CHAPTER 41

REPTILES

A marine iguana, *Amblyrhynchus cristatus,* of the Galápagos Islands warms itself by basking on a rock. These are the only marine lizards in the world, and they feed exclusively on seaweed.

Origin and Evolution of Reptiles

The reptiles (class Reptilia) are one of the largest groups of terrestrial vertebrates. This chapter will discuss the diversity of reptiles and some of the characteristics that make the reptiles a successful group.

SECTION 1

OBJECTIVES

- **Summarize** the factors that led to the rise of reptiles as the dominant land vertebrates.
- **Identify** three factors that contributed to the success of dinosaurs.
- **Compare** two hypotheses to explain the extinction of the dinosaurs.
- **Identify** examples of the four modern orders of reptiles.
- **Describe** three characteristics of modern reptiles that make them well adapted to life on land.

VOCABULARY

dinosaur
asteroid impact hypothesis
amniotic egg
amnion
yolk sac
allantois
chorion
albumen
keratin

HISTORY OF REPTILES

From studies of fossils and comparative anatomy, biologists infer that reptiles arose from amphibians. The oldest known fossils of reptiles were found in deposits from the early Carboniferous period (359 million to 299 million years ago). The earliest reptiles were small, four-legged vertebrates that resembled lizards and had teeth adapted for eating insects. The abundance of insects at the time may have been one reason the early reptiles flourished. By the Permian period (299 million to 251 million years ago) reptiles had become the dominant land vertebrates.

By the end of the Permian nearly all of the continents had joined to form the supercontinent *Pangaea* (pan-JEE-uh), shown in Figure 41-1. The interior of Pangaea had a dryer climate than the coastal regions. Reptiles were suited to dry climates and were highly successful. The end of the Permian period (and of the Paleozoic era) is marked by a mass extinction during which a large number of species became extinct. The cause of this extinction is still debated. Reptiles that survived diversified to take over the ecological roles of the extinct species. The Mesozoic era (251 million to 66 million years ago) is often called the Age of Reptiles because nearly all of the large vertebrates during that time were reptiles.

EVOLUTION OF DINOSAURS

Beginning about 235 million years ago, **dinosaurs,** a group of extinct reptiles, dominated life on land for roughly 150 million years. They evolved from *thecodonts,* an extinct group of crocodile-like reptiles. Dinosaurs include a wide variety of reptiles that were adapted to very different environments. One factor that affected dinosaur evolution was the movement of the continents. Early in the Mesozoic era, Pangaea started to break apart. The climates of the separate landmasses changed. Some species of dinosaurs could not adapt and became extinct, while new kinds flourished.

FIGURE 41-1
When dinosaurs first appeared, all of Earth's landmasses were joined in a single supercontinent called *Pangaea,* shown above.

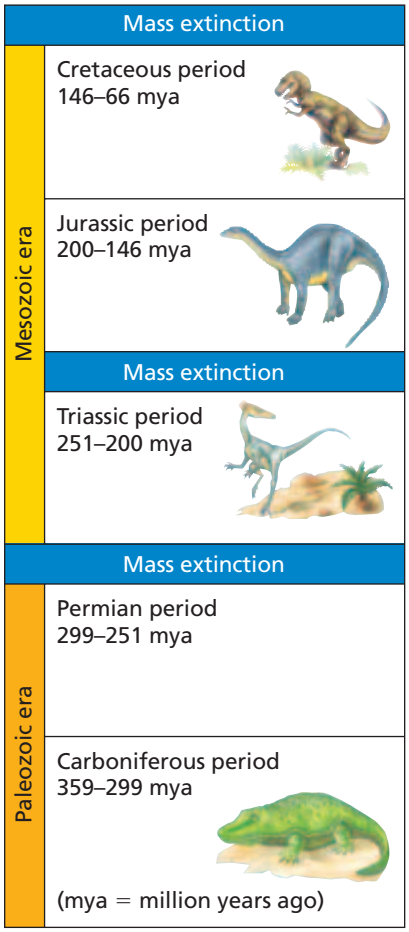


FIGURE 41-2

The evolution of reptiles has been marked by three mass extinction events. For more information about the geologic time scale, see the Appendix at the back of this textbook.

Triassic Dinosaurs

The oldest known dinosaur fossils are in rocks from the early Triassic period, about 235 million years ago. By the end of the Triassic, small, carnivorous dinosaurs, were very common and had largely replaced the thecodonts.

There are at least three reasons why dinosaurs were so successful. First, legs positioned directly under the body provided good support for the dinosaur's body weight, enabling dinosaurs to be faster and more agile runners than the thecodonts. Second, dinosaurs were well adapted to the dry conditions found in Pangaea during the late Triassic period. Finally, at the end of the Triassic period, another mass extinction wiped out about 80% of living species, including the thecodonts and the last of the large amphibians. Recent research suggests that asteroid impacts in what are now Canada, France, the Ukraine, and Minnesota occurred almost simultaneously and contributed to this mass extinction event. This event marked the end of the Triassic period, outlined in Figure 41-2. Reduction in competition for resources may have allowed dinosaurs to flourish.

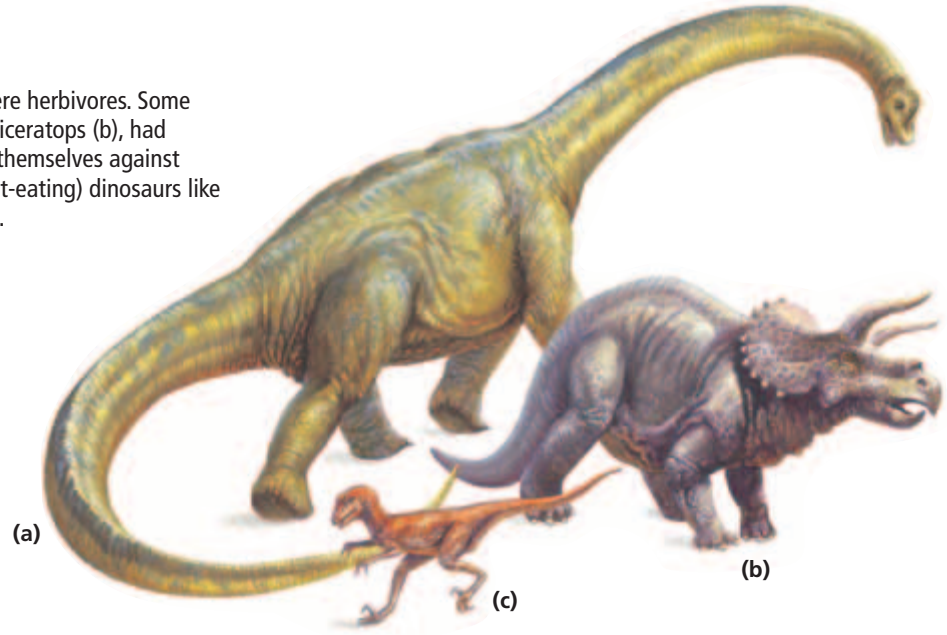
Jurassic and Cretaceous Dinosaurs

The Jurassic period, graphed in Figure 41-2, is considered the golden age of dinosaurs because of the variety and abundance of dinosaurs that lived during this time. They included the largest land animals of all time, the sauropods (SAWR-uh-PAHDZ), shown in Figure 41-3a.

By the late Jurassic period, a new type of dinosaur had evolved. The carnivorous theropods (THER-uh-PAHDZ), shown in Figure 41-3c stood on two powerful legs and had short arms. Their large heads were equipped with sharp teeth, and each foot had sickle-shaped claws used for ripping open prey. Theropods preyed on the large herbivorous dinosaurs and were the dominant terrestrial predators until the end of the Cretaceous (kruh-TAY-shus) period.

FIGURE 41-3

Sauropods (a) were herbivores. Some herbivores, like triceratops (b), had armor to defend themselves against carnivorous (meat-eating) dinosaurs like the theropods (c).



