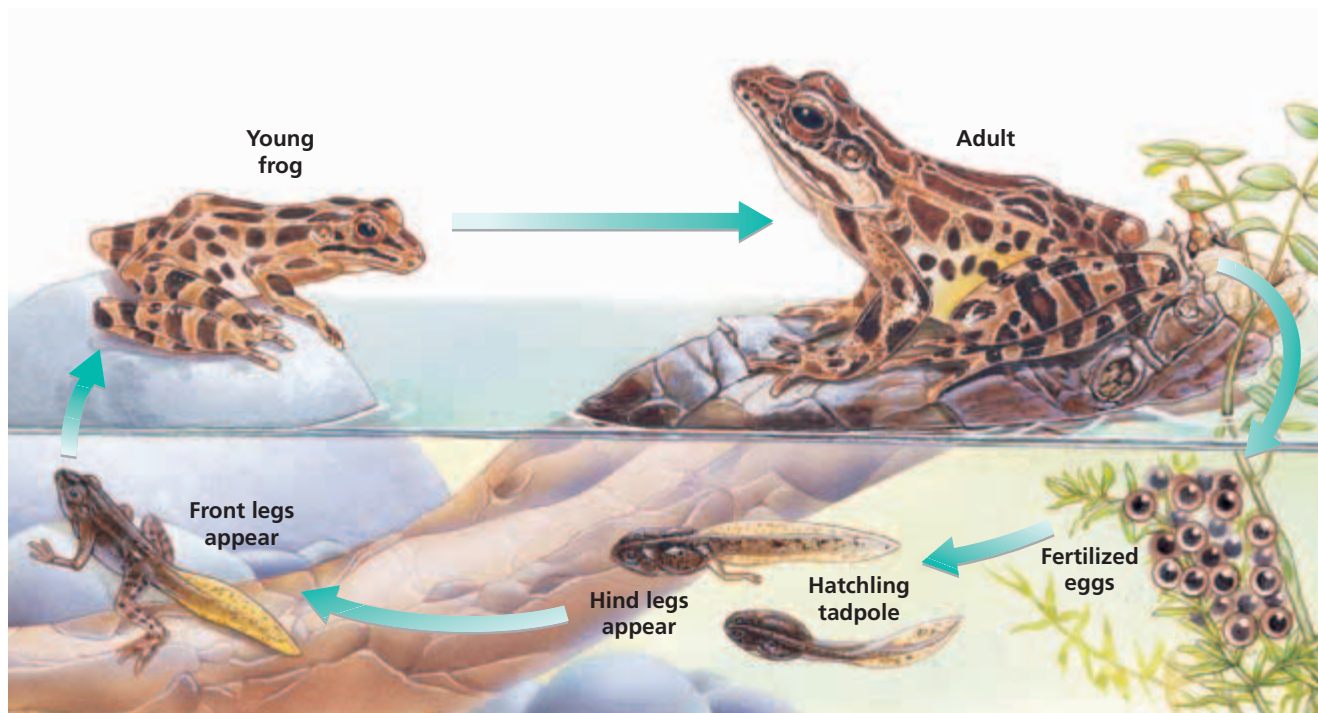
### Reproductive System

The reproductive system of the male frog includes two bean-shaped testes located near the kidneys. During the breeding season, sperm cells develop in the testes and pass through tubes to the kidneys and urinary ducts. During mating, sperm leave the body through the cloacal opening. In female frogs, a pair of large, lobed ovaries containing thousands of tiny immature eggs lie near the kidneys. During the breeding season, the eggs enlarge, mature, and burst through the thin ovarian walls into the body cavity. Cilia move the eggs forward into the funnel-like openings of the oviducts. As the eggs pass down the oviducts, they are coated with a protective jellylike material. The eggs exit by the cloaca to the external environment, where they are fertilized.

**FIGURE 40-13**

Most frogs that sing are males. Their songs attract females and warn off males of the same species.





## LIFE CYCLE

Within a few days of fertilization, the eggs hatch into tadpoles. A newly hatched tadpole lives off yolk stored in its body. It gradually grows larger and develops three pairs of gills. Eventually, the tadpole's mouth opens, allowing it to feed. The tadpole grows and slowly changes from an aquatic larva into an adult. This process of change is called *metamorphosis*. Legs grow from the body, and the tail and gills disappear. The mouth broadens, developing teeth and jaws, and the lungs become functional.

