CHAPTER

26 A Closer Look at Amniotes

KEY CONCEPTS

26.1 Amniotes

Reptiles, birds, and mammals are amniotes.

26.2 Reptiles

Reptiles were the first amniotes.

26.3 Birds

Birds have many adaptations for flight.

26.4 Mammals

Evolutionary adaptations allowed mammals to succeed dinosaurs as a dominant terrestrial vertebrate.

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Is this a monkey or a mouse?

The large eyes and ears of this eastern tarsier make it an excellent nocturnal hunter. These unusual mammals are primates and are closely related to modern monkeys. About the same size as a kitten, a tarsier has strong hind legs similar to those of frogs. The tarsier's eyes cannot move but it has a full range of view because it can rotate its head almost 360 degrees.

Connecting CONCEPTS

Biomes Tarsiers are exceptional climbers that live only in the tropical rain forests of southeastern Asia. Deep within these jungles are areas of the highest biodiversity on Earth. High above the ground, an entire community of species have adapted to become arboreal. They live almost their entire lives in the treetops, or forest canopy, very rarely setting foot on the dense forest floor.

26.1 Amniotes

KEY CONCEPT Reptiles, birds, and mammals are amniotes.

MAIN IDEAS

- Amniote embryos develop in a fluid-filled sac.
- Anatomy and circulation differ among amniotes.
- Amniotes can be ectothermic or endothermic.

VOCABULARY

pulmonary circuit, p. 789
systemic circuit, p. 789
ectotherm, p. 791
endotherm, p. 791

REVIEW AT CLASSZONE.COM

Connect When you were about nine weeks into your development, you had a mass of about 2 grams and measured about 18 millimeters long, roughly the size of a dime. Over the next seven months, you grew and developed while living safely inside a fluid-filled membrane, or amniotic sac. There are many different types of amniotes, but each of them, like you, begins life inside an amniotic sac.

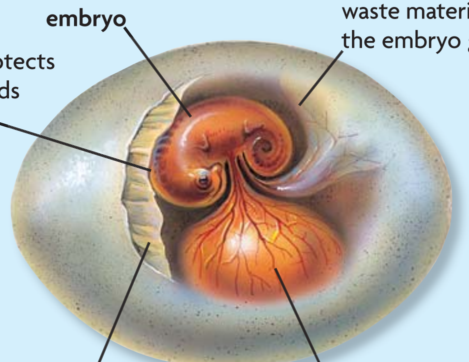
MAIN IDEA

Amniote embryos develop in a fluid-filled sac.

Reptiles, birds, and mammals are all amniotes. Recall from Chapter 25 that amniotes develop in a sac inside the mother's abdomen. This sac contains everything an embryonic vertebrate needs to grow and prepare for the world outside. In some amniotes, the sac is contained inside the mother's body. In other amniotes, a tough outer shell protects embryos as they develop outside of the mother. This shell is semipermeable, which means that it allows gases such as oxygen and carbon dioxide to pass through but prevents the embryo from drying out by holding water inside.

FIGURE 26.1 Amniotic Egg

Inside the shell of an amniotic egg, four membranes perform specific functions during development of the embryo.



An egg is a completely self-sustaining container that provides enough energy and nutrients to enable the embryo to mature. The illustration in **FIGURE 26.1** shows the different membranes found inside an amniotic egg. The egg you may have eaten for breakfast this morning was formed with all of the necessary membranes and nutrient stores to support a chicken embryo. But because the egg was never fertilized, the genetic composition of the egg remained haploid and did not develop into an embryo.

The development of the amniotic egg was an important adaptation because it allowed vertebrates to reproduce on land. Without the self-contained source of energy and water, an egg needed to develop in water or else the embryo would dry out.

Predict **What happens when all of the resources that are stored inside the egg are used?**

MAIN IDEA

Anatomy and circulation differ among amniotes.

Over time, amniotes have evolved many different body shapes and sizes, resulting in many differences in anatomy and blood circulation.

Anatomy

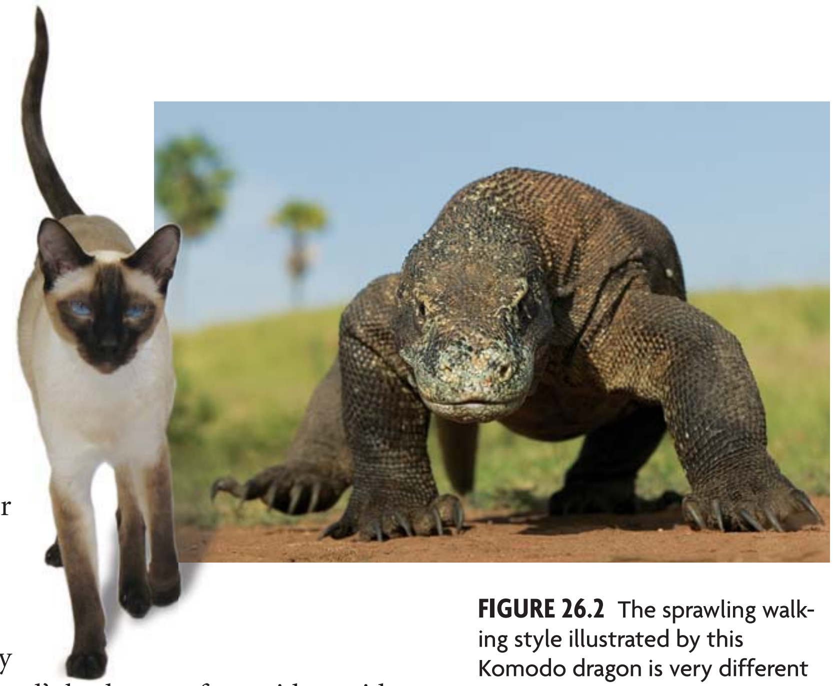


FIGURE 26.2 The sprawling walking style illustrated by this Komodo dragon is very different from the upright stance of a cat. Anatomical features make breathing easier and more efficient for upright walkers.

The first amniotes walked in a sprawl similar to that of the lizard in **FIGURE 26.2**. A lizard's legs stick out on either side of its body. It walks with its elbows and knees bent. Muscles around the ribs help propel the body forward, and their contractions make the lizard's body sway from side to side with each step. Because these same muscles also inflate the lungs, many animals with a sprawling stance cannot run and breathe at the same time. However, some reptiles have adaptations that allow them to breathe while running.

Amniotes such as mammals, dinosaurs, and birds evolved a more upright stance. The cat in **FIGURE 26.2** has straighter limbs than the lizard. Its legs are underneath its body and hold it far away from the ground. When it walks, its legs swing back and forth like pendulums, and its body does not wiggle from side to side. An upright stance uses less energy than a sprawling one. It also separates the muscles the animal uses to breathe from the muscles it uses to walk and run. The evolution of the diaphragm, an independent muscle used to expand the chest cavity and force air into the lungs, separated the muscles needed for walking and breathing. A diaphragm enables amniotes with an upright stance to run and breathe at the same time.

Circulation

As amniotes evolved, their bodies required more energy for movement and growth. To get this energy, their tissues demanded more energy and needed highly efficient ways of delivering this oxygen. This need led to the development of many different types of circulatory systems. All amniotes have a centralized heart that moves blood through a complex system of blood vessels to deliver nutrients to tissues and organs.

All amniotes have two circuits of blood vessels. Because the circuits are separate, amniotes can conserve energy more effectively. The two circuits of blood vessels are the pulmonary and systemic circuits.

- The **pulmonary circuit** moves oxygen-poor blood from the heart to the lungs, and oxygen-rich blood back to the heart.
- The **systemic circuit** moves oxygen-rich blood from the heart to the rest of the body.

The differences in amniote circulatory systems evolved over millions of years. As you will see, these differences affect the efficiency of an organism's everyday functions and behavior.

TAKING NOTES

Use a two-column chart to take notes on the pulmonary and systemic blood circuits.

Pulmonary Circuit	Systemic Circuit

Connecting CONCEPTS

Circulatory System The heart is a muscle for pumping blood through the body. It is made of two different types of chambers. The right and left atria collect blood from the body and lungs, and the right and left ventricles pump blood to the lungs and body. You will learn more about the heart in **Chapter 30**.

Like amphibians, reptiles have a three-chambered heart. A reptile's heart has two atria and one ventricle, as shown in **FIGURE 26.3.** One atrium collects oxygen-poor blood from the body. The other collects oxygen-rich blood from the lungs. Both atria send blood into the ventricle, which pumps blood into the pulmonary and systemic circuits. This unique anatomy lets these animals temporarily "turn off" their lungs. Like amphibians, amniotes such as lizards and turtles do not breathe continuously. Remember that sprawling amniotes stop breathing when they run. Others spend a lot of time under water. In either case, a single ventricle can divert blood away from the lungs when the animal is not using them. This strategy lets these animals adjust blood flow in response to their oxygen needs.

Mammals and birds have a four-chambered heart. As you can see in **FIGURE 26.3,** four-chambered hearts have two atria and two ventricles. This anatomy keeps oxygen-poor and oxygen-rich blood separate, but it cannot shift blood away from the lungs when the animal is not breathing. Keeping oxygen-rich and oxygen-poor blood separate effectively increases the flow of oxygen-rich blood to tissues. This adaptation gives these active animals a large and constant supply of oxygen. The development of the four-chambered heart allowed for an increase in energy use and eventually gave organisms increased control over their body temperature.

Infer Many reptiles are ambush predators, hiding and waiting for prey to come to them as opposed to actively hunting. Explain how this behavior may be related to their circulatory system.

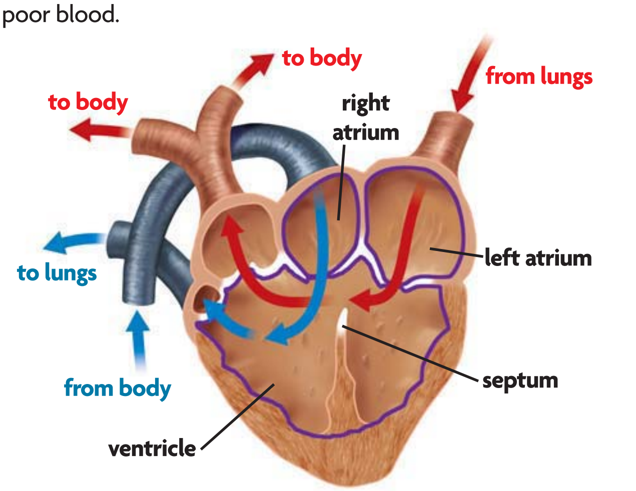
FIGURE 26.3 Amniote Hearts

The heart, the pump that moves blood around an organism's body, has developed differently in reptiles and mammals.