Dinosaur Diversity

Dinosaurs were not limited to terrestrial habitats. Some Mesozoic reptiles called *pterosaurs* (TER-uh-SAWRS), shown in Figure 41-4a, evolved the ability to fly. Several other groups of reptiles, including the ichthyosaurs (IK-thee-uh-SAWRS) and plesiosaurs, lived in the oceans. Ichthyosaurs, illustrated in Figure 41-4b, were sleek aquatic reptiles that resembled modern bottlenose dolphins. Plesiosaurs had long, flexible necks and compact bodies.

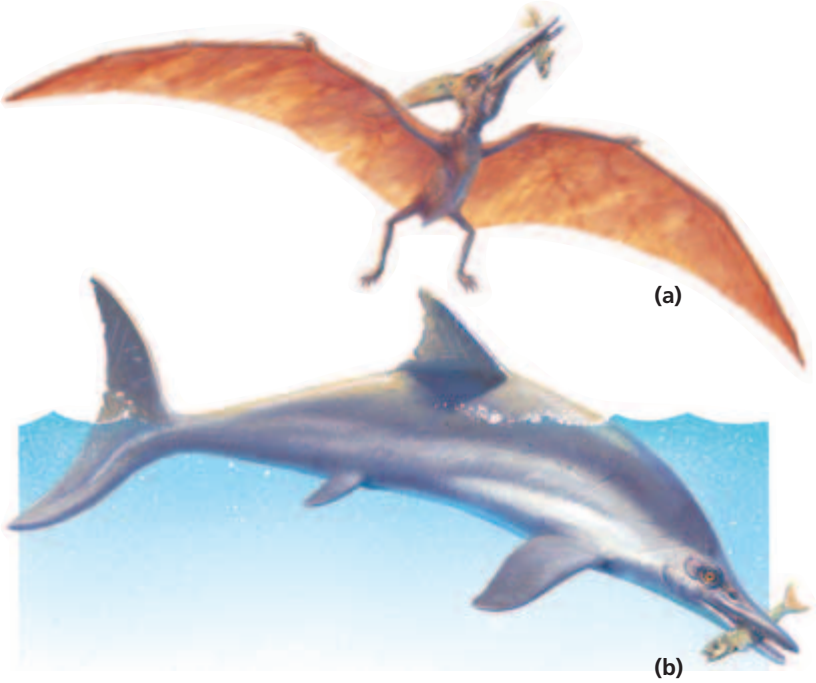


FIGURE 41-4
(a) Pterosaurs ranged in size from the smallest, which were only the size of sparrows, to the largest, which were about the size of a small airplane, with wingspans of 12 m (about 39 ft). (b) Like dolphins, ichthyosaurs were probably fast swimmers and fed on fish.

EXTINCTION OF DINOSAURS

Although the fossil record provides many clues about what dinosaurs were like, paleontologists who study dinosaurs still have many unanswered questions. For example, why did the dinosaurs and many other species become extinct 66 million years ago, at the end of the Cretaceous period?

Asteroid Impact Hypothesis

Until recently, most scientists thought that a single catastrophic event was responsible for the mass extinction of dinosaurs. The **asteroid impact hypothesis** suggests that a huge asteroid hit Earth and formed a crater on the Yucatán Peninsula in southern Mexico. The impact sent so much dust into the atmosphere that the amount of sunlight reaching the Earth's surface was greatly reduced. The reduced sunlight caused severe climatic changes that led to the mass extinction. The asteroid impact hypothesis is supported by the fact that sediments from the end of the Cretaceous period contain unusually high concentrations of iridium. Iridium is a metal that is very rare in the Earth's crust but more abundant in asteroids and other meteroids. According to this hypothesis, the dinosaurs would have become extinct very quickly.

Multiple Impact Hypothesis

Another hypothesis, called the *multiple impact hypothesis,* proposes that asteroid impacts began before the mass extinction took place. Along with other unfavorable environmental conditions, multiple asteroid impacts, including the impact on the Yucatán peninsula, led to a decline in numbers of organisms among species. In 2004, paleontologist Gerta Keller and her colleagues provided evidence to support this hypothesis. Results of their research suggest that conditions hostile to dinosaur survival were spread over many years. It is likely that these reptiles were not wiped out by a single asteroid impact.

Word Roots and Origins

crocodile

from the Greek *krokodilos,* meaning "lizard of the Nile"

SUCCESS OF REPTILES

Representatives of the four modern orders of reptiles—Chelonia (turtles and tortoises), Squamata (lizards and snakes), Rhynchocephalia (tuataras), and Crocodilia (crocodiles, alligators, caimans)—survived the mass extinction of the Cretaceous period. These four orders of reptiles have diversified to more than 6,000 species. Reptiles successfully occupy a variety of terrestrial and aquatic habitats on all continents except Antarctica. Figure 41-5 is a phylogenetic diagram that shows hypotheses for the relationship among reptiles, birds, and mammals.

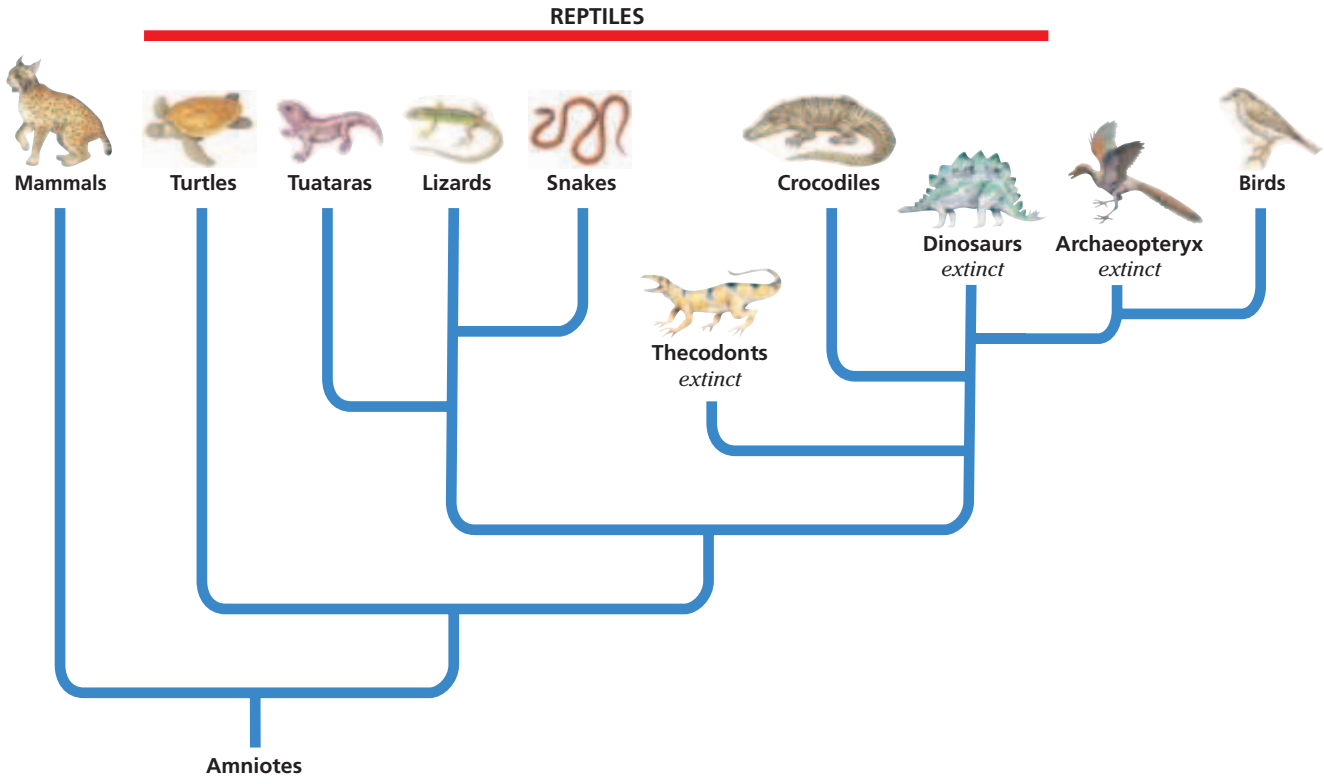
Modern Reptiles

The turtles have the most ancient origins and have changed very little in structure since before the time of the dinosaurs. Tuataras belong to a small group of lizard-like reptiles. The vast majority of living reptiles belong to the group snakes and lizards. The fourth line of living reptiles includes the crocodiles and their relatives. Crocodilians have changed very little in more than 200 million years. Like dinosaurs, crocodilians are descendants of the thecodonts.

