CHAPTER 43

MAMMALS

These young opossums depend on their mother's body to supply milk, a nourishing fluid from her mammary glands. The production of milk is one of the key characteristics of mammals.

SECTION 1

Origin and Evolution of Mammals

Mammals (class Mammalia) are a highly diverse group. The opossums on the previous page are mammals. What makes them recognizable as mammals? What traits do they share with more than 4,000 other mammalian species?

OBJECTIVES

- **Describe** the major characteristics of mammals.
- **Compare** the characteristics of early synapsids, early therapsids, and modern mammals.
- **Relate** the adaptive radiation of mammals to the history of dinosaurs.
- **Differentiate** between monotremes, marsupials, and placental mammals.

VOCABULARY

endothermy
mammary gland
synapsid
therapsid
monotreme
oviparous
marsupial
viviparous
placental mammal
placenta

MAJOR CHARACTERISTICS

All mammals, such as the lions shown in Figure 43-1, have the following six major characteristics:

- **Endothermy**—Mammals, like birds, regulate body heat internally through metabolism and externally through insulation. A mammal's body temperature stays high and nearly constant because of adjustments in metabolic rate and regulation of heat loss through the body surface. This manner of controlling body temperature is called **endothermy.**
- **Hair**—All mammals have some hair. Most mammals are covered with a thick coat of hair, which insulates the body against heat loss. Hair is made of filaments of the protein keratin.
- **Completely divided heart**—Mammals have a four-chambered heart whose two ventricles are completely separated by a muscular wall. This division keeps deoxygenated blood from mixing with oxygenated blood and allows efficient pumping of blood through the circulatory system.
- **Milk**—Female mammals produce milk to feed their offspring. Milk is a nutritious fluid that contains fats, protein, and sugars. Milk is produced by **mammary glands,** which are modified sweat glands located on the thorax or abdomen.
- **Single jawbone**—A mammal's lower jaw is made up of a single bone. By comparison, a reptile's lower jaw is made up of several bones. Mammalian fossils are often identified by the jawbone.
- **Specialized teeth**—Mammals have various types of teeth modified for different functions. Teeth at the front of the jaw bite, cut, or hold prey. Teeth along the sides of the jaw crush, grind, or slice. By comparison, most reptiles' teeth are uniformly sharp and conelike throughout the mouth.

FIGURE 43-1
Lions have the six key characteristics of mammals.

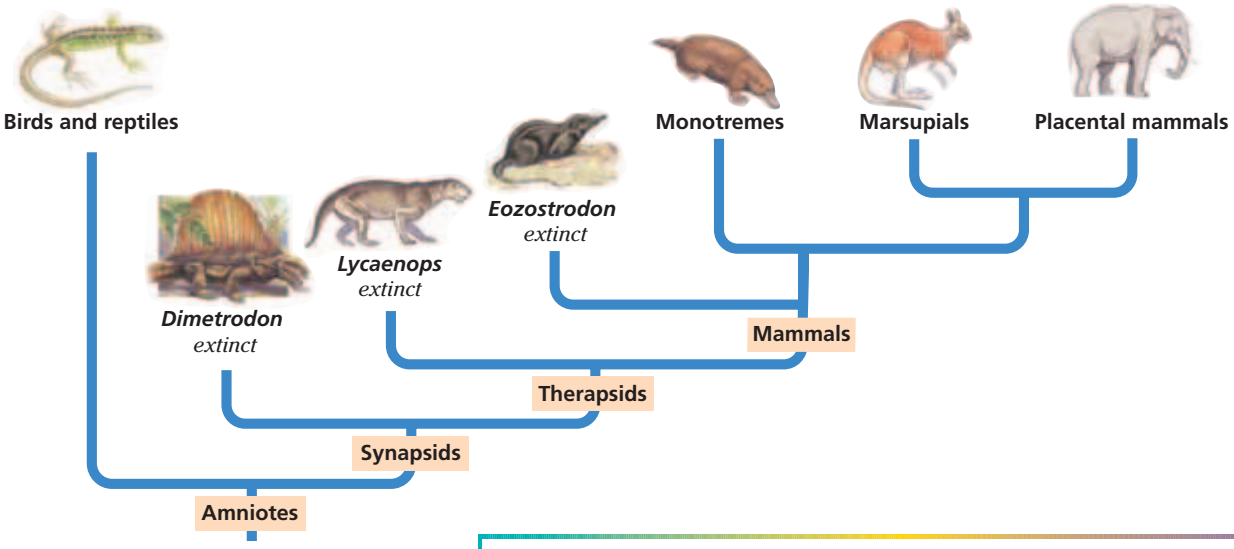


FIGURE 43-2

This phylogenetic diagram reflects hypotheses about the evolutionary relationships among mammals and other vertebrates. Mammals are thought to have descended from four-legged, land-dwelling vertebrates known as *therapsids,* which are sometimes referred to as *mammal-like reptiles.*

ANCESTORS OF MAMMALS

Scientists think that the ancestors of all mammals appeared more than 300 million years ago. Around that time, amniotes seem to have split into two groups. One group gave rise to dinosaurs, birds, and modern reptiles. The other group, known as **synapsids,** gave rise to mammals and their extinct relatives, as shown in Figure 43-2. Paleontologists recognize early synapsids by the structure of their skull, which has a single opening in a bone just behind the eye socket. This same type of skull is found in all later synapsids, including mammals, although often in a modified form.

The first synapsids were small and looked like modern lizards. By the early Permian period (272 million to 298 million years ago), various large synapsids had appeared. Some reached 4 m (13 ft) in length and weighed more than 200 kg (440 lb). Figure 43-3 shows an illustration of a carnivorous synapsid of the genus *Dimetrodon* (die-MET-ruh-DON). Unlike most other reptiles, which have uniformly shaped teeth, these early synapsids had specialized teeth—long bladelike front teeth and smaller back teeth.