Biologists have long studied the process of metamorphosis and regeneration to learn what controls such dramatic physical changes. A hormone called *thyroxine* is produced by the thyroid gland and circulates throughout the bloodstream to stimulate metamorphosis.

The life cycles of many amphibians are similar to that of the frog shown in Figure 40-14. But there are a variety of alternative reproductive patterns among amphibians. For example, many amphibians do not lay their eggs in water. They select a moist place on land, such as under a rock, inside a rotting log, or in a tree. One or both parents may even construct a nest for the eggs. A number of frog species make a nest of mucus, whipping it into a froth by kicking their hind legs. And not all amphibians undergo metamorphosis. Some salamanders, such as the axolotl in Figure 40-15, remain in the larval stage for their entire life. The axolotl's thyroid does not produce thyroxine. Other amphibians bypass the free-living larval stage and hatch from the egg as a small version of the adult.

**FIGURE 40-14**

The life cycle of a frog begins with mating. When the eggs hatch, a tadpole is released. One of the first developments of metamorphosis is the growth of hind legs. When the tadpole completes metamorphosis, a small adult emerges from the water onto the land.

**FIGURE 40-15**

The axolotl does not produce thyroxine, and as a result, does not undergo metamorphosis. It retains its gills and lives a completely aquatic life.





**FIGURE 40-16**

*Rhinoderma darwinii* male frogs exhibit parental care by holding the maturing eggs and larvae in their vocal sacs. This frog has already released his offspring, whose tails are still visible. Not all frogs express parental care in this way, and some frogs express no parental behavior at all.



## PARENTAL CARE

Parental care is common among amphibians. Eggs and larvae are vulnerable to predators, but parental care helps increase the likelihood that some offspring will survive. Most often, one parent (often the male) remains with the eggs, guarding them from predators and keeping them moist until they hatch. The male Darwin's frog (*Rhinoderma darwinii*) of Chile takes the eggs into his vocal sacs, where they hatch and eventually undergo metamorphosis. The young frogs climb out of the vocal sacs and emerge from the male's mouth, as shown in Figure 40-16.

Female gastric-brooding frogs of Australia swallow their eggs, which hatch and mature in the stomach. The eggs and tadpoles are not digested because the stomach stops producing acid and digestive enzymes until the young pass through metamorphosis and are released. Two species of gastric-brooding frogs are known, but both appear to have become extinct within the last two decades. Females of some species of frogs, such as *Eleutherodactylus*, sit on their eggs until they hatch, not to provide warmth but to prevent the eggs from desiccating. The female normally lays the eggs in the leaves of trees or bushes, where they may dry up.

## SECTION 3 REVIEW

1. Identify two functions of the male frog's call.
2. Sequence the stages of a frog's life cycle.
3. Identify the features that are lost and the features that are gained during metamorphosis in frogs.
4. Name the hormone responsible for stimulating tadpoles to undergo metamorphosis.
5. Describe two strategies that have been found in frogs for protecting eggs and developing young.

### CRITICAL THINKING

6. **Applying Information** Why is standing water not always necessary for frog reproduction?
7. **Recognizing Relationships** How do you think the number of eggs produced by amphibians relates to the amount of parental care invested?
8. **Justifying Conclusions** Would you expect an amphibian that bypasses the larval stage to produce more or less thyroxine? Explain.

# CHAPTER HIGHLIGHTS

## SECTION 1

## Origin and Evolution of Amphibians

- Preadaptations are inherited traits used for new functions for which the traits are later selected.
- Fleshy fins with strong bone structure, nostrils, and lungs were preadaptations that allowed the transition from aquatic to terrestrial life.
- Early amphibians had lungs and four legs. Like lobe-finned fish, they were predominantly aquatic, they had a lateral line and a fishlike tail fin, similar skull and vertebral column, similar limb bones, and some had gills.
- Modern amphibians share several characteristics. Most change from aquatic larvae to terrestrial adult. Most have moist thin skin, with no scales. Feet, if present, lack claws and are often webbed. Most use gills, lungs, and skin in respiration. Most lay eggs that lack multicellular membranes or shells.
- Modern amphibians are divided into three orders: Anura (frogs and toads), Caudata (salamanders), and Gymnophiona (caecilians).