In some ways, such as the structure of their heart, crocodilians resemble birds far more than they resemble other living reptiles. And crocodilians are the only living reptiles that care for their young. What does this mean in terms of their relationships to other vertebrate species? Today, many biologists think that birds are direct descendants of the dinosaurs.

FIGURE 41-5

This phylogenetic diagram represents hypotheses for the relationship among reptiles, birds, and mammals. For updates on phylogenetic information, visit **go.hrw.com.** Type in the keyword **HM6 Phylo.**



The Amniotic Egg

Although amphibians were the first vertebrates to successfully invade land, they did not make a full transition to terrestrial life. They still require water in their environment to reproduce. Reptiles are considered the first fully terrestrial vertebrates because they do not need to reproduce in water, as most amphibians do. Reptiles produce **amniotic eggs,** which encase the embryo in a secure, self-contained aquatic environment. Amniotic eggs provide more protection for the developing embryo than do the jellylike eggs of amphibians.

Figure 41-6 shows the internal structure of the amniotic egg, including its four specialized membranes: the amnion, yolk sac, allantois, and chorion. The egg is named for the **amnion** (AM-nee-uhn), the thin membrane enclosing the fluid in which the embryo floats. The **yolk sac** encloses the yolk, a fat-rich food supply for the developing embryo. The **allantois** (uh-LAN-toh-is) stores the nitrogenous wastes produced by the embryo. Its blood vessels, which lie near the porous shell, function in the exchange of oxygen and carbon dioxide gases. The **chorion** (KAWR-ee-AHN) surrounds all the other membranes and helps protect the developing embryo. Protein and water needed by the embryo are contained in the **albumen** (al-BYOO-muhn). You are familiar with albumen as the egg white in a chicken's egg. In most reptiles, the leathery outer shell provides protection from physical damage, limits the evaporation of water from the egg, and allows diffusion of oxygen and carbon dioxide.

The amniotic egg first evolved in reptiles, but it also occurs in mammals and birds. The presence of this feature is strong evidence that reptiles, birds, and mammals evolved from a common ancestor. The eggs of some reptiles and nearly all mammals lack shells, and the embryo develops within the mother's body.

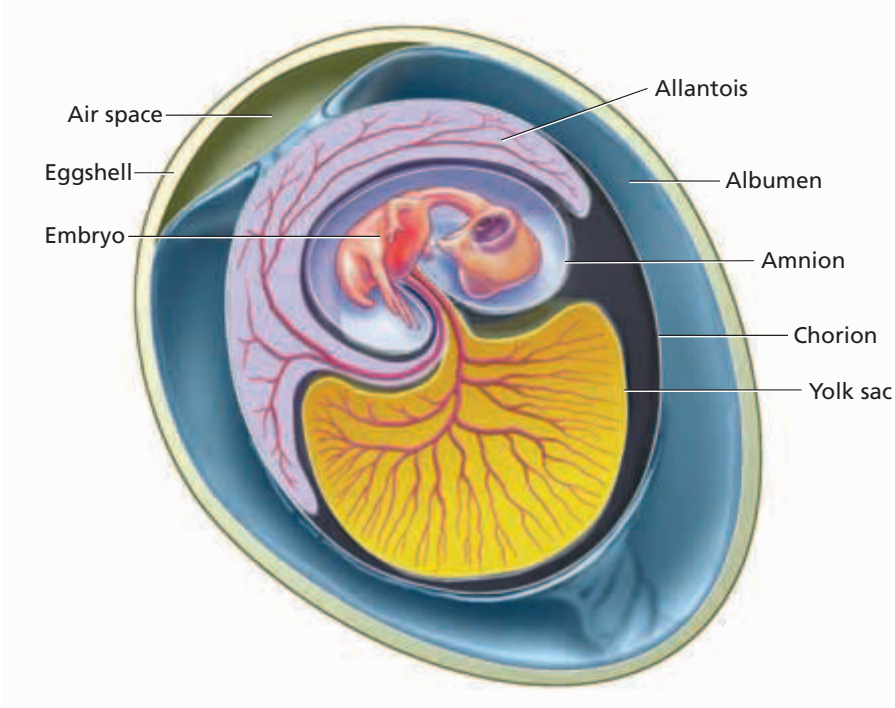


FIGURE 41-6

Amniotic eggs have four major membranes. The tough but porous shell provides protection while allowing the exchange of oxygen and carbon dioxide. The amniotic eggs of reptiles and birds (shown here) are very much alike internally.

FIGURE 41-7

The skin of this spiny lizard, *Sceloporus poinsetti,* protects it from the rugged terrestrial environment and from water loss.

Watertight Skin

Because amphibians exchange gases through their skin, the skin must be moist and thin enough to allow rapid diffusion. A drawback of this kind of skin is that amphibians face the loss of body water through evaporation. Reptiles, such as the lizard shown in Figure 41-7, are covered by a thick, dry, scaly skin that prevents water loss. This scaly covering develops as surface cells fill with **keratin,** the same protein that forms your fingernails and hair. Lipids and proteins in the skin help make the skin watertight. The tough skin of a reptile not only helps conserve body water but also protects the animal against infections and injuries.

Respiration and Excretion

Modern reptiles have developed efficient respiratory and excretory systems that help them conserve water. All reptiles have lungs for gas exchange. All of the tissues involved in gas exchange are located inside the body, where they can be kept moist in even the driest environments. The excretory system of reptiles also helps them conserve body water. Land-dwelling reptiles excrete nitrogenous wastes in the form of uric acid which requires little water for dilution. Reptiles lose small amounts of water in their urine.

SECTION 1 REVIEW

1. Explain the role of climate in the success of early reptiles.
2. Compare and contrast characteristics of Triassic and Jurassic dinosaurs.
3. Explain the importance of iridium found in sediments from the end of the Cretaceous period.
4. Summarize the two asteroid impact hypotheses.
5. Describe three characteristics that contribute to the success of reptiles on land.

CRITICAL THINKING

6. **Analyzing Information** Why might dinosaurs have survived the asteroid impact at the end of the Triassic period but not one at the end of the Cretaceous?
7. **Relating Concepts** Dinosaurs are now thought to have been warmblooded. How does this support the theory about their relationship to birds?
8. **Inferring Relationships** In what ways are the adaptations of reptiles to land similar to the adaptations of plants to land?

Characteristics of Reptiles

Reptiles live in many different habitats and show a great deal of diversity in size and shape. Think of the differences between a snake and a turtle or between a lizard and a crocodile. This section discusses some of the anatomical, physiological, and behavioral characteristics of reptiles.

SECTION 2

OBJECTIVES

- **Identify** advantages associated with the structure of a reptile's heart.
- **Describe** the respiratory system of reptiles.
- **Describe** four methods reptiles use to sense their environment.
- **Explain** how reptiles regulate their body temperature.
- **Compare** oviparity, ovoviviparity, and viviparity as reproductive strategies.

VOCABULARY

septum
alveolus
Jacobson's organ
thermoregulation
ectotherm
endotherm
oviparity
ovoviviparity
viviparity
placenta

CIRCULATORY SYSTEM

The circulatory system of a reptile, like those of all terrestrial vertebrates, is composed of two loops. The pulmonary loop carries deoxygenated blood from the heart to the lungs and returns oxygenated blood to the heart. The systemic loop transports oxygenated blood to the tissues of the body, where oxygen and nutrients are unloaded and where carbon dioxide and wastes are picked up, and returns deoxygenated blood to the heart.

Heart Structure and Function

In lizards, snakes, tuataras, and turtles, the heart has two atria and a single ventricle partially divided by a wall of tissue called a **septum.** In crocodiles, there are two atria and two separate ventricles. The sinus venosus and the conus arteriosus, which are major accessory structures to the heart of a fish, are much smaller in reptiles. The sinus venosus is absent in some species. When it is present, it collects blood from the body and channels it into the right atrium. The conus arteriosus forms the base of the three large arteries exiting from the reptilian heart.