Oxygen-poor blood
Oxygen-rich blood

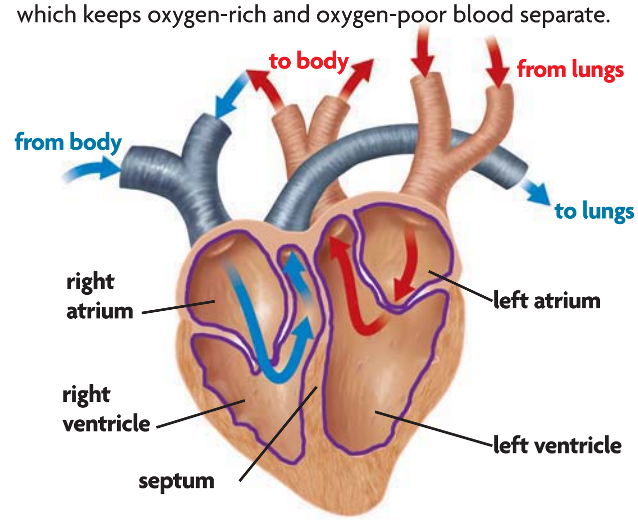
THREE-CHAMBERED HEART

Reptile hearts have three chambers. A septum that only partially divides the heart helps direct oxygen-rich and oxygen-poor blood.



FOUR-CHAMBERED HEART

Birds and mammals have a heart divided into four chambers, which keeps oxygen-rich and oxygen-poor blood separate.



Contrast How do differences in the septum affect blood flow in these hearts?

MAIN IDEA

Amniotes can be ectothermic or endothermic.

Like all organisms, amniotes are more active when they are warm. Enzymes that speed up the chemical reactions inside cells are more active at higher temperatures. A warm amniote digests food faster and can send more nutrients to its tissues. It can also move faster because its muscles contract more quickly and more often. All living organisms absorb heat from the environment and release heat as a byproduct of metabolism. But all animals manage heat in different ways.

You may have heard the term "cold-blooded" to describe a snake or a lizard. This term does not accurately describe reptiles and amphibians, because their blood is not actually cold. Instead, scientists use the term **ectotherms** to refer to organisms whose body temperatures are determined by their surrounding environment. These organisms' body temperature fluctuates with the temperature of their environment. They have higher body temperatures in a warm environment than in a cool one.

Ectotherms regulate their body temperature through their behavior. For example, many reptiles, such as the chameleon in **FIGURE 26.4**, bask in sunny places to warm their tissues when they are cold. Similarly, desert lizards move into shady burrows when outside temperatures climb too high. Large animals have a harder time shedding heat than small animals. If an ectothermic animal is massive enough, it will take a long time to cool down. Large ectotherms, such as crocodiles, can stay warm even when the environment is relatively cool.

On the other hand, you have probably heard humans and other mammals described as "warm-blooded." But to describe these organisms more accurately, scientists use the term *endotherm.* **Endotherms** are organisms that use their own metabolic heat to keep their tissues warm. More specifically, endotherms regulate their metabolic activity in ways that keep their body temperature relatively constant all of the time. They may shiver when they get too cold, contracting their muscles to generate extra heat. If they get too hot, they may cool down by sweating or panting. Many endotherms, such as the polar bear in **FIGURE 26.4**, are covered with insulation in the form of hair, fat cells, or feathers, which helps them control heat loss.

You can think of endotherms and ectotherms as having two different strategies for managing energy use. There is a trade-off between an animal's body temperature and the amount of energy it uses. Warm tissues work quickly and require more ATP, which requires an animal to eat more. For example, lions and crocodiles are both large predators, but a crocodile can survive on much less meat than a lion can. In short, ectotherms are less active when it is cold but can survive on less food than endotherms. Endotherms are active all the time but must eat more than ectotherms eat.

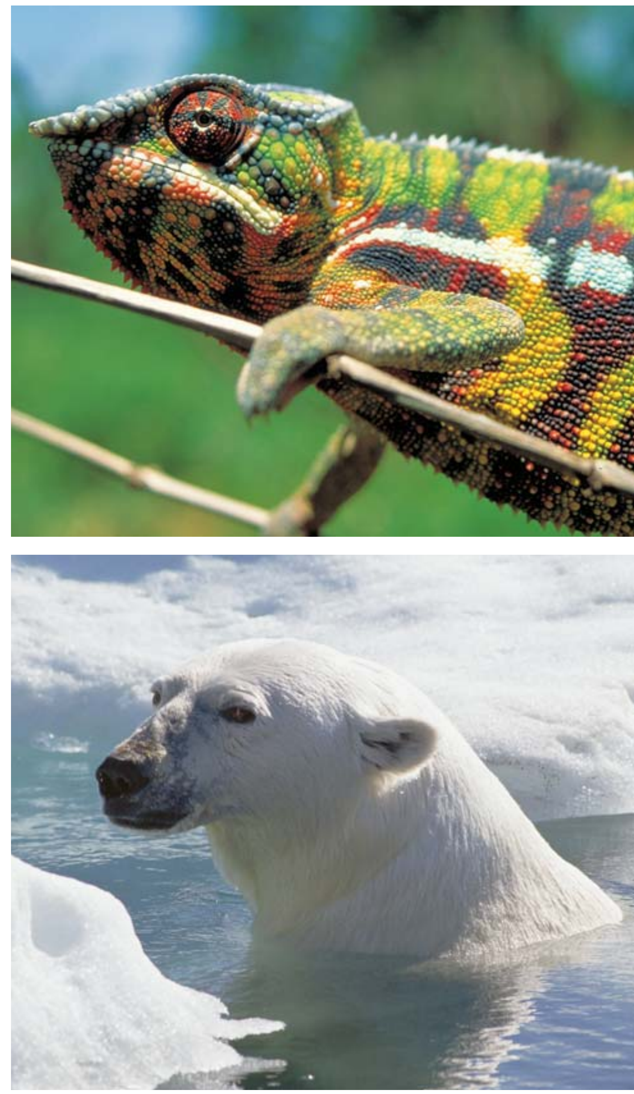


FIGURE 26.4 As an ectotherm, a chameleon increases its body temperature by basking in sunlight. Endotherms such as this polar bear can maintain a relatively constant body temperature even in cold environments.

DATA ANALYSIS

CHOOSING GRAPHS

Choosing an appropriate type of graph to represent data collected in an experiment is an important part of the scientific process.

The table to the right contains data that show the differences in energy requirements for endotherms and ectotherms. Despite having similar sizes, endotherms and ectotherms use energy in different ways and therefore require different amounts of food.

TABLE 1. BODY MASS AND FOOD INTAKE

Organism	Mass (kg)	Food Intake (kg/yr)
Nile crocodile	150	750
Grey kangaroo	45	1108
Komodo dragon	45	250
Koala	8	252
Monitor lizard	8	93

Source: Nagy, K.A. *Nutrition Abstracts and Reviews* Series B:71.

1. **Graph** Choose and construct one graph that can represent both sets of data.
2. **Analyze** Explain why there is a difference in energy requirements between endotherms and ectotherms.

The ability to regulate their own temperature served as an important function in the early stages of endotherm evolution. This adaptation gave endotherms a distinct advantage over ectotherms as Earth's climate changed millions of years ago. Because they could stay warm in colder weather, endotherms were able to exploit resources that the ectotherms could not. Many scientists believe that the ability to regulate their own body temperature allowed endotherms to survive the catastrophic events that led to the extinction of dinosaurs.

Analyze As you move away from Earth's equator into colder latitudes, why are there fewer ectotherms and more endotherms?

26.1 ASSESSMENT

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REVIEWING MAIN IDEAS

1. How did the development of an amniotic egg allow vertebrates to reproduce on land?
2. How does anatomy and circulation differ among amniotes?
3. What is the difference between an **endotherm** and an **ectotherm**?

CRITICAL THINKING

4. **Infer** A 30-gram shrew will die if it cannot eat for a few hours. A 30-gram gecko thrives on a few crickets every other day. Why might shrews need food more often?
5. **Compare** Illustrate the path of blood through a three-chambered heart when the animal is breathing. Show how the pathway changes when the animal is not breathing.

Connecting CONCEPTS

6. **Survivorship** When eggs are laid by a species of reptile or bird, they generally stay in a nest that is closely guarded by a mother. How does this behavior affect the chances for offspring to survive to adulthood? What type of survivorship strategy does this represent?

26.2 Reptiles

KEY CONCEPT Reptiles were the first amniotes.

MAIN IDEAS

- Reptiles are a diverse group of amniotes.
- Reptiles have been evolving for millions of years.
- There are four modern groups of reptiles.

VOCABULARY

reptile, p. 793
oviparous, p. 793
viviparous, p. 793

REVIEW AT CLASSZONE.COM

Connect Basking on the sunny banks of the river, the lizard may look slow, but it has a top speed of almost 20 kilometers per hour, and strong jaws filled with sharp teeth. It is a daunting predator. The eastern water dragon may only grow to 80 centimeters in length and may never compare to a crocodile as a threat to humans, but it hunts, kills, and eats its prey in the same way that its larger cousins do. What makes reptiles unique?

MAIN IDEA

Reptiles are a diverse group of amniotes.

About 200 million years ago, a mass extinction resulted in the loss of many of Earth's plant and animal species. One group of organisms that survived—the reptiles—have thrived for millions of years. **Reptiles** are ectotherms that are covered with dry scales or plates and reproduce by laying amniotic eggs covered with a tough outer shell.

VOCABULARY

The name *reptile* comes from the Latin word, *reptilis,* which means "creeping."

Unlike amphibians, reptiles produce a completely self-sustaining, amniotic egg that allows an embryonic reptile to develop fully before it is born. There are two ways that reptile eggs develop.

- **Oviparous** reptiles deposit their eggs into an external nest, and the eggs develop completely independent of the adult reptile.
- **Viviparous** reptiles hold the eggs inside their body through the duration of development and give birth to live offspring.

The shapes and sizes of modern reptiles vary widely. Some reptiles have no legs. Other reptiles run swiftly on land or spend much of their time in the water. The oddly shaped turtles and tortoises carry their homes on their backs. Each reptile group has adapted different features that allow it to be successful. But despite these differences, all reptiles share a few similarities.

All living reptiles are ectotherms. Recall that an ectotherm's body temperature changes based on the surrounding environment. Similar to the eastern water dragon in **FIGURE 26.5**, many reptiles spend a great deal of time basking, or sunbathing, to absorb energy from sunlight. In addition, reptiles have dry scales or plates that absorb energy and help contain heat needed to maintain normal body functions.

Analyze **What advantages does a self-sustaining egg give reptiles?**

FIGURE 26.5 As a reptile, this eastern water dragon must use energy from sunlight to maintain its body temperature. From its perch atop a rock, it can also spot predators or look for prey.