FIGURE 43-3

This synapsid had a sail-like structure on its back. Scientists think that this structure was filled with blood vessels that may have helped regulate the animal's body temperature. This illustration was made based on information from the fossil record.

Dimetrodon sp.

Therapsids

A subset of synapsids, called **therapsids,** appeared later in the Permian period and gave rise to mammals. Therapsids were the most abundant terrestrial vertebrates during the late Permian period. They survived through the Triassic period (251 million to 203 million years ago) and into the Jurassic period (203 million to 144 million years ago).

A rich fossil record of transitional forms between therapsids and mammals exists. By studying these fossils, scientists can trace the anatomical changes that occurred during this transition and infer additional physiological, ecological, and behavioral changes. Several features we associate with mammals evolved first among early therapsids. For example, like the limbs of many early therapsids, mammals' limbs are directly beneath the body. Evidence suggests that some early therapsids were endothermic and may have had hair.

Early Mammals

Both the first mammals and the first dinosaurs appeared during the Triassic period. So, dinosaurs coexisted with mammals for more than 150 million years. Figure 43-4 shows a hypothesized image of an early mammal. Early mammals were about the size of mice. Fossil skulls with large eye sockets suggest that these mammals were active at night. Also, their teeth were adapted for feeding on insects. Hiding by day and specializing on insects allowed the mammals to avoid threats from dinosaurs or competition with them. Similarities in the mammary tissues of several kinds of mammals suggest that milk production had evolved by the end of the Triassic.

FIGURE 43-4

The earliest mammals, such as this species of the genus *Eozostrodon,* had to compete with the larger, dominant dinosaurs. These early mammals were active at night, when dinosaurs were probably less active.

DIVERSIFICATION OF MAMMALS

Dinosaurs dominated most terrestrial habitats while populations of small mammals continued to evolve. By the middle of the Cretaceous period, about 100 million years ago, three different kinds of mammals had appeared. Modern mammals belong to one of these three groups. The first group is made up of **monotremes.** They are **oviparous,** meaning that they lay eggs. The second group is made up of **marsupials.** They are **viviparous,** which means that they give birth to live young. In marsupials, the young develop within a pouch on the mother's body for some time after birth. The third group is made up of **placental mammals.** They are also viviparous, but in this group, the fetus typically develops within the mother's reproductive system for a longer time than it does in marsupials. Also, in this group, the developing fetus receives nourishment through a blood-rich structure called the **placenta.**

Many scientists think that some sort of natural disaster changed Earth's climate and forced the dinosaurs into extinction about 65 million years ago, at the end of the Cretaceous period. This change opened up many new habitats and resources to mammals. So, mammals took over many of the ecological roles that dinosaurs previously had. Today, nearly all large terrestrial animals are mammals.

SECTION 1 REVIEW

1. What is the function of hair in mammals?
2. Identify two differences between the skull of a mammal and the skull of a reptile.
3. Compare the characteristics of early synapsids, early therapsids, and modern mammals.
4. Differentiate between monotremes, marsupials, and placental mammals.

CRITICAL THINKING

5. **Analyzing Theories** Describe a possible species that would be a transitional form between therapsids and mammals.
6. **Examining Evidence** What factors limit biologists' knowledge of early mammals?
7. **Making Comparisons** Which trait(s) do monotremes share with reptiles?

SECTION 2

OBJECTIVES

- **Explain** the advantage of endothermy in mammals.
- **Identify** features of the mammalian respiratory and circulatory systems that help sustain a rapid metabolism.
- **Describe** mammalian adaptations for obtaining food.
- **Compare** the nervous system of mammals to that of other groups of animals.
- **Differentiate** among the patterns of development in monotremes, marsupials, and placental mammals.

VOCABULARY

diaphragm
incisor
canine
premolar
molar
baleen
rumen
cecum
echolocation

CHARACTERISTICS OF MAMMALS

Mammals live in many different kinds of habitats and climates all over the world. Several adaptations enable mammals to live in such diverse environments.

ENDOTHERMY

All animals produce heat internally when they metabolize, or produce energy from food. Mammals are *endotherms,* meaning they conserve and regulate this body heat. Most other animals, such as insects and lizards, are *ectotherms,* animals that are heated or cooled by their surroundings. Endothermy allows mammals to live in cold climates yet remain active. Moreover, the type of metabolism needed for endothermy also provides energy to perform strenuous activities for extended periods, such as migrating long distances.

Mammalian organ systems are uniquely adapted for endothermy. Figure 43-5 shows the internal anatomy of a mammal. Because of its faster metabolism, a mammal uses more oxygen and food than does a reptile of the same size. So, mammals have unique circulatory and digestive systems. Also, the body temperature of a mammal is often above that of its environment, so heat constantly escapes through the animal's skin and breath. The energy used to heat a mammal's body would be wasted without adaptations such as body insulation. Often, mammals that live in very cold climates have heavy coats of fur and, or thick layers of fat, called *blubber.*