Because the ventricle is not completely divided (except in crocodiles), it might seem that deoxygenated and oxygenated blood would mix. However, very little blood mixing occurs when a reptile is active. Deoxygenated and oxygenated blood are kept separate during contraction of the heart by the actions of the heart valves and the movement of the septum and ventricular walls.

Pumping blood through lungs requires energy. Under some conditions, it is advantageous for a reptile to divert blood away from the lungs to conserve energy. For example, an inactive reptile needs so little oxygen that it may go a long time without breathing. Similarly, aquatic reptiles do not breathe while they are underwater. Under these conditions, the heart pumps blood to the body while reducing circulation through the lungs.

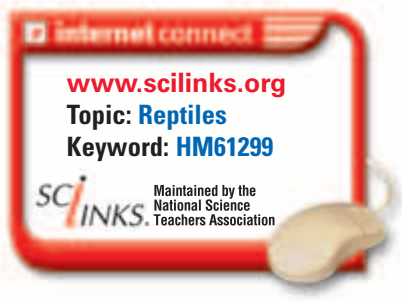
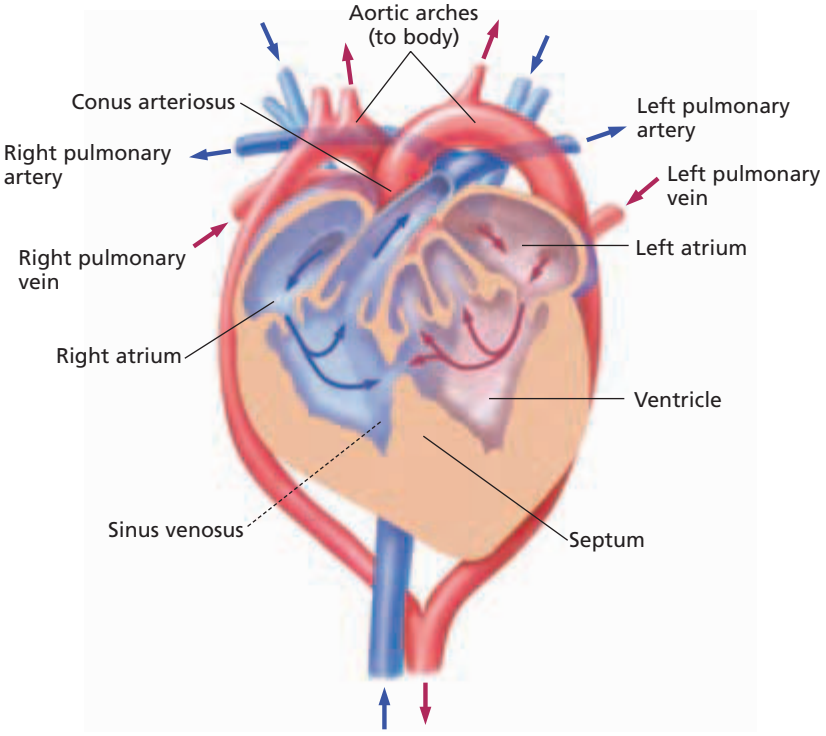


FIGURE 41-8

The turtle's heart, shown in cross section, has a partially divided ventricle, unlike an amphibian's three-chambered heart or a crocodile's four-chambered heart. Because the flow of blood through a turtle's heart is asynchronous, deoxygenated blood and oxygenated blood pass through the upper part of the ventricle at different times and so mix very little.



By constricting the pulmonary arteries, a reptile's blood flow through the heart can be redirected to send some deoxygenated blood back to the body instead of to the lungs. Bypassing the lungs may help a reptile raise its body temperature quickly—warm blood from the skin can be directed to the organs deep within the body. During periods of activity, almost all deoxygenated blood is directed to the lungs to meet the muscles' demand for oxygen. The reptilian heart has a degree of circulatory flexibility that the hearts of birds and mammals do not. Instead of being a handicap, this flexibility is actually well suited to reptilian physiology and activity patterns. Figure 41-8 shows a schematic diagram of the heart of a turtle.

RESPIRATORY SYSTEM

The lungs of reptiles are large, and they are often divided internally into several chambers. The lining of the lungs may be folded into numerous small sacs called **alveoli.** Alveoli greatly increase the internal surface area of the lungs, thus increasing the amount of oxygen that can be absorbed. In most snakes, only the right lung actively functions. It is elongated and may be half as long as the body. The left lung is either reduced to a small nonfunctional sac or absent entirely.

A reptile fills its lungs by expanding its rib cage. This expansion reduces the pressure within the thorax and draws air into the lungs. When the ribs return to their resting position, pressure within the thorax increases, and air is forced out of the lungs. Similar movements help humans to breathe.

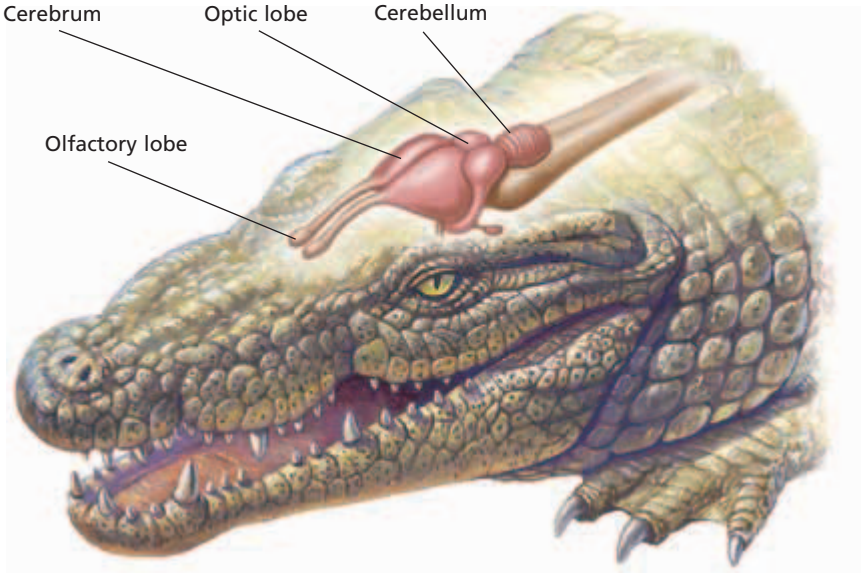


FIGURE 41-9

The crocodile's sense of smell is very important for its survival. The olfactory lobe of the reptile's brain, where the sense of smell is located, is highly developed.

NERVOUS SYSTEM

The brain of a reptile is about the same size as that of an amphibian of the same size. However, the reptilian cerebrum is much larger. This region of the brain is involved in controlling and integrating behavior. Because vision is an important sense for most reptiles, the optic lobes, which receive input from the eyes, are large. Figure 41-9 shows the structure of a crocodile's brain.

Most reptiles rely on their sense of sight to detect predators and prey. The eyes of reptiles are usually large, and many species have keen vision. Hearing is also an important sense. As in amphibians, sound waves first strike the tympanum, or eardrum, and are transmitted to the inner ear through the movements of a small bone called the *columella.* The inner ear contains the receptors for sound. Snakes lack a tympanum and are sensitive only to low-frequency sounds. They are able to detect ground vibrations, which are transmitted to the columella by the bones of the jaw.

Jacobson's organ is a specialized sense organ located in the roof of the mouth of reptiles. Jacobson's organ is sensitive to odors. Like the snake shown in Figure 41-10, reptiles use their tongue to collect small particles from the environment. These particles are transferred to the Jacobson's organ when the tongue is drawn back into the mouth. Jacobson's organ is found in all reptiles except crocodiles and most turtles, but it is highly developed in lizards and snakes.

Pit vipers, such as rattlesnakes, copperheads, and water moccasins, are able to detect the heat given off by warm-bodied prey, such as mammals and birds. These snakes have one heat-sensitive pit below each eye, as shown in Figure 41-10. Input from these pits allows a snake to determine the direction of and distance to a warm object.