### Vocabulary

preadaptation (p. 799)

tadpole (p. 802)

## SECTION 2

## Characteristics of Amphibians

- Adult amphibians respire through their lungs and skin. Mucous glands produce slimy mucus that helps retain moisture.
- The skeleton of an amphibian supports the body against the pull of gravity. In addition, the spine interlocks to provide rigid structure, strong limbs support the body, and the pectoral and pelvic girdle transfer body weight to the limbs.
- The amphibian pulmonary circuit carries blood between the heart and lungs. The systemic circuit carries blood to the body and returns blood to the heart.
- The heart of an amphibian consists of two atria and one ventricle. The right atrium receives blood from the body, pumps blood to the ventricle, and then pumps blood to the lungs. The left atrium receives blood from the lungs, pumps blood to the ventricle, and then to the body.
- Amphibians pump air into their lungs by raising and lowering the floor of their mouth cavity while closing and opening their nostrils.
- In an amphibian, food passes through the mouth, esophagus, stomach, small intestine, large intestine, and cloaca. The kidneys remove wastes from the blood. Adult amphibians eliminate nitrogenous wastes as urea.
- The brain of a frog has large optic lobes that process visual information, large olfactory lobes that control the sense of smell, a cerebrum that integrates behavior and controls learning, a cerebellum that coordinates movement, and a medulla oblongata that controls the heart and respiration rate. Fish have brains of similar size, but with smaller olfactory lobes.

### Vocabulary

mucous gland (p. 804)

pulmonary  
circulation (p. 805)

systemic circulation (p. 805)

pulmonary  
respiration (p. 806)

cutaneous  
respiration (p. 806)

duodenum (p. 807)

ileum (p. 807)

mesentery (p. 807)

vent (p. 807)

nictitating  
membrane (p. 809)

tympanic membrane (p. 809)

columella (p. 809)

## SECTION 3

## Reproduction in Amphibians

- Male frogs call to attract females of the same species.
- The male frog grasps the female in an embrace called amplexus and fertilizes her eggs as they are released.
- A life cycle is the stages through which an organism passes from fertilization to reproductive maturity. Most amphibians lay their eggs in water, and have an aquatic larval stage and a terrestrial adult stage.
- The hormone thyroxine triggers metamorphosis. During metamorphosis, the tadpole loses its tail and gills and grows legs and lungs.
- Many amphibians show parental care by guarding their eggs and keeping their eggs moist. Some take their eggs into their body to develop.

### Vocabulary

amplexus (p. 810)

# CHAPTER REVIEW

## USING VOCABULARY

- For each pair of terms, explain how the meanings of the terms differ.
  - systemic circulation* and *pulmonary circulation*
  - amplexus* and *metamorphosis*
  - pulmonary respiration* and *cutaneous respiration*
- Use the following key terms in the same sentence: *duodenum*, *mesentery* and *ileum*.
- Explain the relationship between preadaptation and adaptation.
- Word Roots and Origins** The word *columella* comes from the Latin *columna*, which means “pillar.” Using this information, list two characteristics of this amphibian ear bone.

## UNDERSTANDING KEY CONCEPTS

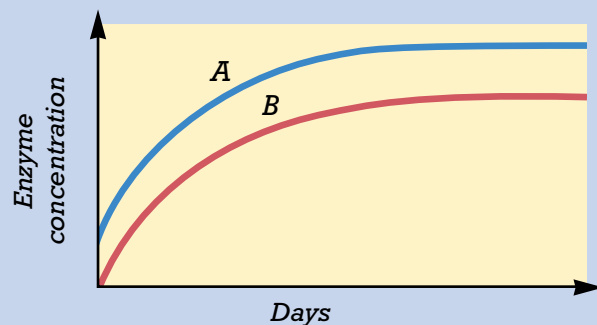
- Discuss** the preadaptations important in the evolution of amphibians.
- Identify** two characteristics that indicate that amphibians are descendants of ancient lobe-finned fish.
- Name** five major characteristics of amphibians.
- Identify** the order to which each of the following belong: frogs, salamanders, caecilians.
- Explain** how some species of frogs survive in desert environments even though they do not have watertight skin.
- Relate** the adaptations in the amphibian skeleton to the change in gravity with life on land.
- Outline** the route of blood flow through the body of a frog, beginning with the right atrium.
- Determine** the next step for air within the oral cavity of a frog when it closes its nostrils and raises the mouth floor.
- Trace** the digestive process as food passes through a frog’s digestive system.
- Explain** how an amphibian’s nervous system is similar to that of a bony fish.
- Explain** how male frogs attract the attention of female frogs during mating season.
- Describe** the reproductive system of a frog.
- Discuss** the life cycle of a frog.
- Contrast** the physical characteristics of a larval frog to those of an adult frog.
- Describe** two different examples of parental care found in frogs.