MAIN IDEA

Reptiles have been evolving for millions of years.

Fossil evidence suggests that reptiles began to emerge from the water during the late Paleozoic era, almost 350 million years ago. They became the dominant vertebrate during the Mesozoic era.

FIGURE 26.6 Turtles and tortoises are anapsids. Aside from the holes for eyes and nose, this skull of a modern turtle has no temporal holes.

Synapsids, Anapsids, and Diapsids

Scientists discovered that, over time, amniotes evolved into three different groups. This discovery was based on temporal holes that are found on the sides of the amniote skull.

Synapsids Reptiles that had one hole in each temporal region were synapsids. The synapsids eventually gave rise to modern mammals.

Anapsids Reptiles that have skulls with no temporal holes are anapsids. Scientists do not know why anapsids have no skull holes. Some think that they may still have the same skull anatomy as the first amniotes or that they may have lost skull holes through natural selection. The anapsids of today are turtles and tortoises, with skulls similar to the one shown in **FIGURE 26.6**.

AMNIOTE SKULL TYPES

SKULL TYPE	NUMBER OF HOLES	EXAMPLE
Anapsid	0	turtles
Synapsid	1	mammals
Diapsid	2	birds, lizards, crocodilians

Diapsids Reptiles that have two holes in each temporal region, one above the other, are diapsids. Diapsid skulls came about as reptiles began to colonize land. For the next 200 million years, diapsid reptiles ruled Earth. Eventually, this group gave rise to many of the modern reptiles and birds of today.

Skull holes may have started out as a weight-reducing adaptation. Less bone would have made the skull lighter and easier to move and given more space for muscle attachments, allowing jaw muscles to get larger. The phylogenetic tree in **FIGURE 26.7** shows how the ancient and now extinct groups of reptiles may have evolved.

Diversity of Extinct Amniotes

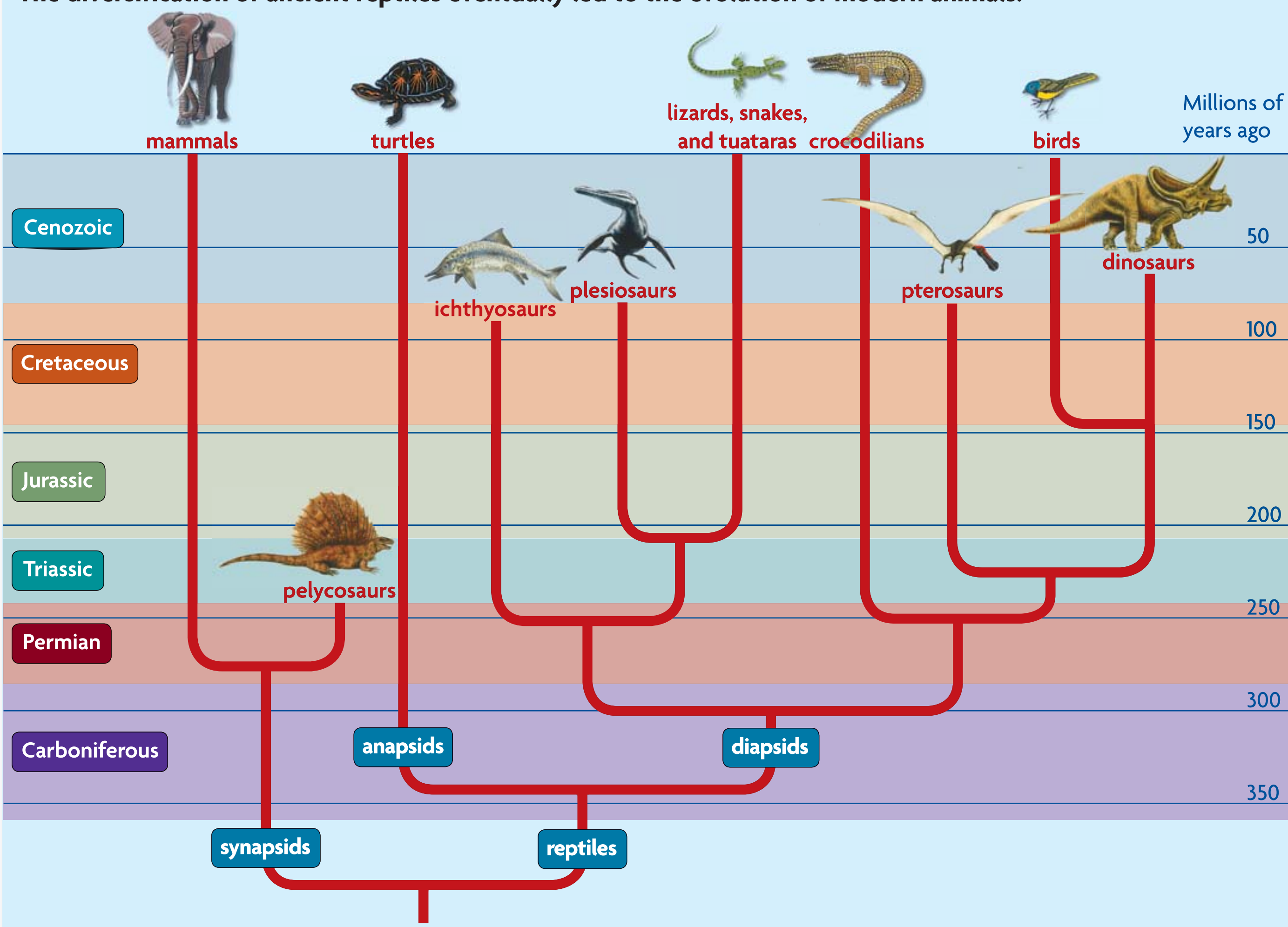
Pelycosaurs were synapsids that first appeared during the late Carboniferous period. This group included both carnivores and herbivores. Some pelycosaurs had a distinctive "sail-back" made of elongated vertebral spines. Most pelycosaurs died in a mass extinction 245 million years ago, but some of their descendants later gave rise to the mammals.

Ichthyosaurs were some of the first diapsid reptiles. An ichthyosaur's sleek body, flipper-shaped limbs, and fleshy dorsal fin were similar to those of the modern day dolphin. Ichthyosaurs swam by beating their fishlike tails back and forth in the water, and their peglike teeth suggest that they ate fish. Fossil evidence indicates that ichthyosaurs first appeared about 250 million years ago and went extinct about 90 million years ago.

Plesiosaurs were some of the strangest prehistoric marine reptiles. They "flew" through the water like sea lions, using four limbs like elongated flippers. Some plesiosaurs had small heads and very long necks, which were likely used to help them catch fish. Others had short necks and long heads and probably chased down larger prey. Fossils show the plesiosaurs first appeared around 220 million years ago and then died out around 80 million years ago.

FIGURE 26.7 Phylogenetic Tree of Reptiles

The diversification of ancient reptiles eventually led to the evolution of modern animals.



Analyze Are there any diapsid mammals? Explain your answer using the diagram.

Dinosaurs were the second great radiation of the amniote family. They appeared 230 million years ago and were the dominant land vertebrates for the next 150 million years. Many kinds of dinosaurs evolved during that time. Herbivorous species included huge sauropods, tanklike ceratopsians, and duck-billed dinosaurs. They were hunted by carnivorous theropod dinosaurs, which eventually gave rise to birds. All of the nonavian, or walking, dinosaurs went extinct 65 million years ago.

Pterosaurs were the first vertebrates to evolve powered flight. Their wings consisted of skin supported by an extremely elongated fourth finger. The earliest species, from the end of the Triassic, were small animals with long tails. Later species, such as *Pteranodon* lost their tails and grew as large as small airplanes. Recent fossils show that pterosaurs may have been covered with hair, suggesting that they were endothermic. They went extinct at the end of the Cretaceous along with the dinosaurs.

Apply How did the discovery of temporal skull holes help scientists determine phylogeny of amniotes?

Connecting CONCEPTS

Phylogeny Recall from **Chapter 17** that a phylogeny is a type of evolutionary tree that illustrates how different species are related to each other. The relationships between modern animals and ancient reptiles help scientists understand evolution.

MAIN IDEA

There are four modern groups of reptiles.

FIGURE 26.8 Sea turtles live in tropical ocean waters all over the world.

Of all the reptiles that evolved during the Mesozoic era, only four groups are alive today: turtles, sphenodonts, snakes and lizards, and crocodilians.

Turtles

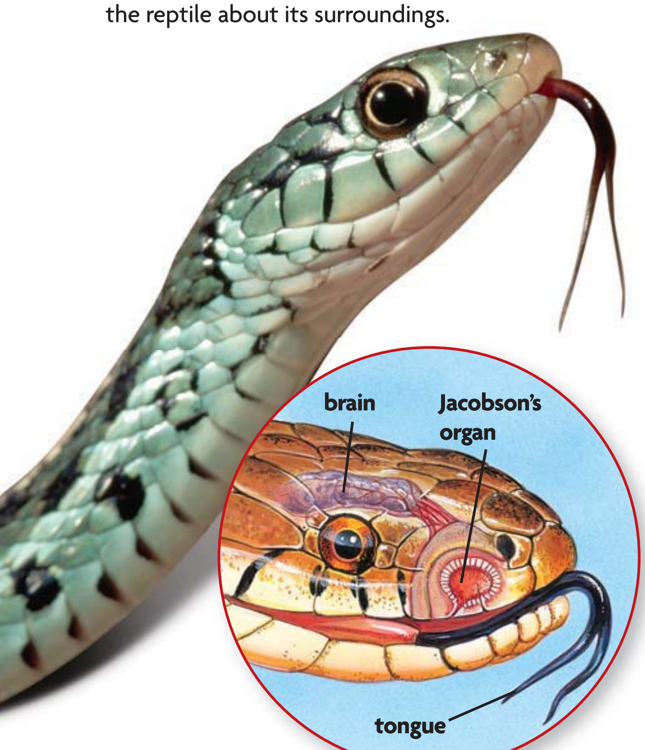
There are about 200 living species of turtles today. Turtles, tortoises, and terrapins are the only remaining anapsid group of amniotes. The distinctive shape of a turtle is actually a bony shell that encases the reptile's body. The domed back of a turtle's shell is called the carapace, while the smooth ventral part is called the plastron. This shell is covered with tough, flattened plates made of keratin that are fused to the turtle's rib cage and vertebrae. Many turtles can pull their head and limbs into the shell for protection.

Turtles are toothless and have sharp, horny beaks. Most turtles are omnivorous—they eat plants as well as animals. They are found in terrestrial, freshwater, and marine environments. Fully terrestrial turtles are called tortoises. They have high domed shells and thick stumpy limbs. Freshwater turtles have flatter shells. Some species have lost the bone in their shells to become "soft shell" turtles. The sea turtle in **FIGURE 26.8**, like most marine turtles, has forelimbs that are large flippers that let it "fly" underwater.