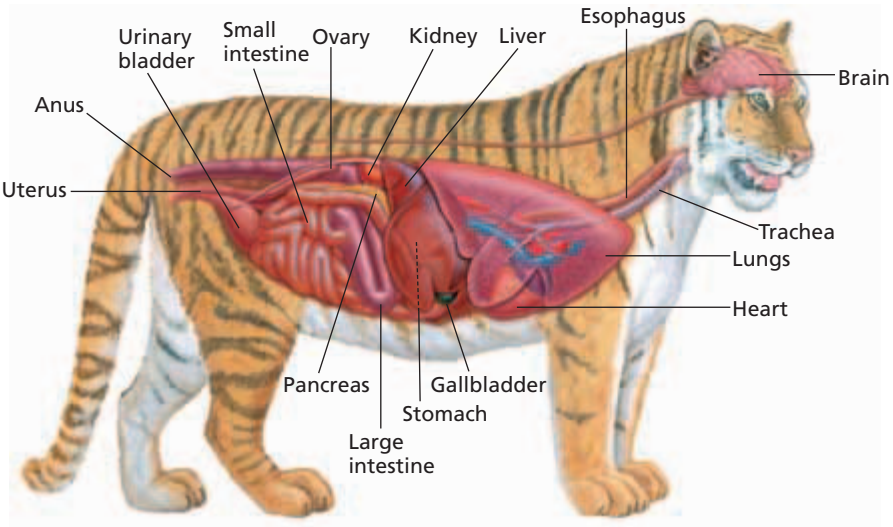


FIGURE 43-5
The organs and organ systems of modern mammals have a high demand for energy. The mammalian heart efficiently pumps oxygenated blood throughout the body, delivering nutrients that fuel the high-energy requirements of endothermy.

Circulatory System

The structure of the mammalian heart allows efficient pumping of blood throughout the body, as shown in Figure 43-6. The mammalian heart has two atria and two ventricles. A *septum,* or wall of tissue, completely separates the ventricles. The septum prevents oxygenated and deoxygenated blood from mixing. Recall that in the hearts of lizards and turtles, an incomplete septum allows the oxygen-rich blood and oxygen-poor blood to mix when the animal is inactive. The complete septum is an adaptation that allows mammals' bodies to transport oxygen more efficiently.

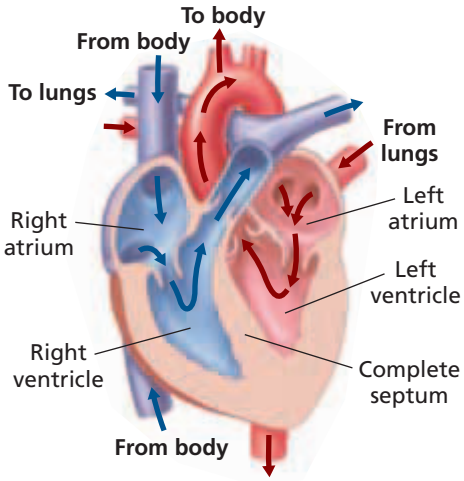


FIGURE 43-6

The red arrows show the path of oxygenated blood through the heart, and the blue arrows show the path of deoxygenated blood. Notice that the ventricles are completely separated by a septum. As a result, the blood pumped to the body contains a higher percentage of oxygen than a reptile's or fish's pumping heart can circulate.

Respiratory System

A mammal's respiratory system is adapted for efficient gas exchange. The lungs are large and contain millions of *alveoli,* the small sacs in which gas exchange occurs. As a result, mammalian lungs have a much larger surface area available for gas exchange than reptilian lungs do.

Mammals breathe using two mechanisms: one they share with some reptiles and one that is unique. Lizards and snakes inhale by using their rib-cage muscles to expand the thoracic cavity, the body cavity that holds the lungs. Mammals inherited this breathing mechanism but use it mostly under conditions of strenuous activity. The second mammalian breathing mechanism uses a sheet of muscle below the rib cage called the **diaphragm.** Contraction of the diaphragm enlarges the thorax and thus expands the thoracic cavity. At rest, mammals breathe primarily with the diaphragm.

FEEDING AND DIGESTION

For most mammals, the breakdown of food begins with chewing. Other vertebrates simply swallow their food whole or in large pieces. Chewing speeds up digestion by breaking food into small pieces that provide a large surface area for attack by enzymes. Variations in the size and shape of teeth among different mammalian species reflect differences in diet. Chisel-like **incisors** cut. Pointed **canines** grip, puncture, and tear. **Premolars** shear, shred, cut, or grind. **Molars** grind, crush, or cut. For example, predatory carnivores, such as the bear in Figure 43-7, have a set of teeth specialized for gripping, holding, tearing, and crushing food. Mammalian carnivores are recognizable by their sharp incisors and long canines.

Baleen whales, such as the blue whale, lack teeth. Instead, they have **baleen,** thin plates of keratin that hang from the skin of the upper jaw like a curtain. As a baleen whale swims, it gulps water, then closes its mouth, and pushes the water out through the baleen. Shrimp and other invertebrates get trapped behind the baleen and then are swallowed.

FIGURE 43-7

Carnivores, such as this bear, have large, sharp incisor and canine teeth that can cut and tear flesh. Bears and many other carnivores also have strong, crushing molars.

FIGURE 43-8

Many herbivores, such as this zebra, have flat teeth that can efficiently grind grasses, grains, or leaves. Herbivores also have digestive systems that harbor symbiotic microbes that help digest plant materials.

Special Adaptations for Digesting Plants

Meat is simple to digest, so most carnivores have short, simple digestive systems. Plants, however, can be difficult to digest because plants contain *cellulose,* a polymer of the sugar glucose. Animals do not produce enzymes that can break down cellulose. However, the long digestive tracts of herbivorous mammals, such as the zebra shown in Figure 43-8, contain microorganisms that can break down cellulose.

In some herbivorous mammals, the structure that is called a *stomach* is actually made up of four chambers. One of these chambers is the true stomach. Another chamber, known as the **rumen** (ROO-muhn), contains symbiotic microorganisms. Plant material that has been chewed and swallowed enters the rumen, where microorganisms begin to break the cellulose into smaller molecules that can be absorbed into the animal's bloodstream. The material is partly digested in the rumen, then regurgitated, chewed again, and swallowed again. The animal may regurgitate and swallow the same food several times. Mammals that have a rumen are called *ruminants* and include cows, sheep, goats, giraffes, and deer.