- CONCEPT MAPPING** Use the following terms to create a concept map that shows the methods of respiration in frogs: *frogs*, *skin*, *mouth floor*, *body wall muscles*, *nostrils*, *lungs*, *air pressure*, *oral cavity*, *environment*.

## CRITICAL THINKING

- Inferring Relationships** Charles Darwin noticed that frogs and toads are often absent from oceanic islands, such as the Galápagos Islands, even though they may be found on the nearby mainland. Darwin conducted some experiments that showed that frogs’ eggs cannot tolerate exposure to salt water. What hypothesis do you think Darwin was trying to test?
- Recognizing Relationships** In the brains of amphibians, the largest parts are the olfactory lobes and the optic lobes, the centers of smell and sight. This is very important to amphibians in hunting prey and avoiding predators. Why else is the capacity for hearing important?
- Recognizing Relationships** The female gastric-brooding frogs of Australia did not produce stomach acid or digestive enzymes while brooding their young in their stomachs until the tadpoles completed metamorphosis and left. If the mother frog did not eat during this period, from where did she get her energy?
- Analyzing Graphics** When tadpoles undergo metamorphosis, their bodies begin to produce an enzyme that converts ammonia into urea. The time that a tadpole takes to produce this enzyme varies among species. In the graph below, the rate of enzyme production is shown for a species that inhabits a desert-like environment and a species that inhabits a forest environment. Which curve represents which frog? Explain.

Enzyme Production in Two Frog Species





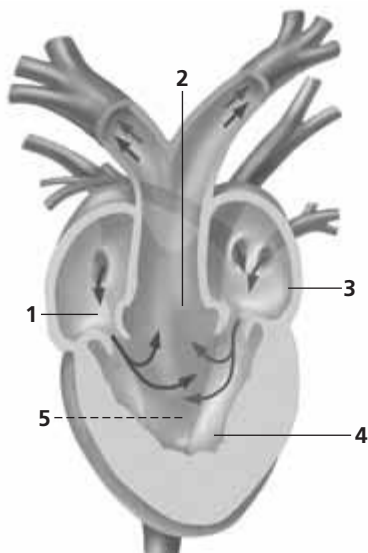


# Standardized Test Preparation

**DIRECTIONS:** Choose the letter that best answers the question or completes the sentence.

- The forelimbs of vertebrates evolved from which structures in lobe-finned fishes?
  - anal fin
  - pelvic fins
  - pectoral fins
  - pectoral girdle
- Amphibians must lay eggs in water primarily for what reason?
  - The eggs are not laid in nests.
  - The eggs need oxygen from water.
  - The eggs need protection from predators.
  - The eggs do not have multicellular membranes and a shell.
- Metamorphosis must take place before amphibians are able to do what?
  - swim
  - live on land
  - respire with gills
  - feed themselves

**INTERPRETING GRAPHICS:** The figure below shows a longitudinal section, dorsal view, of a frog heart. Use the figure below to answer question 4.

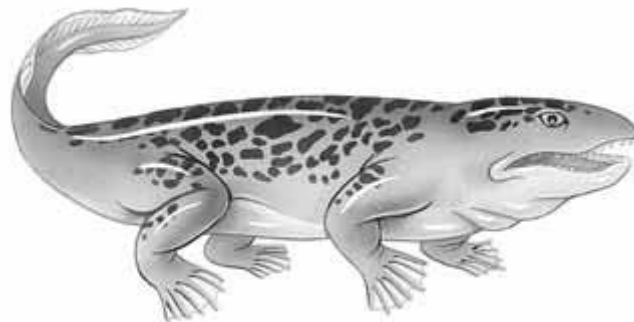


- Identify the source of blood flow in the section of the heart labeled 1.
  - the body
  - the aorta
  - the lungs
  - both lungs and body

**DIRECTIONS:** Complete the following analogy.

- Anura : frogs :: Gymnophiona :
  - toads
  - newts
  - caecilians
  - salamanders

**INTERPRETING GRAPHICS:** The figure below shows an artist's rendering of *Ichthyostega*. Use the figure to answer the question that follows.