Sphenodonts

The only living sphenodonts are two species of tuatara that live on a few small islands off the coast of New Zealand. They are closely related to lizards and snakes, and look similar to a spiny iguana. Tuataras have primitive characteristics, such as a diapsid skull and an eyespot in the center of their head.

FIGURE 26.9 Snakes and lizards protrude a forked tongue to collect tiny molecules out of the air. These molecules are interpreted by the Jacobson's organ to inform the reptile about its surroundings.



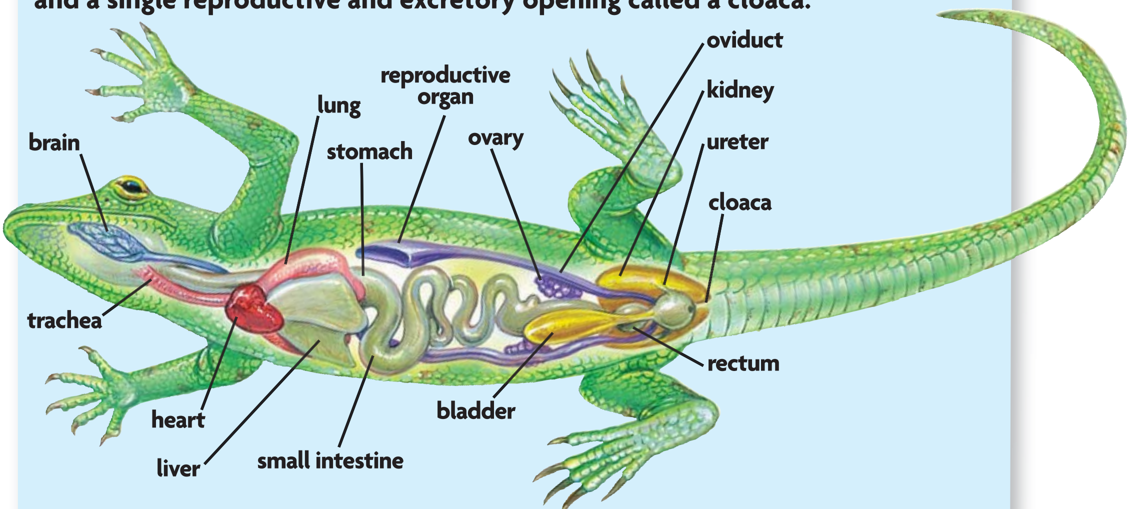
Snakes and Lizards

Snakes and lizards are very closely related and share a number of features. Snakes and lizards all shed their skin at regular intervals. They also have flexible skulls that let them capture and swallow prey larger than their head. All snakes and lizards use a highly developed organ that allows them to "taste" the air. As shown in **FIGURE 26.9**, when a snake or lizard flicks its forked tongue out of its mouth, the tongue collects particles out of the air. Particles are interpreted by a sensory receptor called the Jacobson's organ, which is found in the top of the reptile's mouth. This organ allows lizards and snakes to locate prey and avoid predators.

Most lizards are carnivorous. Small species hunt insects, but large species such as the Komodo dragon prey on mammals. Some species, such as iguanas, are strict herbivores. Snakes are a group of legless lizards. All snakes are predators. Some snakes kill their prey by constriction, wrapping their body around their prey and squeezing. Others use poisons that are injected into their prey through modified teeth.

FIGURE 26.10 Reptile Anatomy

The unique features of reptiles include a three-chambered heart and a single reproductive and excretory opening called a cloaca.



Apply **How does reptile anatomy prevent the organism from running and breathing at the same time?**

Crocodilians

There are 23 species of crocodilians, including alligators, crocodiles, and caimans. They are all semiaquatic predators that live in swamps and rivers in the tropics and subtropics. They are ambush predators, waiting underwater to surprise other animals. Their sprawling resting posture makes them look slow, but they are capable of lifting up their bodies and running at up to 27 kilometers per hour (17 mph).

Crocodilians are one of two groups of archosaurs that survived the mass reptile extinction 65 million years ago. Archosaurs were a large group of reptiles that included crocodiles, dinosaurs, and modern-day birds. Based on fossil evidence, crocodilians are actually more closely related to birds than they are to lizards and snakes. Many of the body shapes and structures of ancient crocodilians are similar to the features of modern crocodilians.

Summarize **What features do all reptiles share?**

26.2 ASSESSMENT

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REVIEWING ▶ MAIN IDEAS

1. How is a **viviparous** reptile different from an **oviparous** reptile?
2. What are the major groups of extinct **reptiles**?
3. What features do modern reptiles share?

CRITICAL THINKING

4. **Classify** You find a fossil of a reptile that has a long neck and four long flippers for limbs. It is in marine sediments. To which group of ancient reptiles could it belong?
5. **Infer** Explain why there are no reptiles found in the Arctic.

Connecting CONCEPTS

6. **Amphibians** Amniotes emerge from their shell fully developed. Amphibians must go through metamorphosis to reach their adult form. What is the advantage of direct development for amniotes?

26.3 Birds

KEY CONCEPT Birds have many adaptations for flight.

MAIN IDEAS

- Birds evolved from theropod dinosaurs.
- A bird's body is specialized for flight.
- Birds have spread to many ecological niches.

VOCABULARY

airfoil, p. 799
sternum, p. 801
air sac, p. 801

REVIEW AT CLASSZONE.COM

Connect You may share certain features with your parents or siblings. Perhaps your eyes are the same color or your nose is the same shape. Certain traits make it easy to identify your ancestors. Birds have a bit more trouble. That cardinal at your bird feeder would probably be surprised to discover that it is related to a ferocious *Velociraptor,* but birds are the surviving relatives of those prehistoric animals. Birds are dinosaurs that evolved powered flight.

MAIN IDEA

Birds evolved from theropod dinosaurs.

Most paleontologists agree that birds are the descendants of one group of theropod dinosaurs. Theropods were bipedal, or two-legged, dinosaurs that evolved during the Triassic period of the Mesozoic era. Most were carnivorous, and some, such as *Allosaurus* and *Tyrannosaurus,* were enormous. Theropod fossils support the hypothesis that these dinosaurs are closely related to birds. They show that birds and many theropods share anatomical features, including

- hollow bones
- fused collarbones that form a V-shaped wishbone, or furcula
- rearranged muscles in the hips and legs that improve bipedal movement
- "hands" that have lost their fourth and fifth fingers
- feathers

In the 1990s scientists discovered theropod fossils with feathers. This important discovery showed that feathers did not originate as an adaptation for flight. These theropods were covered with feathers, but they did not have wings. They were running animals. This means that feathers originally had another function in the theropods. They may have been insulation that trapped air to keep the animals warm. Or they may have been used in courtship or territorial displays. As birds evolved, they used the feathers they had inherited from their theropod ancestors to form wings.

The oldest undisputed fossil bird is shown in **FIGURE 26.11.** *Archaeopteryx* was a chicken-sized animal that lived about 150 million years ago. Like all modern birds, it had feathered wings and a furcula. But it also had many reptilian features, including clawed fingers, a long tail, and teeth. Because of its features, *Archaeopteryx* was classified as a dinosaur. However, its feathers made it an important link between flightless dinosaurs and avian, or flying, dinosaurs, as well as the birds of today.

FIGURE 26.11 Fossil evidence of *Archaeopteryx* shows features such as feathers and a beaklike structure not seen in dinosaurs. *Archaeopteryx* is an important link between dinosaurs and modern-day birds.

Scientists have two hypotheses for the origin of flight in birds. The “trees-down” hypothesis suggests that birds evolved from animals that used their feathers to glide down to the forest floor. In contrast, the “ground-up” hypothesis suggests that birds evolved from running animals that used their feathered arms for balance.

The fossil evidence showing a close relationship between theropods and birds tends to support the “ground-up” hypothesis. Many theropods were bipedal carnivores that hunted by running down their prey. Scientists still do not know how these dinosaurs moved from running and grabbing to flapping and flying. Some recent research suggests that small theropods could have flapped their feathered arms to run up trees and escape predators. Whether they also used those feathered arms to glide back down to the ground is unknown, but future fossil discoveries may provide an answer.

FIGURE 26.12 The broad wings of an eagle owl are adapted for silent flight, making this nocturnal bird a quiet and deadly predator.

Infer **How might hollow bones have helped theropods move more efficiently?**

MAIN IDEA

A bird’s body is specialized for flight.

Birds such as the eagle owl in **FIGURE 26.12** have many specialized adaptations for powered flight. Some of them are modifications of features inherited from their theropod ancestors. Others are unique to birds. These adaptations include

- wings that produce flight
- strong flight muscles that move the wings
- an active metabolism that provides energy to the muscles
- hollow bone structure that minimizes weight
- reproductive adaptations

Wings

Wings are structures that enable birds to fly. Bird wings are curved similar to the shape of an airplane wing. This kind of curved surface is called an airfoil. An **airfoil** is curved down on the top (convex) and curved up on the bottom (concave). The curved shape makes air move faster over the top of the airfoil than underneath it. The difference in air speed above and below the airfoil produces a pressure difference that lifts the wing up. In birds, the airfoil is constructed of limbs that are homologous to human arms and covered by large feathers.

VISUAL VOCAB

An **airfoil** is convex on the top and concave on the bottom. Differences in air pressure above and below the airfoil create lift.