In horses, zebras, rodents, rabbits, and elephants, microorganisms that live in the cecum (SEE-kuhm) complete digestion of the food. The **cecum** is a large sac that branches from the small intestine and acts as a fermentation chamber. Food passes through the stomach and small intestine before entering the cecum. Mammals with a cecum do not chew cud.

NERVOUS SYSTEM

A mammal's brain is about 15 times heavier than the brain of a similarly sized fish, amphibian, or reptile. Of all animals, humans have one of the highest ratios of brain size to body size. Whales, dolphins, and some primates also have high ratios. These differences are due mostly to the size of the cerebrum. The *cerebrum* is the outer region of the brain and the largest part of the brain in mammals. The cerebrum's surface is usually folded and fissured, which greatly increases its surface area without increasing its volume. The cerebrum evaluates input from the sense organs, controls movement, initiates and regulates behavior, and functions in memory and learning.

As with other terrestrial vertebrates, a mammal's survival depends on five major senses: vision, hearing, smell, touch, and taste. The importance of each sense depends on the mammal's environment. For example, most bats, which are active at night, rely largely on sound rather than vision for navigating and finding food. Using a process called **echolocation** (EK-oh-loh-KAY-shuhn), these bats emit high-frequency sound waves, which bounce off objects, including potential prey. The bat then analyzes the returning echoes to determine the size, distance, direction, and speed of the objects.

Word Roots and Origins

cecum

from the Latin *intestinum caecum,* meaning "blind intestine"

DEVELOPMENT

In all living mammals, milk from the mother's mammary glands nourishes newborns. However, the pattern of development of the offspring differs from group to group.

Monotremes

A female monotreme typically lays one or two large eggs encased in thin, leathery shells and then incubates them. Her body heat keeps the eggs warm. The yolk nourishes the developing embryo within the egg. At hatching, a monotreme is very small and only partially developed. Its mother protects it and feeds it milk from her mammary glands until it is ready to survive on its own.

Marsupials

In marsupials, such as opossums and kangaroos, embryos develop for just a short period within the mother's uterus and then emerge from the uterus and crawl into the mother's pouch, a skin-lined pocket on her abdomen. The newborn offspring of a kangaroo at this stage is only 2 to 3 cm (1 in.) long. In the mother's pouch, the newborn attaches to a nipple to feed. The newborn's development and growth then continue inside the pouch for several months.

Placental Mammals

Placental mammals, such as the horse in Figure 43-9, give birth to well-developed young after a long period of development inside the uterus. During this period, the placenta provides nourishment and oxygen to the developing offspring. The placenta begins to form shortly after fertilization, when the fertilized egg attaches to the lining of the uterus. Extensions from the *chorion,* the outer membrane of the embryo, grow into the lining of the uterus. Blood vessels from the uterus surround these extensions. Nutrients and oxygen diffuse from the mother's blood into the blood of the offspring, and carbon dioxide and other wastes diffuse from the offspring into the mother's blood. After birth, infants feed on milk for several weeks or months.

FIGURE 43-9

Placental mammals, such as horses, carry their developing fetuses for a long time and give birth to infants that are relatively large and well developed, but still need parental care.

Word Roots and Origins

placenta

from the Greek *plakos,* meaning "flat object" or "flat cake"

SECTION 2 REVIEW

1. A mammal eats about 10 times as much food as a lizard of the same size. Explain this difference.
2. Compare a mammalian heart to a reptilian heart.
3. Describe the function of a rumen.
4. Compare a mammalian brain to a reptilian brain.
5. Compare the developmental patterns of monotremes, marsupials, and placental mammals.

CRITICAL THINKING

6. **Analyzing Information** What is the advantage of large ears to a bat that is active at night?
7. **Applying Concepts** What ecological relationship does a cow have with the bacteria in its rumen?
8. **Recognizing Relationships** Propose a functional reason why endothermy is associated with an enlarged cerebrum.

SECTION 3

OBJECTIVES

- **Identify** an example from each of the 12 major orders of mammals.
- **Distinguish** between monotremes, marsupials, and placental mammals.
- **Compare** the characteristics of artiodactyls and perissodactyls.
- **Compare** the adaptations for aquatic life in cetaceans, pinnipeds, and sirenians.

VOCABULARY

pinniped
ungulate

DIVERSITY OF MAMMALS

Mammals can be found in a diverse range of habitats, including the open ocean, underground, and mountaintops. Each mammalian species is uniquely adapted for its particular way of life.

MAMMALIAN ORDERS

Mammals are commonly classified into a single order of monotremes, 7 orders of marsupials, and about 18 orders of placental mammals. Possible evolutionary relationships between the mammalian orders are shown in Figure 43-10.