FIGURE 41-10

Some snakes have reduced senses of sight and hearing. They compensate with a sensitive forked tongue that is an organ of touch and smell. As the tongue darts in and out of the mouth, it picks up particles that are taken into the Jacobson's organ inside the snake's mouth, where even extremely low concentrations of odors can be detected.

THERMOREGULATION

The control of body temperature is known as **thermoregulation.** Vertebrates regulate their body temperature in two different ways. An **ectotherm** warms its body by absorbing heat from its surroundings. Reptiles, fishes, and amphibians are ectotherms. **Endotherms,** such as mammals and birds, have a rapid metabolism, which generates heat needed to warm the body. Most endotherms have insulation, such as hair, feathers, or fat, to retain heat. The body temperatures of many aquatic ectotherms, such as fishes and amphibians, remain close to the temperature of their surroundings. Terrestrial ectotherms, such as lizards and snakes, usually keep their body temperatures about the same as the body temperatures of endotherms.

Most reptiles live in warm climates and regulate their body temperature by controlling how much heat they absorb. For example, when a lizard emerges from its nest after a cool night, its body temperature is low and must be raised before it can become active. The lizard warms itself by basking in the sun, as shown in Figure 41-11a. The lizard's warm blood is diverted from the skin to the interior of the body. As the graph in Figure 41-11b shows, a lizard can maintain its body temperature within a narrow range despite variations in air temperature. The lizard uses a variety of behaviors to accomplish this.

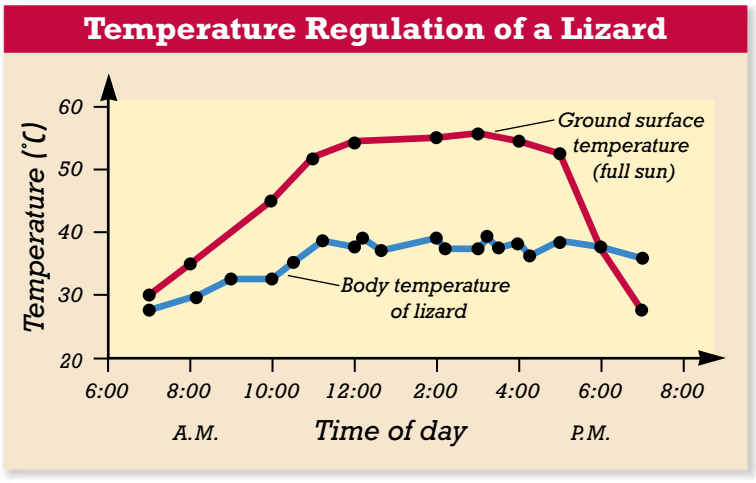
Advantages and Limitations of Ectothermy

Because their metabolism is very slow, ectotherms require very little energy and need only about one-tenth as much food as an endotherm of the same size. Ectotherms cannot live in very cold climates, and they can survive temperate climates only by becoming dormant during the coldest months. Furthermore, ectotherms can run or swim at maximum speed only for short periods of time. Ectothermic metabolism cannot provide enough energy for sustained exertion.

FIGURE 41-11

(a) A lizard regulates its body temperature throughout the day, basking in the sun to warm and seeking shade to prevent overheating. If its body temperature rises too high, the lizard may pant to accelerate heat loss (b). The graph shows an early-morning increase in the lizard's body temperature. The body temperature fluctuates only slightly during the remainder of the day, despite wide fluctuations in ground temperature.

(a)



(b)

REPRODUCTION AND PARENTAL CARE

There are three patterns of reproduction among reptiles. The differences between these three patterns lie in how long the eggs remain within the female and in how she provides them with nutrition.

In **oviparity,** the female's reproductive tract encloses each egg in a tough protective shell. The female then deposits the eggs in a favorable place in the environment. Oviparity is characteristic of most reptiles, all birds, and three species of mammals.

One way to protect delicate eggs is to retain the eggs within the female's body for a time. This strategy, seen in some reptiles including American pit vipers, is called **ovoviviparity.** The eggs may be laid shortly before hatching, or they may hatch within the female's body. The eggs absorb water and oxygen from the female, but they receive no nutrition other than the yolk.

In **viviparity,** a shell does not form around the egg, and the young are retained within the female's body until they are mature enough to be born. Nutrients and oxygen are transferred from mother to embryo through a structure called the **placenta.** The placenta forms from the membranes within the egg, and it brings blood vessels from the embryo near the vessels of the mother. Viviparity is the reproductive pattern shown by most mammals, but it is also found in a few species of lizards and snakes.

Many reptiles provide no care for their eggs or young. However, some species of lizards and snakes guard and warm the eggs until they hatch. Crocodiles and alligators provide the greatest amount of parental care. A female crocodilian, for example, builds a nest for her eggs. She remains nearby while the eggs incubate, guarding against nest-robbing predators. After the young hatch, she breaks open the nest and carries the hatchlings to the water in her mouth, as shown in Figure 41-12. The mother crocodile may protect her young for a year or more.

Word Roots and Origins

ovoviviparous

from the Latin *ovum,* meaning "egg," *vivus,* meaning "alive," and *parere,* meaning "to bring forth"

FIGURE 41-12

Reptiles generally do not provide care for their young, but the hatchlings are usually able to fend for themselves as soon as they emerge from the shell. Crocodiles and alligators, however, care for their young for up to two years. The female crocodile in the photograph is transporting her baby in her mouth.

SECTION 2 REVIEW

1. Describe how the heart of a turtle differs from the heart of a crocodile.
2. Describe how reptiles inhale and exhale.
3. Identify two sense organs reptiles and amphibians share and two sense organs that are unique to reptiles.
4. Compare thermoregulation in animals that are endothermic versus thermoregulation in animals that are ectothermic.
5. Contrast oviparity with viviparity.

CRITICAL THINKING

6. **Applying Information** Which of the patterns of reproduction in reptiles best serves to protect the eggs from predators? Explain.
7. **Making Comparisons** Both crocodiles and turtles are ectothermic. Why do you think crocodile hearts are different from turtle hearts?
8. **Justifying Conclusions** Would change in body temperature over the course of a day prove that an animal is an ectotherm? Why or why not?

SECTION 3

OBJECTIVES

- **Compare** the anatomy of turtles with that of other reptiles.
- **Describe** the structure that allows crocodilians to swallow prey under water.
- **Explain** three antipredator defenses of lizards.
- **Describe** two ways snakes subdue their prey.
- **Identify** two reasons that tuataras are rarely seen.

VOCABULARY

carapace
plastron
autotomy
constrictor
elapid
viper

MODERN REPTILES

Modern reptiles are classified into four orders: Chelonia, Crocodilia, Squamata, and Rhynchocephalia. As different as two species of reptile—such as a turtle and a snake—appear to be, all species of modern reptiles share the following characteristics: an amniotic egg; internal fertilization of eggs; dry, scaly skin; respiration through lungs; and ectothermic metabolism.

ORDER CHELONIA

The order Chelonia consists of about 250 species of turtles and tortoises. The term *tortoise* is generally reserved for the terrestrial members of the order, such as the Galápagos tortoise shown in Figure 41-13a. *Turtle* usually refers to chelonians that live in water, such as the green sea turtle shown in Figure 41-13b.

The earliest known turtle fossils, which are more than 200 million years old, show that ancient chelonians differed little from today's turtles and tortoises. This evolutionary stability may be the result of the continuous benefit of the basic turtle design—a body covered by a shell. The shell consists of fused bony plates. The **carapace** is the top, or dorsal, part of the shell, and the **plastron** is the lower, or ventral, portion. In most species, the vertebrae and ribs are fused to the inner surface of the carapace. Because the ribs are fused to the carapace, the pelvic and pectoral girdles lie within the ribs instead of outside the ribs, as they do in all other terrestrial vertebrates. Unlike other reptiles, turtles have a sharp beak instead of teeth.

FIGURE 41-13

(a) The Galápagos tortoise, *Geochelone gigantops,* is protected from predators by its high domed carapace. (b) The green sea turtle, *Chelonia mydas,* is streamlined for life in the sea.