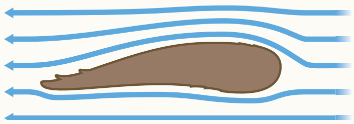
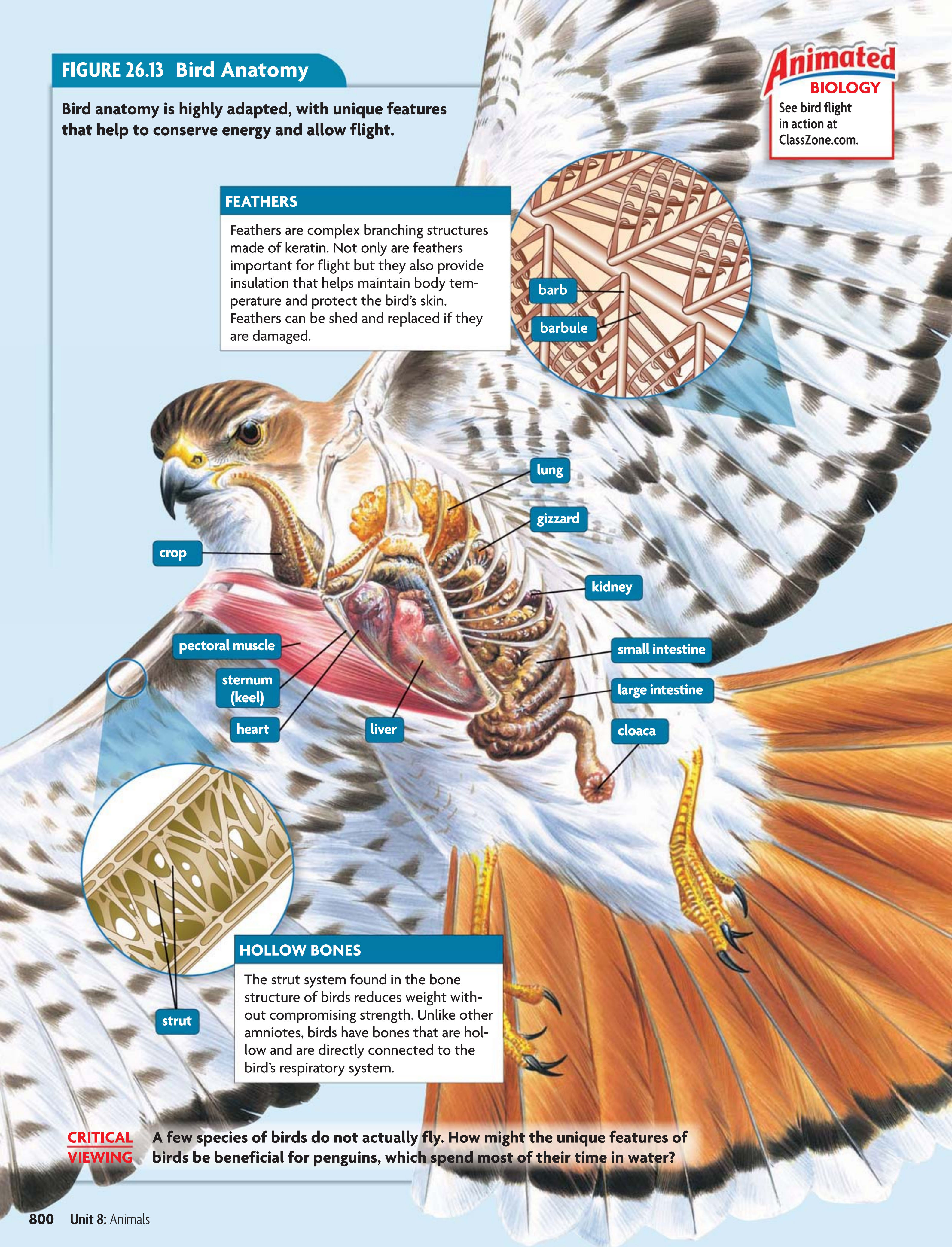


FIGURE 26.13 Bird Anatomy

Bird anatomy is highly adapted, with unique features that help to conserve energy and allow flight.

Animated BIOLOGY
See bird flight in action at ClassZone.com.



FEATHERS

Feathers are complex branching structures made of keratin. Not only are feathers important for flight but they also provide insulation that helps maintain body temperature and protect the bird's skin. Feathers can be shed and replaced if they are damaged.

HOLLOW BONES

The strut system found in the bone structure of birds reduces weight without compromising strength. Unlike other amniotes, birds have bones that are hollow and are directly connected to the bird's respiratory system.

CRITICAL VIEWING **A few species of birds do not actually fly. How might the unique features of birds be beneficial for penguins, which spend most of their time in water?**

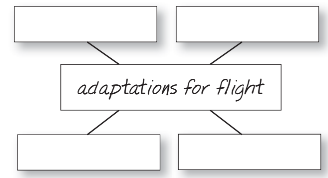
Muscles

A bird's chest muscles provide the power for flight. In almost all vertebrates, chest muscles attach to the arms and the breastbone, or **sternum.** But anyone who has carved a chicken knows that a bird's chest muscles are enormous. They are so large that the sternum has evolved a large keel, or ridge, that supports the muscles. The keel provides a large attachment surface for the chest muscles, and serves as an anchor that they can pull against to flap the wings.

When birds fly, their chest muscles contract to pull their wings backward and down. The downstroke moves the wings to produce lift and propel the animal forward. Deeper chest muscles contract during the upstroke, moving the wings forward and up until the bird starts another downstroke.

TAKING NOTES

Use a main idea diagram to take notes on how the features of birds help them to achieve flight.

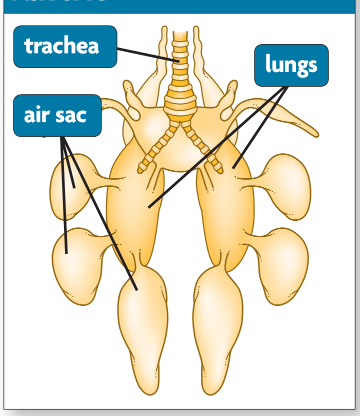


Metabolism

Flying takes a lot of energy. Birds are endotherms and have active metabolisms that can produce large amounts of ATP for the flight muscles. But maintaining an active metabolism during flight requires an enormous amount of oxygen. Birds meet this challenge with a respiratory system that increases the amount of oxygen they can take out of the air.

A bird's body is filled with a series of **air sacs** that connect to the lungs. Air sacs store air as the bird breathes. During flight, movements of the furcula help push air through the air sacs and lungs. Inhaled air travels through the lungs and air sacs in such a way that oxygen-rich air is always available. In other vertebrates, oxygen-rich air mixes with oxygen-poor air inside the lungs during respiration. But because only oxygen-rich air flows through a bird's lungs, the amount of oxygen that can be absorbed into the bloodstream is dramatically increased and maximizes a bird's metabolism.

AIR SAC



***Connecting* CONCEPTS**

Cellular Respiration Birds require large amounts of ATP to provide the energy needed for flight. Recall from **Chapter 4** that cellular respiration needs oxygen and glucose to produce ATP. Air sacs provide a great deal of oxygen, but birds must also consume large amounts of food to support their active metabolism.

Bone Structure

The structure of a bird's skeletal system is different than that of other amniotes. Birds have evolved bones that are hollow. As you can see in **FIGURE 26.13**, inside bird bones, a system of struts and support structures maintain the bird's bones to meet the demanding requirements of flight. In all birds, many bones are connected to the air sacs, and air fills the cavities in the bone, aiding in flight. This adaption further increases the amount of air in a bird's body, and makes flying easier. It also helps to decrease the mass of the bird. In fact, a bird's skeleton makes up only five percent of its overall body mass.

Reproductive Adaptations

The reproductive organs of both male and female birds are only active for the two to three months of the mating season. During the rest of the year, the unused organs shrink to reduce the mass of the bird. This weight-reducing adaptation serves to decrease the amount of energy needed for flight.

Summarize **How are bird bodies adapted to flying?**

QUICK LAB OBSERVING

Comparing Feathers

Feathers are features that allow birds to adapt to a unique way of life. In this lab, you will examine three different types of feathers.

SKILL Observing

PROBLEM How do the structures and functions of different feathers compare?

MATERIALS
- purchased quill feather
- purchased contour feather
- purchased down feather

PROCEDURE

1. Obtain a large quill feather and study its overall shape, structure and weight. Draw the features.
2. Examine the central shaft of the feather. Hold the end of the shaft with one hand. With your other hand, gently try to bend the upper third of the feather without breaking it.
3. Observe the vane, the flat part of the feather on either side of the shaft. Separate some of the barbs of a vane. Join them again with your fingers.
4. Hold the end of the shaft and wave the feather so that it catches the air. Note the resistance you feel as you move the feather through the air.
5. Repeat steps 1–4 with the contour and down feathers.

ANALYZE AND CONCLUDE

1. **Analyze** What is the function of the shaft?
2. **Analyze** How are down feathers different from contour and quill feathers?
3. **Infer** Describe the function of each type of feather.
4. **Apply** What characteristics make quill feathers well suited for their function?
5. **Apply** How are contour feathers designed to make a bird streamlined?
6. **Infer** How do you think the structure of down feathers helps to insulate a bird?

MAIN IDEA

Birds have spread to many ecological niches.

Birds first evolved during the Mesozoic era, but most Mesozoic bird species went extinct with the dinosaurs. All modern birds are the descendants of the one group that survived the mass extinction. This group diversified into the more than 9000 species of bird we see today. Through natural selection, birds have adapted to many different habitats and methods of feeding. This has led to visible physical differences in the shapes of the wings, beaks, and feet.

Differences in Wing Shape

The shape of a bird's wing reflects the way it flies. Most birds have short, broad wings that allow them to maneuver very easily. In contrast, albatrosses and gulls, such as the blue-footed booby in **FIGURE 26.14**, have long, narrow wings specialized for soaring long distances over water. Hawks, eagles, and condors have wide, broad wings specialized for soaring at low speeds over land. Many types of songbirds, including woodpeckers, finches, and robins, have stout, tapered wings that help them to maneuver through tight spaces. Penguins have short wings adapted to "fly" in water. Flightless birds, such as ostriches and emus, have wings that are too small to let them fly at all.

Differences in Beak Shape

The shape of a bird's beak reflects how it eats. A bird's beak is a sheath of keratin that covers the jaw bones. As Charles Darwin observed in the many finch species of the Galapagos Islands, beak shapes are adapted for many different functions. For example, the blue-footed booby uses its long, spearlike beak to capture fish on the bird's dives into the ocean. The beak of the bald eagle is hooked to tear flesh from its prey. Birds that catch insects often have thin, pointed bills. Woodpeckers have beaks like chisels to pry insects out of trees. Other birds, such as hummingbirds, have long, thin beaks that can reach deep into flowers for nectar. Pelicans have large pouches of skin attached to their beaks for scooping fish out of the water. Parrots use their thick, strong beaks for ripping open fruits and cracking nuts.

Differences in Foot Shape

With few exceptions, bird feet have four toes. But as **FIGURE 26.14** shows, their feet can look very different. The blue-footed booby and other aquatic birds have webbed feet, with skin connecting the toes to form paddles. Predatory birds such as the bald eagle have heavy claws that they use to capture and kill prey. Birds that live in trees have feet that can grab onto branches and tree bark. Woodpeckers, for example, have two toes pointing forward and two pointing backward, which lets them cling to vertical tree trunks. Sparrows and crows have three toes pointing forward and one pointing backward, which lets them perch on horizontal tree limbs.

Infer **Where would you expect to find a bird with webbed feet and very long and narrow wings?**

FIGURE 26.14 Birds' features are specifically adapted to their habitat and niche. Natural selection has led to a wide array of wings, beaks, and feet.

26.3 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. What are three anatomical features that birds share with their theropod ancestors?
2. What adaptations do birds have that help them with flight?
3. Describe how the wings, beak, and feet of an eagle are well adapted to its niche.