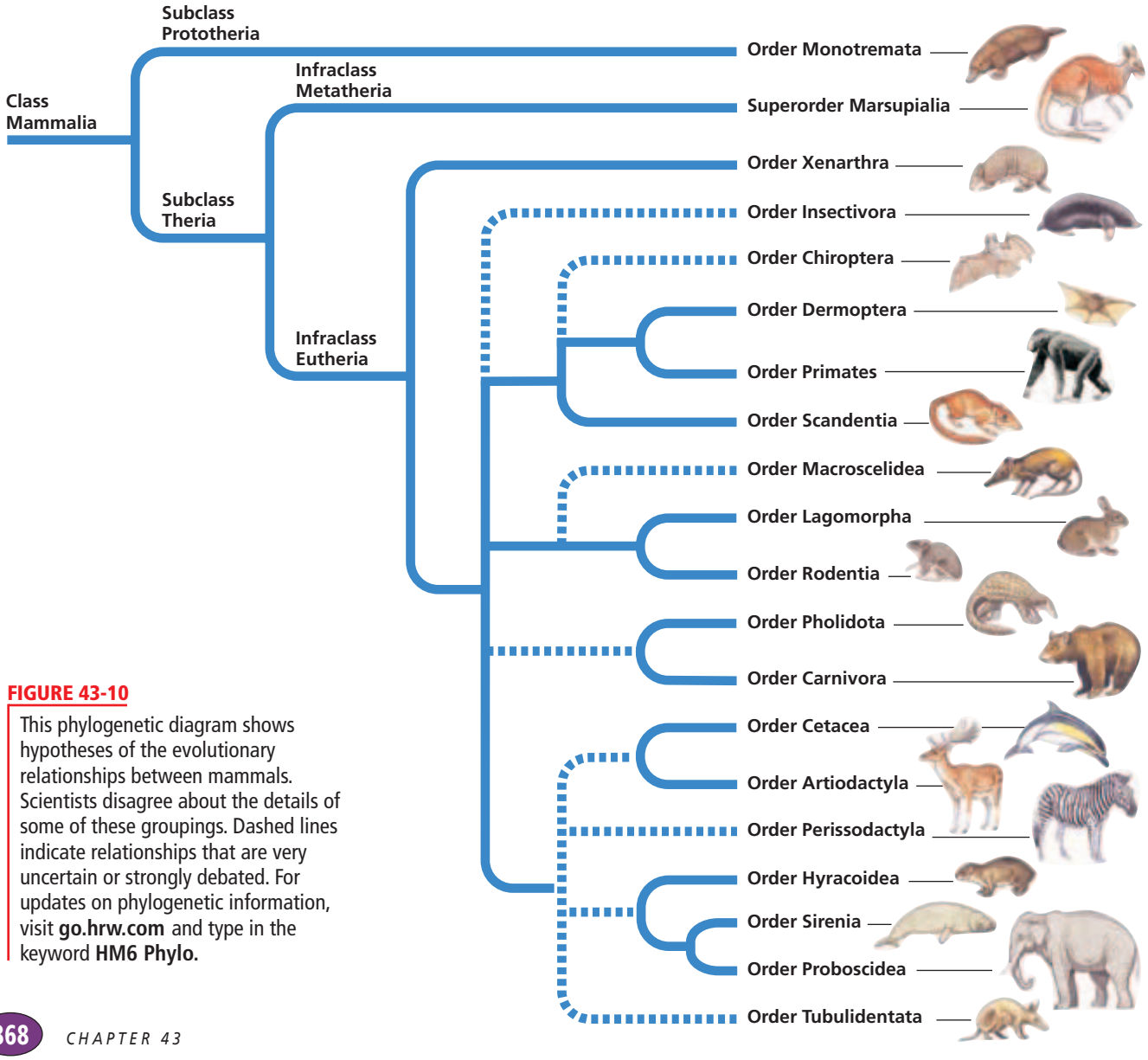


FIGURE 43-10

This phylogenetic diagram shows hypotheses of the evolutionary relationships between mammals. Scientists disagree about the details of some of these groupings. Dashed lines indicate relationships that are very uncertain or strongly debated. For updates on phylogenetic information, visit **go.hrw.com** and type in the keyword **HM6 Phylo.**

(a) Duckbill platypus, *Ornithorhynchus anatinus*

(b) Short-beaked echidna, *Tachyglossus aculeatus*

FIGURE 43-11

Two of the three species of the order Monotremata are shown here: the duckbill platypus (a) and an echidna that is also called a *spiny anteater* (b).

MONOTREMES

The order Monotremata (MAHN-oh-truh-MAHT-uh), the *monotremes,* is the only order in the subclass Prototheria. Because monotremes lay eggs, biologists consider this order to be very ancient, meaning that monotremes existed before other kinds of mammals did. Just three species exist today: the platypus and two echidna species.

The duckbill platypus, shown in Figure 43-11a, is adapted to life around rivers or streams in Australia. It has waterproof fur, webbed feet, and a flattened tail that aids in swimming. It uses its wide, flat, leathery bill to find worms, crayfish, and other invertebrates in soft mud. The female platypus digs a den in a riverbank to lay her eggs and curls around the eggs to protect and warm them. The babies lick milk from mammary glands on the mother's abdomen.

The two echidna species live in dry woodlands or deserts in Australia and New Guinea. As shown in Figure 43-11b, they have protective spines, a long snout, and a sticky tongue used to feed on ants and other insects (though they are unrelated to other mammal anteaters). Echidnas incubate their eggs in a pouch on the belly.

MARSUPIALS

The marsupials had previously been classified in one order, Marsupialia (mahr-SOO-pee-AY-lee-uh), but are now divided into at least seven orders within the super order Marsupialia. The majority of about 280 species of marsupials live in Australia, but some live in New Guinea and the Americas. The Virginia opossum is the only marsupial native to the United States.

Scientists think that marsupials began to evolve in isolation when Australia and New Guinea drifted away from the other continents more than 40 million years ago. At that time, placental mammals were rare in the Australian region, so marsupials evolved to take advantage of many ecological opportunities. Marsupials were once common in South America as well but were displaced by placental mammals that migrated in from the north.

PLACENTAL MAMMALS

Nearly 95 percent of all mammalian species are placental mammals, making up the infraclass Eutheria of the subclass Theria. They are classified into about 20 orders.

Order Xenarthra

The order Xenarthra (zuh-NAHR-thruh) includes about 30 living species of anteaters, armadillos, and sloths living in southern North America, Central America, and South America. Biologists think that, based on fossil and molecular evidence, Xenarthra evolved as a unique lineage in what is now South America. The name *xenarthra* means "strange joints" and refers to the unique structure of the lumbar vertebrae of members of this order.