(a)

(b)

Turtles and tortoises live in a variety of habitats. Some species are permanently aquatic, some are permanently terrestrial, and some spend time both on land and in the water. The differing demands of these habitats are reflected in the shells and limbs of turtles. For example, water-dwelling turtles usually have a streamlined, disk-shaped shell that permits rapid turning in water, and their feet are webbed for swimming. The limbs of marine turtles, which spend their entire lives in the ocean, have evolved into flippers for swimming and maneuvering. Many tortoises have a domed carapace into which they can retract their head, legs, and tail as a means of protection from predators. Their limbs are sturdy and covered with thick scales.

Reproduction

All turtles and tortoises lay eggs. The female selects an appropriate site on land, scoops out a hole with her hind limbs, deposits the eggs, and covers the nest. She provides no further care for the eggs or the hatchlings. Marine turtles often migrate long distances to lay their eggs on the same beach where they hatched. For example, Atlantic green sea turtles travel from their feeding grounds off the coast of Brazil to Ascension Island in the South Atlantic—a distance of more than 2,000 km (1,242 mi). These turtles probably rely on several environmental cues, possibly even the Earth's magnetic field and the direction of currents, to find this tiny island.

ORDER CROCODILIA

The living reptiles most closely related to the dinosaurs are the crocodilians, order Crocodilia. This group is composed of about 21 species of large, heavy-bodied, aquatic reptiles. In addition to crocodiles and alligators, the order includes the caimans and the gavial. Figure 41-14 shows some examples of crocodilians.

Crocodilians live in many tropical and subtropical regions of the world. Alligators live in China and the southern United States. Caimans are native to Central America and South America, and they have been introduced into Florida.

(a)

(b)

FIGURE 41-14

(a) Crocodiles, such as genus *Crocodylus,* are found in Africa, Asia, Australia, and the Americas. (b) The gavial, *Gavialis gangeticus,* is a crocodilian with an extremely long and slender snout adapted for seizing and eating fish. Gavials live only in India and Burma.

All crocodilians are carnivorous. They feed on fish and turtles and on land animals that come to the water to feed or drink. Crocodilians capture their prey by lying in wait until an animal approaches and then attacking swiftly. A crocodilian can see and breathe while lying quietly submerged in water. A valve at the back of the throat prevents water from entering the air passage when a crocodilian feeds underwater.

ORDER SQUAMATA

The order Squamata consists of about 5,500 species of lizards and snakes. A distinguishing characteristic of this order is an upper jaw that is loosely joined to the skull. Squamates are the most structurally diverse of the living reptiles, and they are found worldwide.

Lizards

There are about 3,000 species of living lizards. Common lizards include iguanas, chameleons, and geckos. Lizards live on every continent except Antarctica. Figure 41-15 shows some examples of lizards. Most lizards prey on insects or on other small animals. A few of the larger species, such as the chuckwalla and desert iguana of the southwestern United States, feed on plants. The Komodo dragon feeds on prey as large as goats and deer. Only two species of lizards are venomous. They are the Gila monster of the southwestern United States and northern Mexico and the related beaded lizard of southern Mexico.

Most lizards rely on agility, speed, and camouflage to elude predators. If threatened by a predator, some lizards have the ability to detach their tail. This ability is called **autotomy.** The tail continues to twitch and squirm after it detaches, drawing the predator's attention while the lizard escapes. The lizard grows a new tail in several weeks to several months, depending on the species.

Most lizards are small, measuring less than 30 cm (12 in.) in length. The largest lizards belong to the monitor family (Varanidae). Like snakes, monitors have deeply forked tongues that pick up airborne particles and transfer them to the Jacobson's organ in the roof of the mouth.

FIGURE 41-15

(a) The largest of all monitors is the Komodo dragon, *Varanus komodoensis,* of Indonesia. The Komodo dragon can grow to 3 m long (10 ft). (b) A colorful gecko of the genus *Phelsuma* has specialized structures on the pads of its fingers and toes that allow it to cling to almost any surface.

(a)

(b)

(a)

(b)

FIGURE 41-16

(a) The Gaboon viper, *Bitis gabonica,* injects a toxic venom to kill its prey before it begins the process of swallowing. (b) The boa constrictor, *Constrictor constrictor,* suffocates its prey.

Snakes

There are about 2,500 species of snakes, and like lizards, they are distributed worldwide. Figure 41-16 shows some examples of snakes. The most obvious characteristic of snakes is the lack of legs, which affects all other aspects of their biology. What was the selective pressure that caused snakes to evolve leglessness? One possibility is that the ancestors of snakes were terrestrial but lived in thick vegetation, where legs were a hindrance to rapid movement.

The graceful movements of snakes are made possible by their unique anatomy. A snake has a backbone of 100 to 400 vertebrae, and a pair of ribs is attached to each vertebra. These bones provide the framework for thousands of muscles. The muscles manipulate not only the skeleton but also the snake's skin, causing the overlapping scales to extend and contract, propelling the snake.

Capturing and Consuming Prey

A snake may just seize and swallow its prey. However, many snakes employ one of two methods for killing: constriction or injection of venom. Snakes that are **constrictors** wrap their bodies around prey. A constrictor suffocates its prey by gradually increasing the tension in its coils, squeezing a little tighter each time the prey breathes out. This technique is used both by large snakes, such as boas, pythons, and anacondas, and by smaller snakes, such as gopher snakes and king snakes.

Some snakes inject their prey with a toxic venom in one of three different ways. The snakes with fangs in the back of the mouth, such as the boomslang and twig snakes of Africa, bite the prey and use grooved teeth in the back of the mouth to guide the venom into the puncture. Cobras, kraits, and coral snakes are elapids. **Elapid** snakes inject poisons through two small, fixed fangs in the front of the mouth. **Vipers** inject venom through large, mobile fangs in the front of the mouth. Rattlesnakes, copperheads, and water moccasins are examples of vipers. When a viper strikes, these hinged fangs swing forward from the roof of the mouth and inject venom more deeply than can the fangs of elapids.

Quick Lab

Modeling Snake Swallowing

Materials rubber tubing, small marble

Procedure Find a way to get the marble into the middle of the rubber tubing.

Analysis How is this model similar to the feeding mechanism of a snake? If you used a marble that was larger than the opening of the tubing, what problems would you encounter? Why is the size of larger prey not a problem for snakes?

FIGURE 41-17
This series of photographs shows a snake, *Dasypeltis scabra,* swallowing a bird's egg. Prey is often larger than the diameter of the snake's head, so the process of swallowing can take an hour or more.

Once killed, the prey must be swallowed whole because a snake's curved, needlelike teeth are not suited for cutting or chewing. Several features of a snake's skull enable it to swallow an animal larger in diameter than its head, as shown in Figure 41-17. The upper and lower jaws are loosely hinged, move independently, and can open to an angle of 130 degrees. In addition, a snake's lower jaw, palate, and parts of its skull are joined by a flexible, elastic ligament that allows the snake's head to stretch around its prey.

FIGURE 41-18
Unlike most reptiles, the endangered tuataras, such as the one shown, are most active at low temperatures.

ORDER RHYNCHOCEPHALIA

The order Rhynchocephalia (RING-koe-suh-FAY-lee-uh) is an ancient one that contains only the tuataras of the genus *Sphenodon.* Tuataras inhabit only a few small islands of New Zealand. The Maoris of New Zealand named the tuataras for the conspicuous spiny crest that runs down the animal's back, seen in Figure 41-18. The word *tuatara* means "spiny crest". Tuataras grow to about 60 cm (24 in.) in length. They usually hide in a burrow during the day and feed on insects, worms, and other small animals at night.

Since arriving in New Zealand about 1,000 years ago, humans have radically changed the landscape and introduced predators such as rats and cats, which feed on tuataras and their eggs. As a result, tuataras have disappeared from most of their original range.

SECTION 3 REVIEW

1. Compare the characteristics of aquatic turtles to the characteristics of land tortoises.
2. Identify characteristics of crocodilians that allow them to feed efficiently in water.
3. Identify three strategies employed by lizards to avoid predators.
4. Describe two methods snakes use for killing prey.
5. Explain why tuataras are rarely seen in the wild.