CRITICAL THINKING

4. **Analyze** The red-headed woodpecker has an unusually long tongue and a stout, pointed beak. How are these features related to the woodpecker's feeding habits?
5. **Connect** Reptiles and birds are closely related. Why is the evolution from being an ectotherm to being an endotherm so important for bird evolution?

Connecting CONCEPTS

6. **Selection** Male cardinals have bright red feathers, whereas females have dull brown feathers. What type of selection likely caused these differences?

A Bird's Airframe

Wings were an important adaptation for birds. The structure of wings gave birds the ability to fly and move great distances in search of resources. But for some birds, flight was not necessary for survival. In this lab, you will investigate the differences and similarities between flying and flightless birds, and compare them with mammals.

MATERIALS

- balance
- 100 mL graduated cylinder
- 50 mL water
- boiled chicken bone (flightless bird)
- boiled duck or turkey bone (flying bird)
- boiled cow bone (mammal)
- hammer
- hand lens

PROCESS SKILLS

- **Observing**
- **Measuring**
- **Analyzing**

PROBLEM Besides wings, what major adaptation is beneficial for flight?

PROCEDURE

1. Measure the mass of each bone (chicken, duck, cow) using the balance. Record the mass for each.
2. Pour the water in the graduated cylinder and note the volume. Add one of the bones to the cylinder and record the volume again. To find the volume of the bone, subtract the original volume from the second reading.
3. Repeat step 2 for each bone used.
4. Attempt to break the bone by hand and note how easy or difficult it is. (If you can't break the bone by hand, it is okay.)

   Caution: Wearing your safety goggles, carefully break each experimental bone with the hammer (watch out for flying pieces).
5. Examine the internal structure of each bone with the hand lens. Make a labeled drawing for each bone.

ANALYZE AND CONCLUDE

1. **Predict** Which bone do you think has the greatest density? Which bone is the least dense?
2. **Calculate** Calculate the densities for each bone (density = $\frac{\text{mass}}{\text{volume}}$).
3. **Apply** What can you conclude about bone density and the ability to fly?
4. **Observe** How does the structure of the flightless bird bone compare with that of the flying bird bone? with the cow bone?
5. **Infer** What bones are easier to break by hand than others? Explain why you think this is true.
6. **Analyze** What features of the bird bones might be adaptations for flight?
7. **Contrast** Were there any significant differences between bones from flying birds and those from flightless birds? Why might one bird be able to fly while another cannot fly?

100 mL graduated cylinder

26.4 Mammals

KEY CONCEPT Evolutionary adaptations allowed mammals to succeed dinosaurs as a dominant terrestrial vertebrate.

MAIN IDEAS

- All mammals share several common characteristics.
- Modern mammals are divided into three main groups.

VOCABULARY

mammal, p. 805
mammary gland, p. 806
monotreme, p. 807
marsupial, p. 808
eutherian, p. 809

REVIEW AT CLASSZONE.COM

Connect Each time you get your hair cut, you are having a feature clipped off that sets humans and other mammals apart from reptiles, birds, amphibians, and fish. In addition to hair, what other traits make mammals unique?

MAIN IDEA

All mammals share several common characteristics.

All **mammals** are active, large-brained, endothermic animals with complex social, feeding, and reproductive behaviors. Modern mammals—such as the bat in **FIGURE 26.15**—come in many shapes, but they share a set of four anatomical characteristics.

- hair
- mammary glands
- a middle ear containing three bones
- a jaw that lets them chew their food

Mammals are as ancient as dinosaurs and are the only group of synapsids alive today. They are descended from a group of carnivorous synapsids. Many of the characteristics we now see only in mammals were actually inherited from these reptilian ancestors. Earth's first mammals appeared more than 200 million years ago, when dinosaurs were already on their way to becoming the top predators and herbivores on the planet. During the Cretaceous period, while *Tyrannosaurus rex* was hunting *Triceratops,* tiny rodentlike mammals had found a niche as nocturnal insect eaters.

Fossil evidence suggests that early mammals had long noses and short legs. They may have looked similar to modern-day shrews. They probably lived underground, reproduced by laying eggs, and nursed their young on nutrient-rich milk produced by highly adapted glands. The ability to regulate their own body temperature was an important adaptation that gave mammals a distinct advantage over reptiles. When the dinosaurs went extinct, mammals survived and filled their vacant ecological niches. In time, mammals succeeded dinosaurs as a dominant terrestrial life form.

FIGURE 26.15 This Yuma myotis bat has all of the basic mammalian features. Bats are the only mammals that can fly.

Connecting CONCEPTS

Natural Selection All mammals have hair or, more accurately, hair follicles. Whales are mammals, but most adult whales do not have hair. Recall from **Chapter 10** that natural selection favors traits that increase the fitness of individuals. In the underwater environment of whales, hair causes resistance and may be obstructions in catching prey, thus making them less likely to survive and reproduce.

Hair

Mammals are furry. Most species are covered with a layer of hair that helps them retain heat. Each hair is a long, thin shaft of dead, keratinized cells that grows out of a follicle in the skin. The hair traps a layer of air next to the skin, which insulates the animal, much like a down vest insulates you. When mammals get cold, muscles around the follicles pull the hair upright. When you get "goose bumps," your insulating air layer is thickening to help keep you warm.

Hair also has other functions. Anyone who has watched a frightened cat fluff up knows that mammals can use hair for behavioral displays. Patterns of pigmented hairs provide camouflage for many mammals. Porcupines and hedgehogs have modified hairs that form stiff protective quills. And many mammals have long, stiff whiskers that collect sensory information. Even mammals that have lost most of their hair, such as whales, retain some sensory bristles.

FIGURE 26.16 Mammals produce milk in mammary glands to provide nutrients to their offspring. These piglets will nurse from their mother for three to eight weeks.

Mammary Glands

All mammals take care of their babies after they are born. Females feed them a specialized fluid called milk. **Mammary glands** are specialized glands that produce milk. Milk contains water, sugars, protein, fats, minerals, and antibodies that help young animals grow and develop.

Mammary glands are unique to mammals. They are present in both males and females but produce milk only in females. Some mammals, such as pigs or dogs, have a series of glands along the belly. Other mammals have glands only in specific areas, such as udders in a cow's groin or the pair of glands on a primate's chest. Mammary glands contain masses of milk-producing tissues that are connected to a series of ducts. The ducts bring milk to the surface of the skin. In most mammals, the ducts empty into nipples or teats that young mammals, such as the piglets in **FIGURE 26.16**, can hold in the mouth and suckle.

Middle Ear

Mammals have three small bones in their middle ear. One of the bones, the stapes, is also found in other tetrapods. The other two, the malleus and incus, are unique to mammals. They were derived from reptilian jaw bones.

The top part of the hyoid arch became modified to form the stapes in early tetrapods. Bones that supported the jaws in fish became bones that transferred vibrations to the inner ear in tetrapods. A similar shift, illustrated in **FIGURE 26.17**, occurred as mammals evolved from their reptilian ancestors.

Synapsids such as the pelycosaur had jaws that were made of many bones fused together. The middle ear of these reptiles contained only one bone, the stapes, which transmitted sound to the inner ear, where it was converted to nerve impulses and interpreted by the brain. This is the same configuration of bones we see in reptiles today.

Over time, the formation of these bones changed. Two bones, the quadrate and the articular bones, once formed the joint between the jaws of reptiles. These bones evolved to serve a different function—hearing. In mammals, the quadrate and articular bones are now tiny and are incorporated into the middle ear as the malleus and the incus. Sounds collected in the ear canal vibrate the eardrum. These vibrations are transferred through the malleus and incus bones to the stapes. These tiny vibrations are converted into nerve impulses in the inner ear and then interpreted by the brain. The ability to detect small vibrations allowed mammals to hear higher-pitched sounds.

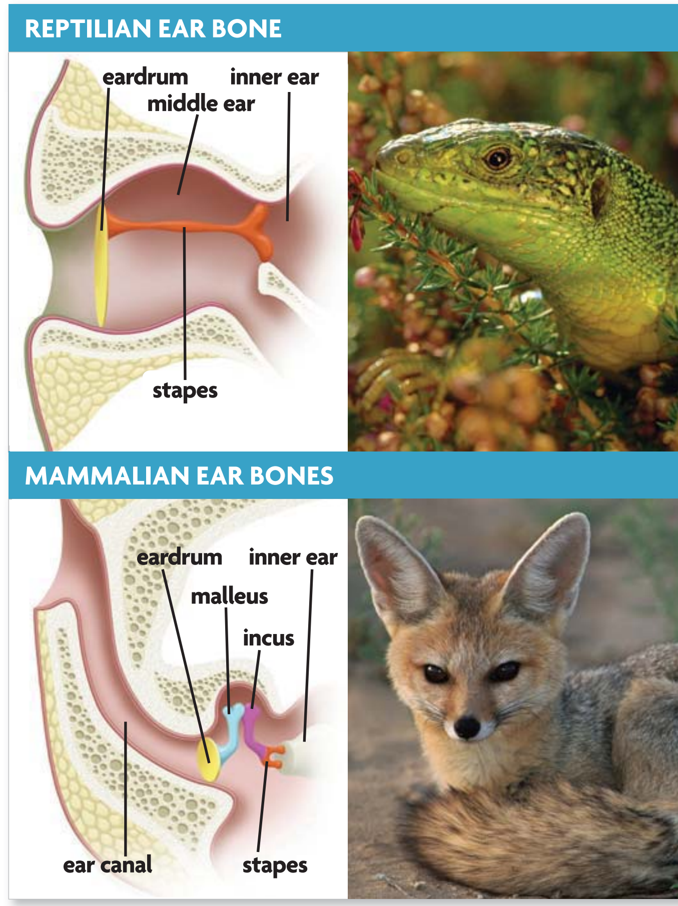


FIGURE 26.17 As mammals evolved, the structures of the inner ear changed. The incus and malleus bones that were once part of reptilian jaw structures evolved in ways that enhanced hearing.

Chewing

Mammals developed the ability to chew their food. Amphibians, reptiles, and birds usually bite off large chunks of food or swallow it whole. Most of their mechanical processing occurs inside their digestive tract. Mammals, in contrast, start to break up their food as soon as it enters the mouth.

A set of adaptations in the mammalian jaw makes chewing possible. While food is in the mouth, a secondary palate separates the nasal and oral cavities. It keeps the passages for air and food separate, so mammals can chew and breathe at the same time. In addition, complex muscles can move the jaw from side to side.

Infer Hair was an important adaptation for mammals. How might hair and other adaptations have enabled mammals to survive where reptiles could not?

MAIN IDEA

Modern mammals are divided into three main groups.

More than 4500 species of mammal are alive today. They can be classified into three groups: monotremes, marsupials, and eutherian mammals.