This order was once named Edentata (EE-den-TAH-duh), meaning "toothless," because many members of this order do not have prominent teeth. Anteaters completely lack teeth. Armadillos and sloths have peglike teeth that lack enamel. Most edentates feed on insects, which they capture with a long, sticky tongue. With their powerful front paws and large, sharp claws, they rip open anthills and termite nests. Armadillos supplement their insect diet with small reptiles, frogs, mollusks, and scavenged meat. Sloths, on the other hand, are herbivores; their continuously growing teeth are adapted to grinding plants.

FIGURE 43-12

The North American pika (a) is a lagomorph, related to rabbits and hares. The North American porcupine (b), a rodent, ranges from Canada to northern Mexico.

(a) North American pika, *Ochotona princeps*

(b) North American porcupine, *Erethizon dorsatum*

Order Lagomorpha

The order Lagomorpha (LAG-uh-MAWR-fuh), members of which are called *lagomorphs*, includes about 70 species of rabbits, hares, and pikas. A pika (PIE-kuh) is shown in Figure 43-12a. Lagomorphs are native to many continents. They differ from rodents in that lagomorphs have a double row of upper incisors, with two large front teeth backed by two smaller ones. The teeth of lagomorphs continue to grow throughout their lifetime. Such teeth are an adaptation to a herbivorous diet.

Order Rodentia

Related to Lagomorpha is the order Rodentia (roh-DEN-chuh), members of which are called *rodents*. Rodentia is the largest mammalian order, which includes more than 1,800 species, or about 40 percent of all placental mammals. Rodents flourish on every continent except Antarctica and are adapted to a wide range of habitats. They tend to produce many young in each litter. Squirrels, marmots, chipmunks, gophers, muskrats, mice, and rats are rodents. The porcupine in Figure 43-12b is also a rodent.

A rodent's teeth consist of a few molars or premolars and two pairs of incisors that continue to grow as long as the rodent lives. The sharp incisors are an adaptation to gnaw on seeds, twigs, roots, and bark. As a rodent gnaws, the back surface of the tooth wears away faster than the front surface, maintaining the tooth's edge.

Order Primates

The order Primates is made up of 235 living species, including lemurs, tarsiers, lorises, monkeys, gibbons, apes, and humans. Most primates are omnivores and have teeth suited for a varied diet. Primates have brains that have a relatively large cortex, which make possible the complex behaviors characteristic of this group.

A wide range of body sizes and adaptations allow primates to live in a variety of terrains. The smallest known primate, the pygmy mouse lemur, weighs only about 30 g and was discovered in 2000 in Madagascar, where it lives mostly in trees. In contrast, the largest primate, the mountain gorilla, can weigh 140–180 kg (300–400 lb) and lives on the ground in dense African mountain forests.

Most primates have forward-facing eyes, a feature that enables depth perception. Many primates are active at night and have large eyes adapted for night vision. All primates have grasping hands and, with the exception of humans, grasping feet. Some primates also have a grasping tail. Many primates live in trees, where grasping feet, hands, and tails are essential adaptations. In humans, grasping hands serve many purposes.

Order Chiroptera

The only mammals that truly fly, the bats, make up the order Chiroptera (kie-RAHP-tuh-ruh). There are more than 900 species of bats, and they live throughout the world, except in polar environments. A bat's wing is a modified front limb with a membrane of skin that stretches between extremely long finger bones to the hind limb, as shown in Figure 43-13a. A bat's wingspan can measure up to 1.5 m (4.5 ft). The bat's clawed thumb sticks out from the top edge of the wing. Bats use their thumbs for walking, climbing, and grasping.

Most bats have small eyes and large ears and navigate by echolocation. Most bats are active at night and feed on insects. However, some tropical bats are active in the day and feed on fruit or flower nectar. These bats locate food by using their large eyes and keen sense of smell. A few species of bats feed on meat or blood.

Order Insectivora

The order Insectivora (in-sek-TIV-uh-ruh) includes about 390 species of shrews, hedgehogs, and moles living in North America, Africa, and Europe. Figure 43-13b shows a shrew. Most members of this order are *insectivores,* which means "animals that eat insects." However, not all insectivores are members of the order Insectivora. Furthermore, some Insectivora eat meat.

Scientists disagree about whether to include certain families of mammals in this order. For example, a family of mammals called *colugos,* which are commonly called *flying lemurs,* was once placed in Insectivora. This family is now usually classified as another order, Dermoptera. The Insectivora are usually small animals with a high metabolic rate. Most have long, pointed noses that enable them to probe in the soil for insects, worms, and other invertebrates. Their sharp teeth are adapted for grasping and piercing prey.

FIGURE 43-13

(a) Bats, in the order Chiroptera, are the only mammals that truly fly. The physics of the bat's wing in flight gives the bat more lift in relation to its body weight than most birds have. Thus, bats can remain airborne at slower speeds than birds can. (b) Shrews, in the order Insectivora, must eat more than twice their own body weight daily to fuel their high metabolic rate.

(a) Peter's epauletted fruit bat, *Epomophorus crypturus*

(b) Least shrew, *Cryptotis barua*

Word Roots and Origins

ungulate

from the Latin *ungula,* meaning "hoof"

Order Carnivora

The 274 living species of the order Carnivora (kahr-NIV-uh-ruh) are distributed worldwide. Most members of this order are called *carnivores,* which means "animals that eat meat." Dogs, cats, raccoons, bears, hyenas, otters, seals, and sea lions are some well-known carnivores. Most are skilled hunters with strong senses of sight and smell. Other adaptations of carnivores include strong jaws, long canine teeth, and clawed toes to seize and hold prey. Many terrestrial carnivores have skeletal adaptations, such as long limbs, to run quickly.

Aquatic carnivores, known as **pinnipeds,** include the sea lions, seals, and walruses. They are efficient at swimming, with streamlined bodies and four limbs adapted as flippers. Although pinnipeds spend much of their time in the sea feeding, they return to land to sleep and to give birth. They are generally larger than land carnivores, and their large size helps them maintain body temperature. Most pinnipeds can dive to depths of 400 m (1,313 ft) and remain underwater for up to five minutes, but some can remain submerged for as long as one hour. Some scientists once placed pinnipeds in their own order—Pinnipedia.