- Ichthyostega* is an early amphibian. Which of the following characteristics is most likely to help it live on land?
  - fishlike tail
  - seven-toed feet
  - four strong limbs
  - lateral-line canals on the head

## SHORT RESPONSE

Modern amphibians are a diverse group, but they do have some common characteristics.

Describe five key characteristics shared by modern amphibians.

## EXTENDED RESPONSE

Frogs breathe by a positive pressure system.

**Part A** Describe how frogs move air into their lungs. Which part of inhaling is "positive pressure?"

**Part B** Describe how frogs move air out of their lungs and into the atmosphere.

## Test TIP

Be sure to read all of the answer choices carefully. Do not assume that the first correct answer is the only one.

# Observing Live Frogs

## OBJECTIVES

- Observe the behavior of a frog.
- Explain how a frog is adapted to life on land and in water.

## PROCESS SKILLS

- observing
- relating structure to function
- recognizing relationships

## MATERIALS

- live frog in a terrarium
- aquarium half-filled with dechlorinated water
- live insects (crickets or mealworms)
- 600 mL beaker

## Background


1. What does *amphibious* mean?
2. Describe how amphibians live part of their life on land and part in water.
3. What are some major characteristics of amphibians?



## PART A Observing the Frog in a Terrarium



1. Observe a live frog in a terrarium. Closely examine the external features of the frog. Make a drawing of the frog in your lab report. Label the eyes, nostrils, tympanic membranes, front legs, and hind legs. The tympanic membrane, or eardrum, is a disc-like membrane behind each eye.
2. In your lab report, make a table similar to the one on the facing page to note all your observations of the frog in this investigation.
3. Watch the frog's movements as it breathes. Record your observations in your data table.
4. Look closely at the frog's eyes, and note their location. Examine the upper and lower eyelids as well as a third transparent eyelid called a *nictitating membrane*. The upper and lower eyelids do not move. The nictitating membrane moves upward over the eye. This eyelid protects the eye when the frog is underwater and keeps the eye moist when the frog is on land.
5. Study the frog's legs. Note in your data table the difference between the front and hind legs.
6. Place a live insect, such as a cricket or a mealworm, in the terrarium. Observe how the frog reacts.
7. Gently tap the side of the terrarium farthest from the frog, and observe the frog's response.

## PART B Observing the Frog in an Aquarium

8.  **CAUTION** You will be working with a live animal. Handle it gently and follow instructions carefully. Frogs are slippery. Do not allow the frog to injure itself by jumping from the lab bench to the floor. Place a 600 mL beaker in the terrarium. Carefully pick up the frog and examine its skin. How does it feel? The skin of a frog acts as a respiratory organ, exchanging oxygen and carbon dioxide with the air or water. A frog also takes in and loses water through its skin.
9. Place the frog in the beaker. Cover the beaker with your hand, and carry it to a freshwater aquarium. Tilt the beaker and gently submerge it beneath the surface of the water until the frog swims out of the beaker.

## OBSERVATIONS OF A LIVE FROG

Characteristic	Observation
Breathing	
Eyes	
Legs	
Response to food	
Response to noise	
Skin texture	
Swimming behavior	
Skin coloration	

10. Watch the frog float and swim in the aquarium. How does the frog use its legs to swim? Notice the position of the frog's head.
11. As the frog swims, bend down and look up into the aquarium so that you can see the underside of the frog. Then look down on the frog from above. Compare the color on the dorsal and ventral sides of the frog. When you are finished observing the frog, your teacher will remove the frog from the aquarium.
12. Record your observations of the frog's skin texture, swimming behavior, and skin coloration in your data table.
13.   Clean up your materials and wash your hands before leaving the lab.



## Analysis and Conclusions

1. From the position of the frog's eyes, what can you infer about the frog's field of vision?
2. How does the position of the frog's eyes benefit the frog while it is swimming?
3. How does a frog hear?
4. How can a frog take in oxygen while it is swimming in water?
5. Why must a frog keep its skin moist while it is on land?
6. How are the hind legs of a frog adapted for life on land and in water?
7. What adaptive advantage do frogs have in showing different coloration on their dorsal and ventral sides?
8. What features provide evidence that an adult frog has an aquatic life and a terrestrial life?
9. What adaptations does the frog display in order to eat? What senses are involved in catching prey?
10. What movement does the frog make in order to breathe?

## Further Inquiry

Observe other types of amphibians, or do research to find out how they are adapted to life on land and in water. How do the adaptations of other types of amphibians compare with those of the frog you observed in this investigation?