Monotremes

The **monotremes** are mammals that lay eggs. They are remnants of an ancient group of mammals that have characteristics of both mammals and reptiles. The group split off from the line that led to the other living mammals sometime during the Mesozoic. Their fossils suggest that they once lived throughout the Southern Hemisphere. But today only three species of monotreme survive. The duck-billed platypus is found only in Australia and Tasmania. Two types of echidna live in Australia, Tasmania, and New Guinea.

VOCABULARY

The name *monotreme* comes from a Greek word that means "single opening," referring to the cloaca opening, which these mammals have in common with birds and reptiles.

FIGURE 26.18 The shovel-like bill of the duck-billed platypus is tightly packed with nerve endings. The platypus uses this bill to scrape the bottom of rivers and lakes in search of food.

Monotremes such as the platypus in **FIGURE 26.18** have a mix of ancestral mammalian and reptilian features. Monotremes have retained reptilian characteristics such as

- a sprawling posture
- a single external opening, called the cloaca, for their urinary, digestive, and reproductive tracts
- amniotic eggs with leathery shells that develop outside the body

Monotremes also have characteristic mammalian features, including mammary glands. When monotreme babies hatch, their mothers feed them milk. But monotremes do not have nipples. Their babies lick milk from pools on their mother's belly.

Marsupials

Kangaroos, wombats, koalas, and opossums are a few of the 282 living species of marsupial. **Marsupials** are mammals that give birth to immature, underdeveloped live young that grow to maturity inside a marsupium, or pouch. After fertilization, marsupial embryos begin to develop internally, attached to a placenta that exchanges nutrients and wastes with the mother. But the amount of time the embryo develops inside the mother is very short. Most marsupial species give birth only a few weeks after fertilization. The immature babies, such as the one seen in **FIGURE 26.19**, attach themselves to a nipple inside the marsupium and nurse for up to six months before emerging from their mother's pouch.

Fossil evidence shows marsupials once lived all over the world. They have gone extinct over most of their former range. Most living species are found only in Australia and New Guinea. A few live in South America. One species, the Virginia opossum, lives in North America. Australian marsupials have diversified into many forms, and there are many examples of convergent evolution between these marsupials and eutherian mammals. In each case, the animals share similar ecological roles. For example, Australia is home to mouselike, molelike, anteating, and gliding marsupials that are physically similar to unrelated mice, moles, anteaters, and flying squirrels.

FIGURE 26.19 The red kangaroo of Australia gives birth to tiny babies that develop within a pouch in the mother's abdomen. Inside the pouch, the infant attaches to a mammary gland, where it will stay until it is mature.

Eutherian Mammals

All the mammals most familiar to you are eutherians. **Eutherian** mammals give birth to live young that have completed fetal development. Eutherian mammals are commonly called placental mammals, but this term is misleading because most marsupials also use a placenta during embryo development. In most eutherian development, an embryo is attached to the mother's uterine wall. The connection between the fetus and the mother forms an organ called the placenta. Through the placenta, the mother delivers oxygen and nutrients to the embryo and removes waste products. The placenta only forms during gestation and leaves the mother's body following birth. The placenta is the only example of a disposable organ.

Eutherian gestation lasts longer than in marsupials—often months—and the babies are born at a more advanced stage of development. In some species, including the Bengal tiger in **FIGURE 26.20**, newborns are still relatively helpless and need extensive parental care until they can survive on their own. In others, such as deer or horses, the time shortly after birth is when the newborn is most vulnerable to predators, so it is important that they are able to get up and run within hours of birth.

After the extinction of the dinosaurs, eutherians quickly filled vacant ecological niches, and the modern groups of mammals appeared quickly. Rodents and carnivores appeared about 55 million years ago, and the first known species of bat, elephant, manatee, and horse appeared soon afterwards. Modern eutherians include fast carnivores such as cheetahs, and massive herbivores such as elephants. Three groups of aquatic eutherians—whales, manatees, and seals—evolved from land-dwelling mammals. Bats evolved powered flight. And one group of primates, the humans, evolved the ability to think about their ancestors.

FIGURE 26.20 The cubs of this Bengal tiger will stay with their mother for up to 18 months until they are able to hunt on their own. Many eutherian mammals care for their young after birth.

NSTA scilinks.org SCILINKS

To find out more about mammals, visit scilinks.org.
Keycode: MLB026

Compare and Contrast **Compare and contrast the advantages and disadvantages of marsupial and eutherian mammal reproduction.**

26.4 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. What features make **mammals** different from reptiles?
2. How does fetal development differ among the three living groups of mammals?

CRITICAL THINKING

3. **Summarize** How did the mass extinction that ended the reptile reign help lead to today's mammal diversity?
4. **Classify** **Monotremes** were confusing to early scientists because they had both reptilian and mammalian features. How might scientists have classified monotremes differently?

Connecting CONCEPTS

5. **Ecology** A sea turtle may lay up to 200 eggs in a nest, then leave and return to the ocean. When the young turtles hatch they must fend for themselves. How do mammals differ in the number of offspring produced and in the role of parental care of offspring?

Use these inquiry-based labs and online activities to deepen your understanding of amniotes.

INVESTIGATION

The Parts of an Egg

Birds, some reptiles, and even a few mammals lay eggs. In this lab, you will dissect and identify the parts of an egg.

SKILL **Observing**

PROBLEM What are the parts of an egg, and what are their functions?

MATERIALS

- chicken egg
- dissecting tray
- Egg Drawing
- colored pencils
- fine scissors
- dissecting needle
- dissecting forceps
- hand lens

PROCEDUR

1. Use colored pencils to illustrate and label the structures you observe.
2. With the various dissecting tools, carefully chip away at the eggshell without breaking the delicate membranes beneath the shell or the yolk. Make observations with the hand lens and record them.
3. In an unfertilized egg, you will find several structures, including the vitelline membrane, which surrounds the yolk; a white spot on the yolk called the germinal disk; and two cordlike strands on either side of the yolk, called chalazae.
4. In a fertilized egg, you may find an embryo attached to the yolk and two additional membranes within the yolk: the amnion and the allantois. Surrounding the yolk is chorion.
5. Use the Egg Drawing to identify and illustrate additional structures.
6. When you have identified all structures and investigated both fertilized and unfertilized eggs, dispose of the eggs and wash your hands.

ANALYZE AND CONCLUDE

1. **Infer** What do you think would happen to the yolk if the egg were to become fertilized?
2. **Infer** What is the function of the vitelline membrane and the albumen? Explain.

INVESTIGATION

Migration and Range

Each year, when the days begin to get shorter and the temperature begins to drop, you may notice flocks of birds flying across the sky. The seasonal movement of birds is called migration. Birds use a great deal of energy to migrate.

Tiny ruby-throated hummingbirds, for example, spend much of the spring and summer in the eastern United States and Canada. But each year, they make an incredible migration, flying south around the Gulf of Mexico to Central America, and some go as far south as Panama. Compare this to the Arctic tern, which travels over 32,000 kilometers (20,000 mi) per year.

In this activity, you will research aspects of bird migration.

SKILL Researching

MATERIALS
- pencil
- North America map

PROBLEM Why do birds migrate?

PROCEDURE

Choose three of the following questions to research and help explain bird migration.

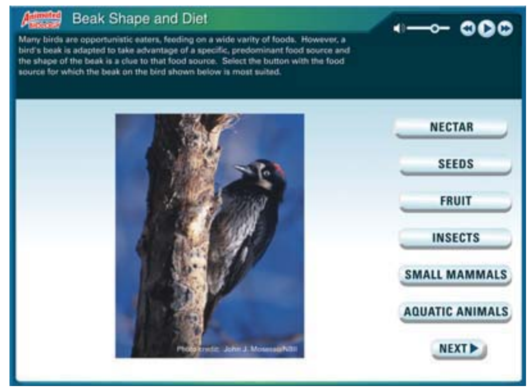
1. Why do birds migrate?
2. How do birds know when to start migrating?
3. How do migrating birds navigate?
4. What methods do scientists use to monitor bird migration?
5. What problems do migrating birds face?
6. What are the major routes of bird migrations in North America? On the attached map, shade in areas of major flyways over the United States.

Online BIOLOGY
CLASSZONE.COM

ANIMATED BIOLOGY

Beak Shape and Diet

The shape of a bird's beak allows it to take advantage of specific food sources. Examine a set of bird images and use the shape of each beak as a clue to identify the food source.



WEBQUEST

There are seven species of sea turtles on Earth; all are endangered or threatened. In this WebQuest, you will explore the threats sea turtles face and the actions people are taking to save them. Find out if we can reverse the sea turtles' paths to extinction.

DATA ANALYSIS ONLINE

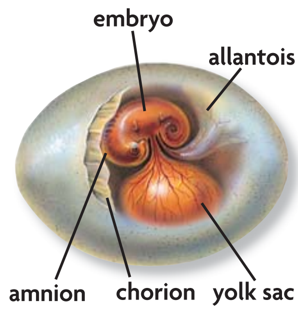
Internal body temperature can provide information about an unknown amniote. Graph and compare body temperatures of four hypothetical animals over a range of environmental temperatures. Use data in the graphs to make inferences about the animals.

CHAPTER 26

Interactive Review @ CLASSZONE.COM

KEY CONCEPTS | Vocabulary Games | Concept Maps | Animated Biology | Online Quiz

26.1 Amniotes



Reptiles, birds, and mammals are amniotes. Organisms that develop inside an amniotic sac are called amniotes. Inside this sac, an embryo is provided with the necessary nutrients to help it develop and prepare for life. Amniotes pump blood through pulmonary and systemic circuits and use lungs to exchange essential gases with the environment and provide for the body. In ectotherms, the external environment plays an important role in maintaining body temperature, while endotherms control their body temperature by regulating their metabolism.

26.2 Reptiles

Reptiles were the first amniotes. Reptiles come in many shapes and sizes, but all have a three-chambered heart and are ectotherms. Oviparous reptiles lay eggs externally, and viviparous reptiles retain eggs internally to full development. Scientists have traced the ancestors of modern reptiles based on skull anatomy and have determined how modern birds, reptiles, and mammals are descended from ancient reptiles. Today, turtles, sphenodonts, snakes and lizards, and crocodilians are the major reptile groups.