FIGURE 43-14

This caribou (a) is an artiodactyl. Artiodactyls are native to all continents except Australia and Antarctica. Although this tapir (b) looks like a pig (Order Artiodactyla), it is a perissodactyl. The similarity to a pig is an example of convergent evolution.

(a) Caribou, *Rangifer tarandus*

(b) Baird's tapir, *Tapirus bairdi*

Order Artiodactyla

Mammals with hoofs are **ungulates** (UHNG-yoo-lits). Two main groups of ungulates are characterized by their foot structure and by the presence of either a rumen or a cecum.

Ungulates with an even number of toes are *artiodactyls,* in the order Artiodactyla (AHRD-ee-oh-DAK-tuh-luh). This order includes about 210 species of deer, cattle, giraffes, pigs, and camels. Artiodactyls are native to every continent except Antarctica and Australia. Figure 43-14a shows a common artiodactyl, a caribou. Most artiodactyls can run quickly to escape predators.

Most artiodactyls are herbivores, although pigs are omnivores. Their molars are usually large and flat, for grinding plant material. Most artiodactyls are ruminants, or animals that have a rumen.

Order Perissodactyla

Ungulates with an odd number of toes are *perissodactyls,* in the order Perissodactyla (PUH-ris-oh-DAK-tuh-luh). This order includes about 17 living species, such as horses, zebras, rhinoceroses, and tapirs. Most species are native to Africa and Asia. However, some species of tapirs, such as the one in Figure 43-14b, live in Central and South America. Perissodactyls have a cecum.

Order Cetacea

Closely related to Artiodactyla is the order Cetacea (see-TAY-shuh), members of which are called *cetaceans*. Cetaceans include about 90 species of whales, dolphins, and porpoises worldwide. The orca in Figure 43-15a is an example. Cetaceans have fish-shaped bodies with forelimbs modified as flippers. They lack hind limbs and have broad, flat tails that help propel them through the water.

(a) Killer whale, *Orcinus orca*

(b) Manatee, *Trichechus manatus*

FIGURE 43-15

This orca (a), a cetacean, looks very different from most artiodactyls, but scientists think cetaceans are closely related to artiodactyls. These manatees, or sea cows (b), belong to one of four species of Sirenians. Sirenia may share recent ancestry with Proboscidea.

Cetaceans are totally aquatic but evolved from land-dwelling mammals. They breathe through modified nostrils called *blowholes*. Adult cetaceans lack hair except for a few bristles on the snout. A thick layer of blubber below the skin provides insulation. Cetaceans use echolocation to navigate, communicate, and find prey.

Two subgroups of cetaceans are the toothed whales and baleen whales. Toothed whales include sperm whales, narwhals, dolphins, porpoises, and orcas. Toothed whales can have up to 100 teeth. They prey on fish, squid, seals, and other whales. Baleen whales, such as blue whales, lack teeth and filter food from the water with the baleen attached to the roof of the mouth.

Order Sirenia

Four species of manatees and dugongs (DOO-gawngz) make up the order Sirenia (sie-REE-nee-uh), commonly called the *sirenians*. These large torpedo-shaped herbivores live in tropical seas, estuaries, and rivers. Their front limbs are flippers modified for swimming. Like whales (order Cetacea), sirenians lack hind limbs and have a flattened tail for propulsion. Although manatees and dugongs look like whales, they are more closely related to elephants. The similarities between whales and sirenians came about through convergent evolution. Figure 43-15b shows the only sirenian found in North America, the manatee.

Quick Lab

Comparing Gestation Periods

Materials paper, pencil

Procedure

1. Make a table of gestation periods for different mammals. Make three columns labeled "Mammal," "Gestation period," and "Offspring per pregnancy."
2. Fill in your table with the following data:

Bat, 210 days, 1 offspring
Gerbil, 19–21 days, 4–7 offspring
Horse, 332–342 days, 1 offspring
Monkey, 226–232 days, 1 offspring
Rabbit, 31 days, 3–6 offspring
Squirrel, 44 days, 3 offspring
Whale, 420–430 days, 1 offspring
Wolf, 63 days, 4–5 offspring

Analysis Make a graph that relates gestation length and the number of offspring per pregnancy. Then, propose a hypothesis to explain this relationship.

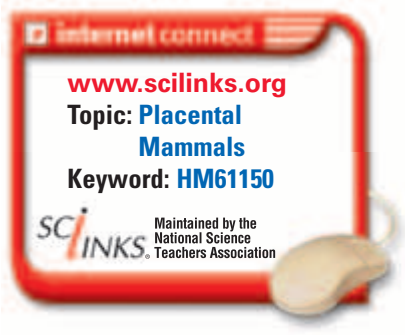
TABLE 43-1 *Minor Orders of Mammals*

Order	Description	Examples
Macroscelidea	ground-dwelling insectivores with long, flexible snouts; 15 species found only in Africa	elephant shrews (not true shrews)
Pholidota	insectivores with protective scales composed of fused hair; resemble reptiles; found in Africa and southern Asia	pangolins or scaly anteaters (not true anteaters)
Tubulidentata	nearly hairless insectivores with piglike bodies and long snouts; found in southern Africa	aardvarks
Scandentia	squirrel-like omnivores that live on ground and in trees; feed on fruit and small animals; found in tropical Asia	tree shrews (not true shrews)
Dermoptera	only two species exist; glide in air using a thin membrane stretched between their limbs; found only in parts of Asia	colugos or flying lemurs (not true lemurs)
Hyracoidea	small rabbitlike herbivores; 7 species found mostly in Africa	hyrax

Order Proboscidea

Members of the order Proboscidea (PROH-buh-SID-ee-uh) have a nose that is modified into a long, boneless trunk, or *proboscis*. The only living species of this order are the Asian elephant and the African elephant, which is the largest living land mammal. Mammoths and mastodons are extinct members of this order. The African elephant can reach 6,000 kg (13,200 lb). To sustain such a large body, an elephant feeds on plants for up to 18 hours a day. The trunk allows an elephant to gather water or gather leaves from high branches. Modified incisors, called *tusks,* efficiently dig up roots and strip bark from branches. Large, jagged molars at the back of the jaw can grow up to 30 cm (1 ft) long and grind plant material.