CRITICAL THINKING

6. **Making Comparisons** Compare the costs versus the benefits of autotomy for lizards.
7. **Inferring Relationships** Why do you think turtles migrate long distances to lay eggs on the same shore on which they hatched?
8. **Applying Information** Why do you think snakes have many more vertebrae than any other group of reptiles does?

CHAPTER HIGHLIGHTS

SECTION 1 Origin and Evolution of Reptiles

- An abundance of food, a dry climate, and a mass extinction of other species led to the dominance of reptiles. The Mesozoic era is often called the age of reptiles.
- Several factors contributed to the success of dinosaurs. Legs positioned under their bodies made dinosaurs faster and more agile than other reptiles. Dinosaurs were well adapted to dry conditions. At the end of the Triassic period, a mass extinction reduced competition and allowed dinosaurs to flourish.
- Dinosaurs became extinct about 65 million years ago. Evidence suggests that environmental conditions over many years endangered dinosaur survival, and either a single asteroid impact or multiple asteroid impacts might have triggered a mass extinction event.
- There are four modern orders of reptiles: Chelonia (turtles and tortoises), Crocodilia (alligators and crocodiles), Squamata (lizards and snakes), and Rhynchocephalia (tuataras).
- Three characteristics that contribute to the success of reptiles on land are the amniotic egg, watertight skin, and efficient respiration and excretion.

Vocabulary

dinosaur (p. 819)
asteroid impact hypothesis (p. 821)
amniotic egg (p. 823)
amnion (p. 823)
yolk sac (p. 823)
allantois (p. 823)
chorion (p. 823)
albumen (p. 823)
keratin (p. 824)

SECTION 2 Characteristics of Reptiles

- Most reptiles have a three-chambered heart, but crocodiles have a four-chambered heart. Reptiles can divert blood from the lungs to conserve energy and warm their bodies.
- Reptiles inflate their lungs by expanding the ribs, which lowers air pressure in the chest cavity and draws in air. When the ribs relax, air is forced out.
- A reptile's brain is about the same size as the brain of an amphibian but has a much larger cerebrum. A reptile's senses include sight, hearing, smell, and heat detection.
- All living reptiles are ectotherms. Ectotherms warm their bodies mainly by absorbing heat from their surroundings.
- Many reptiles lay shelled eggs, which is called oviparity. Some species retain shelled eggs inside the female's body, which is ovoviviparity. Other species have eggs with placentas rather than shells, which develop within the female's body. This is viviparity.
- Of the reptiles, crocodiles and alligators provide the greatest amount of parental care.

Vocabulary

septum (p. 825)
alveolus (p. 826)
Jacobson's organ (p. 827)
thermoregulation (p. 828)
ectotherm (p. 828)
endotherm (p. 828)
oviparity (p. 829)
ovoviviparity (p. 829)
viviparity (p. 829)
placenta (p. 829)

SECTION 3 Modern Reptiles

- The order Chelonia, which includes turtles and tortoises, have a shell composed of bony plates. The vertebrae and ribs are fused to the interior surface of the shell.
- Members of the order Crocodilia are large aquatic or semiaquatic carnivores. They include crocodiles, alligators, caimans, and gavials. A valve in the oral cavity of crocodilians covers the esophagus and windpipe while the mouth is submerged. This allows crocodilians to capture and swallow prey underwater.
- The order Squamata consists of lizards and snakes. Most lizards rely on speed, agility, and camouflage to elude predators. Some can detach their tail to distract predators.
- Some snakes kill their prey by constriction. Others kill their prey by injecting venom.
- The order Rhynchocephalia contains only the tuataras. Tuataras hide in burrows during the day and feed at night. The arrival of humans and new predators in New Zealand has reduced the number of tuataras.

Vocabulary

carapace (p. 830)
plastron (p. 830)
autotomy (p. 832)
constrictor (p. 833)
elapid (p. 833)
viper (p. 833)

CHAPTER REVIEW

USING VOCABULARY

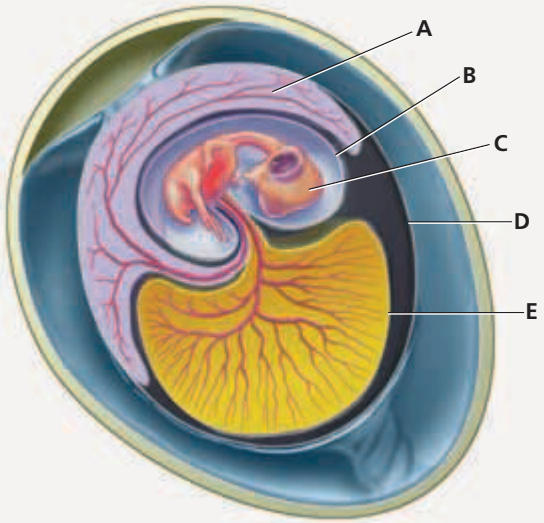
1. Choose the term that does not belong in the following group, and explain why it does not belong: *elapids, vipers, constrictors,* and *dinosaurs*.
2. Explain the relationship between amnion and chorion.
3. Use each of the following terms in a separate sentence: *oviparity, ovoviviparity,* and *viviparity*.
4. **Word Roots and Origins** The word *ectotherm* comes from the Greek word *ecto,* meaning "outside" and *therm,* meaning "heat". The word *endotherm* comes from the Greek word *endo,* meaning "within" and *therm,* meaning "heat". Explain why each term is a good name for the biological process that the term describes.

UNDERSTANDING KEY CONCEPTS

5. **Summarize** the events that led to the rise of reptiles during the Permian period.
6. **Identify** three factors that contributed to the success of dinosaurs during the Triassic period.
7. **Explain** why scientists advocate the asteroid impact hypothesis for dinosaur extinction.
8. **Name** one example of each of the four modern orders of reptiles.
9. **Explain** how the evolution of the amniotic egg is an adaptation to life on land.
10. **Explain** how the respiratory and excretory systems in reptiles show adaptations for life on land.
11. **Contrast** a turtle's heart and a crocodile's heart.
12. **Describe** how the structure of a turtle's heart allows for flexibility in blood circulation.
13. **Identify** the advantage of alveoli in respiration.
14. **Describe** two senses other than vision and hearing that reptiles use to find prey.
15. **Identify** the major benefit of ectothermy.
16. **Compare** the reproductive strategies of oviparity, ovoviviparity, and viviparity.
17. **Describe** the features that make turtles unique among reptiles.
18. **Explain** how crocodilians swallow prey underwater.
19. **Explain** the purpose of a lizard's ability to lose its tail and grow a new one.
20. **List** three ways in which snakes can inject venom into their prey.
21. **Identify** the reason populations of tuataras have decreased in the last 1,000 years.
22. **CONCEPT MAPPING** Use the following terms to create a concept map that relates various adaptations of reptiles to life on land: *reptiles, water loss, amniotic eggs, keratin, scales, watertight,* and *skin*.

CRITICAL THINKING

23. **Analyzing Information** If birds did not evolve from the pterosaurs, what can you conclude about the evolution of the ability to fly?
24. **Analyzing Concepts** Why is it advantageous for a snake to kill its prey, either through constriction or venom, before trying to eat the prey?
25. **Recognizing Relationships** The skin of a basking lizard is usually dark. As the lizard warms, the skin lightens. Suggest a functional explanation for this change. (Hint: Consider how this change might affect the lizard's absorption of heat.)
26. **Analyzing Data** Fossil evidence collected in Alaska suggests that some dinosaurs were year-round residents of areas subject to freezing temperatures and long periods of darkness. Does this evidence of arctic dinosaurs support or contradict the hypothesis that the extinction of dinosaurs was due to the intense cold produced by a cloud of debris in the atmosphere? Explain your answer.
27. **Relating Concepts** Some viviparous snakes and lizards live in cold climates. Why might viviparity be advantageous in such environments?
28. **Interpreting Graphics** The following diagram shows five parts of the amniotic egg, indicated by the letters A, B, C, D, and E. Name and identify the function of each part.



Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

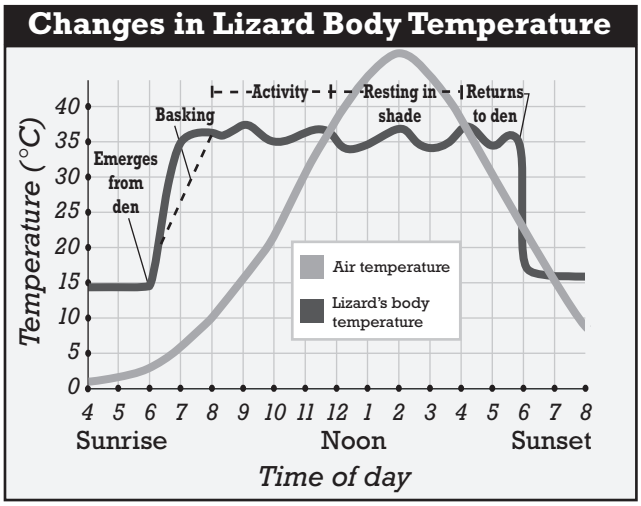
1. Which is an adaptation that made reptiles the dominant species in the Mesozoic era?
   A. They were endotherms.
   B. They could live in Antarctica.
   C. They were all large predators.
   D. They were well adapted to dry areas.

2. What are the two basic parts of a turtle's shell?
   F. septum and amnion
   G. chorion and allantois
   H. keratin and columella
   J. carapace and plastron

3. What is the purpose of a lizard's ability to lose its tail and grow a new one?
   A. to capture prey
   B. to hide from predators
   C. to escape from predators
   D. to reduce its need for food

4. Long legless bodies may have arisen as an adaptation that helped snakes do what?
   F. catch prey
   G. swallow large animals
   H. absorb oxygen through their skin
   J. burrow and move through thick vegetation

INTERPRETING GRAPHICS: The graph below shows changes in air temperature and changes in the body temperature of a lizard. Use the graph below to answer the question that follows.

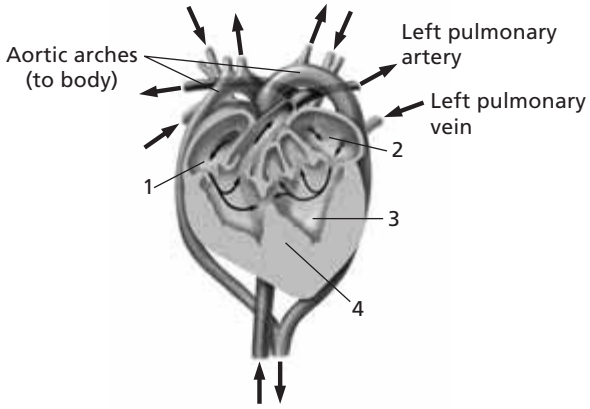


5. In order for the lizard to raise its internal temperature it must do which of the following?
   A. rest in the shade
   B. bask in sunshine
   C. increase its internal temperature through activity
   D. decrease its internal temperature through activity

DIRECTIONS: Complete the following analogy.

6. Ectotherm : reptiles :: endotherm :
   F. fishes
   G. insects
   H. mammals
   J. amphibians

INTERPRETING GRAPHICS: The illustration below shows a cross section of a turtle's heart. Use the illustration to answer the question that follows.



7. Which feature of a turtle's heart structure is different from that of a crocodile?
   A. 1
   B. 2
   C. 3
   D. 4

SHORT RESPONSE

A reptile can redirect blood flow through the heart to send some deoxygenated blood back to the body instead of to the lungs.

What is the advantage to the lizard of redirecting blood flow in this manner?

EXTENDED RESPONSE

There are three patterns of reproduction among reptiles. They differ in how long eggs remain in the female and how the developing young are provided with nutrition.

Part A With these differences in mind, compare oviparity, ovoviviparity, and viviparity.

Part B In which pattern of reproduction is a placenta present? Explain the function of the placenta.

Test TIP When analyzing a graph, pay attention to its title. It should tell you what the graph is about and provide a context for the data.

Observing Color Adaptation in Anoles

OBJECTIVES

- Observe live anoles.
- Test whether background color stimulates color change in anoles.

PROCESS SKILLS

- observing
- hypothesizing
- experimenting
- organizing data
- analyzing data

MATERIALS

- glass-marking pencil
- 2 large clear jars with wide mouths and lids with air holes
- 2 live anoles
- 6 shades each of brown and green construction paper, ranging from light to dark (2 swatches of each shade)

Background

1. Anoles include 250–300 species of lizards in the genus *Anolis.*
2. Anoles can change color, ranging from brown to green, and are sometimes mottled.
3. Anoles live in shrubs, grasses, and trees. Describe some ways in which the ability to change color might be an advantage to anoles.
4. Light level, temperature, and other factors, such as whether the anole is frightened or whether it has eaten recently, can affect color. When anoles are frightened, they usually turn a dark grey or brown and are unlikely to respond to other stimuli.
5. Anoles can change color within a few minutes.

Procedure

1. Observe the anoles in two terraria, and discuss the purpose of this investigation with your partners. Develop a hypothesis that describes a relationship between anole skin color and background color. Write your hypothesis in your lab report.
2. Obtain swatches of construction paper in at least six different shades of green and brown. You will need two swatches of paper in each color.
3. Obtain two clear jars. Label one jar "Anole 1," and label the other jar "Anole 2."
4. **CAUTION** **You will be working with live animals. Handle them gently and follow instructions carefully.** Select two anoles of the same color from the terraria. Plan your actions and cooperate with a partner to transfer one anole into each labeled jar. Anoles will run fast and are easily frightened. Carefully pick them up and place the animals in separate jars. Do not pick up anoles by their tails. Grasp them gently behind the head. Quickly and carefully place a lid with air holes on each jar.
5. Gently place the jar with Anole 1 on a swatch of construction paper that most closely matches the anole's color. Try not to jostle the anole in the jar, and move the jar as little and as gently as possible. Repeat this procedure for Anole 2. Both anoles should closely match the color of the swatch.

6. When you have obtained and matched two anoles to closely matching colors, label the back of the pieces of paper "Initial Color of Anole 1" and "Initial Color of Anole 2," respectively. Replace the swatches underneath the jars after you have labeled them. The anoles should stay in their respective jars until the end of this investigation.
7. Using the given setup and the remaining swatches of colored construction paper, devise a control experiment to test whether background color stimulates color change in the anole.
8. In your lab report, list the independent variable and the dependent variables that you intend to use in your experiment. Describe how you will vary the independent variable and how you will measure changes in your dependent variable.
9. In your lab report, describe the control you will use in your experiment.
10. Create a data table similar to the one below to record your experimental observations for your lab report. For example, the table below is designed to record any change in anole skin color on four different background colors and the time it took for each change to take place. Design your data table to fit your own experiment. Remember to allow plenty of space to write your observations.
11. Have your experiment approved by your teacher before conducting it. As you conduct your experiment, be sure to record all of your data and observations in your lab report.
12. Attach your color swatches to your lab report, or include a color-coded key so that others reading your report will be able to understand how you measured initial color and color changes in your anoles. Be sure the color that most closely represents the initial color of both anoles is clearly indicated in your lab report.
13.  Clean up your materials and wash your hands before leaving the lab.

Analysis and Conclusions

1. What effect, if any, did changes in the independent variable have on the dependent variable in your experiment?
2. Do your data support your hypothesis? Explain.
3. Can you think of any sources of error in your experiment?
4. Was your experiment a controlled experiment? If yes, describe your control and why you think a control is necessary for your experiment.
5. Were there any uncontrolled variables in your experiment, such as loud noises, bright light, or sudden movements, that could have affected your experiment? Describe how you might be able to improve your methods.

Further Inquiry

Design an experiment that tests the effects of temperature on anole skin color.

DATA TABLE ***OBSERVING ANOLES***

	Color 1		Color 2		Color 3		Color 4	
	Change	Time	Change	Time	Change	Time	Change	Time
Anole 1								
Anole 2								