26.3 Birds

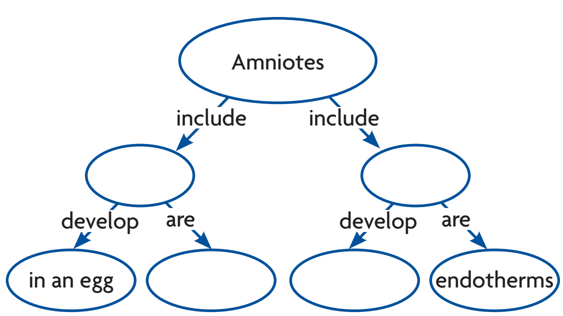
Birds have many adaptations for flight. All birds share unique features such as hollow bones, a highly modified circulatory system, and feathers. Bird wings have a convex curved shape, called an airfoil, to enable flight. Their strong chest muscles are attached to a large sternum, or keel. Birds have a very high metabolism and a unique one-way breathing system that is highly efficient. Birds are directly descended from dinosaurs. Birds come in many shapes and sizes, and features such as wings, beak, and feet are highly adapted to each species' niche.

26.4 Mammals

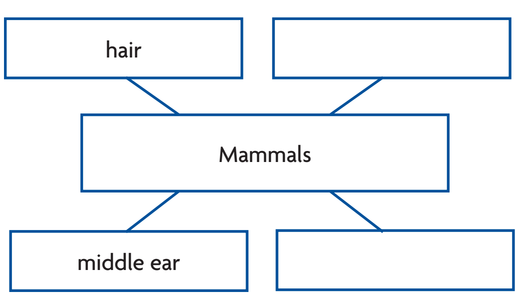
Evolutionary adaptations allowed mammals to succeed dinosaurs as a dominant terrestrial vertebrate. Mammals evolved while dinosaurs were walking Earth. After the dinosaurs went extinct, many new species of mammals evolved and filled the vacant niches. Mammals share four features—hair, mammary glands, a modified middle ear, and a jaw that lets them chew food. Mammals are endotherms, and hair plays an important role in keeping their body temperature stable. Mammary glands produce nutrient-rich milk, which is the primary food source for growing infant mammals. There are three major groups of mammals: monotremes, marsupials, and eutherians.

Synthesize Your Notes

Concept Map Use a concept map like the one below to summarize distinctive amniote characteristics.



Main Idea Web Use a main idea web like the one below to summarize the features of mammals, birds, and reptiles.



Chapter Assessment

Chapter Vocabulary

26.1 pulmonary circuit, p. 789
systemic circuit, p. 789
ectotherm, p. 791
endotherm, p. 791

26.2 reptile, p. 793
oviparous, p. 793
viviparous, p. 793

26.3 airfoil, p. 799
sternum, p. 801
air sac, p. 801

26.4 mammal, p. 805
mammary gland, p. 806
monotreme, p. 807
marsupial, p. 808
eutherian, p. 809

Reviewing Vocabulary

Vocabulary Connections

Write a sentence or two to clearly explain how the vocabulary terms in this chapter are connected. For example, for the terms *mammal* and *mammary gland,* you could write, "The mammary gland is one of the unique characteristics of a mammal."

1. endotherm, mammal
2. reptile, viviparous
3. marsupial, eutherian

Greek and Latin Word Origins

Use the definitions of the word parts to answer the following questions.

Part	Meaning
pulmo-	lung
endo-	inner
-parous	to give birth

4. Explain why the prefix *pulmo-* is used to describe blood circuits.
5. Why is the prefix *endo-* used to describe the temperature regulation strategy of mammals and birds?
6. How is the meaning of the suffix *-parous* related to its use in the word *oviparous*?

Compare and Contrast

Describe one similarity and one difference between the two terms in each of the following pairs.

7. pulmonary circuit, systemic circuit
8. oviparous, viviparous
9. endotherm, ectotherm

Reviewing MAIN IDEAS

10. Name the four membranes found in an amniotic egg and explain the function of each.

11. Describe one similarity and one difference between the functions of a three-chambered heart and those of a four-chambered heart.

12. The desert tortoise, an ectotherm, spends as much as 95 percent of its time in underground burrows. Even in a predator-free environment, why might it have to do this?

13. Birds live in hot deserts and in Antarctica. How is it possible for birds to live in hot and frigid environments where reptiles cannot survive?

14. What are two ways that reptiles can reproduce?

15. Summarize the relationships between modern birds, reptiles, and mammals and their ancient ancestors.

16. Compare how snakes and lizards find prey with how crocodiles find prey.

17. What five pieces of evidence indicate that birds evolved from theropod dinosaurs?

18. What is the sternum? How does it help make flight possible for birds?

19. How is the reproductive system of a bird adapted for flight?

20. What three parts of a bird's body can indicate what ecological niche the bird fills?

21. How is the mammalian middle ear different from that of reptiles?

22. How does development differ among the three groups of mammals?

Critical Thinking

23. **Analyze** A person goes out for a jog wearing a jacket because the morning is cool. After about 15 minutes, the person feels very warm and has to take off the jacket, even though the temperature hasn't changed. Explain what is happening.

24. **Classify** Imagine that a new animal has been discovered in the rain forest. It has four limbs and a tail. Scientists observe that it can eat prey larger than its head. It gives birth to live young. Based on this information, how would you classify this animal? Explain your answer.

25. **Apply** Explain why the number of native reptile species decreases as you move away from Earth's equator.

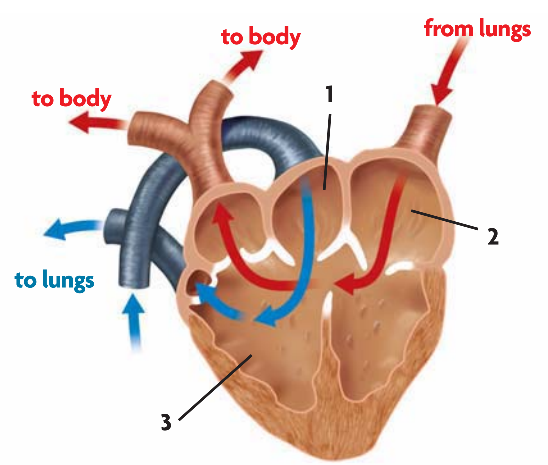
26. **Analyze** Feathers are one of the most important adaptations for birds. Why are feathers a more useful adaptation for flying than hair?

27. **Infer** Elephants and leopards both live in Africa, where it is hot. But elephants have very little hair, and leopards have a full coat of hair. Explain why this might be.

28. **Analyze** Though it is bad manners, why is it possible for a person to talk while chewing a mouthful of food?

Interpreting Visuals

Use the following illustration to answer the next three questions.



29. **Analyze** Blood coming from the lungs enters which part of this heart? Give the number and identify the part.

30. **Analyze** Blood going to the body comes from which part of the heart? Give the number and identify the part.

31. **Synthesize** Is this a three-chambered heart or a four-chambered heart? Explain how you know.

Analyzing Data

The table below shows the weight loss of two box turtles during hibernation. A box turtle should lose only about 1 percent of its body weight during each month of hibernation and no more than 5 percent during the entire hibernating period. Use the data to answer the next two questions.

WEIGHT LOSS DURING HIBERNATION

Turtle	Nov	Dec	Jan	Feb	Mar
No. 1	600g	594g	588g	582g	576g
No. 2	600g	590g	585g	580g	576g

32. **Graph** Which type of graph would best represent both sets of data in the table? Why?

33. **Evaluate** Based on the differences in mass over the course of hibernation, which turtle will be healthier at the end of hibernation? Explain your reasoning.

Connecting CONCEPTS

34. **Write a Script** Birds, reptiles, and mammals coexist in many environments on Earth. But many times their paths cross and confrontations occur. Perhaps while a lion is feeding, a vulture may fly down to try and get a bite to eat, or maybe a bird's nest is being invaded by a reptile. Choose a place where two very different amniotes might interact, and write a script of their conversation. Using what you have learned about birds, reptiles, and mammals and how they function, have them discuss advantages and disadvantages of each other's lifestyles and how their conflict could be resolved.

35. **Apply** Look again at the picture of the tarsier on page 787 and read the description. Despite body parts that might remind you of other types of animals, why are scientists sure that the tarsier is a mammal?

REVIEW AT CLASSZONE.COM

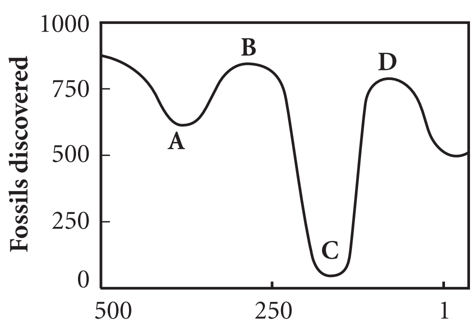
Test Practice
For more test practice, go to ClassZone.com.

1. A researcher studies dairy cows to determine if feed type affects milk production. The researcher gives each cow one of the three types of feed for a month and measures milk production. Which of the following sources of error were unavoidable in this experiment?

A the genetic make up of cows in each group
B the average age of cows in each group
C the number of cows in each group
D the types of cows in each group

2.

Fossils Discovered at Hypothetical Site



This graph shows the number of fossils found at a hypothetical site from each time period over the past 500 million years. Which of these statements is *best* supported by the data?

A Many speciation events occurred at Node A.
B Nodes B and D indicate a lack of biodiversity.
C Species diversity increased after Node D.
D A possible mass extinction occurred at Node C.

3. During the summer, the arctic fox produces enzymes that cause its fur to become reddish brown. These enzymes do not function during the winter, causing the fox's fur to become white and blend in with the snow. Which of the following statements is *most* likely true?

A The genes in arctic fox populations are unstable.
B Reddish brown fur during the fall is likely not selected for in arctic fox populations.
C White fur during the winter is a trait that was selected for in arctic fox populations.
D The enzyme that controls fur color is not affected by temperature.

4. Amniotes are multicellular animals whose embryos develop in an enclosed membrane. What else must be true of *all* amniotes?

A They can only reproduce asexually.
B Fertilization is always external.
C They lay eggs during their life cycle.
D Half of their DNA comes from each parent.

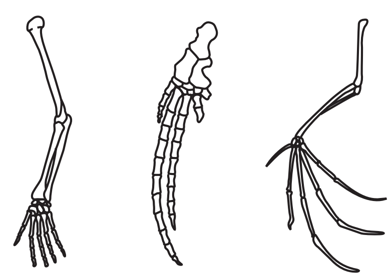
THINK THROUGH THE QUESTION

First, think about what an embryo is. Can an embryo be produced asexually? Next, eliminate answer choices that could be true for some amniotes, but may not be true for all amniotes.

5. During chewing, digestive enzymes in the mouths of mammals begin breaking down food particles. Which is true about enzymes?

A Without enzymes, certain chemical reactions would require more energy input.
B Once enzymes react, new ones must replace those that were changed during the reaction.
C Enzymes work faster at high temperatures.
D Enzymes bond to substrates, forming new molecules.

6.



These illustrations show the bones of the forelimbs of three organisms. The similarities in bone arrangement supports the hypothesis that these organisms

A are members of one species.
B descended from a common ancestor.
C have adaptations for similar environments.
D have the same genetic information.