Elephants have long gestation periods. A calf takes 20 to 22 months to develop. Female elephants can continue to give birth until the age of 70, and elephants can live to be 80 years old.



Other Orders of Placental Mammals

The 12 orders just described include most of the familiar placental mammals. The 6 remaining orders contain just 1 percent of the mammalian species and are summarized in Table 43-1.

SECTION 3 REVIEW

1. Give an example of each from the major orders of mammals.
2. Which continent is a natural home of both monotremes and marsupials?
3. What is unusual about the incisors of rodents?
4. Compare artiodactyls to perissodactyls.
5. Compare manatees to toothed whales.

CRITICAL THINKING

6. **Inferring Relationships** Give an adaptive reason why the pouch of the marsupial mole, a burrowing animal, opens toward the rear of its body.
7. **Applying Information** Why is *flying lemurs* a poor name for members of the order Dermoptera?
8. **Making Comparisons** Cetaceans live in cold ocean waters yet lack fur. Explain this.

SECTION 4

PRIMATES AND HUMAN ORIGINS

To understand human origins, one must understand the relationships of humans to other primates.

OBJECTIVES

- **Identify** traits that distinguish primates from other mammals.
- **Describe** fossil evidence relating humans to primate ancestors.
- **Compare** hypotheses concerning hominid evolution.

VOCABULARY

prehensile appendage
anthropoid primate
opposable thumb
great ape
bipedalism
hominid
australopithecine
human

PRIMATE CHARACTERISTICS

Some people speak of primates as the "highest" mammalian order. However, as Figure 43-16 shows, many primate characteristics are generalized rather than specialized and are similar to features possessed by ancestral mammals. Primate limbs, for example, are most similar to the limbs of the earliest mammals.

Many primate traits are adaptations for living in groups in trees. Examples include strong three-dimensional vision and **prehensile appendages,** or hands, feet, and tails that can grasp. The primate brain, with its large cerebrum, is able to interpret complex visual information and keep track of subtle shifts in social organization.

FIGURE 43-16
Primate characteristics are mostly adaptations for a social life in the trees.

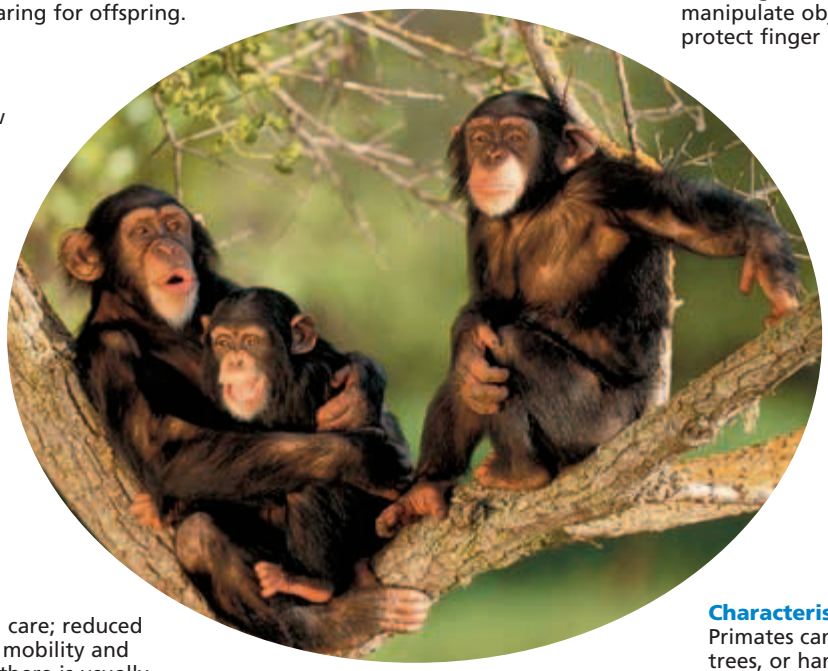
Large brain parts relative to size
Primate brains support complex skills, such as using hands, interpreting visual information, interacting socially, and caring for offspring.

Acute color vision
Forward-facing eyes allow binocular vision, depth perception, and skilled movement in three-dimensional space.

Generalist teeth
The variety of teeth permits herbivorous and omnivorous diets.

Communication
Facial and vocal structure enables broad range of expressions and sounds.

Infant care
Infants require prolonged care; reduced litter size permits greater mobility and attention to each young; there is usually one pair of mammary glands on the chest.



Manual dexterity
Opposable thumbs can touch other four fingers; fingers can grip or manipulate objects; flattened nails protect finger pads.

Social organization
Many primates live in social groups with complex behaviors among members.

Characteristic skeletal structure
Primates can sit upright, cling to trees, or hang from branches; major bones of limbs are like those of earliest mammals, with one upper and two lower bones.

FIGURE 43-17

Anthropoids such as this white-handed gibbon, *Hylobates lar,* have rotating shoulder and elbow joints. This adaptation enables anthropoids to swing by their arms through trees.

Anthropoids

The primate lineages that evolved the earliest include lemurs, lorises, and tarsiers. These groups are sometimes referred to as *prosimians.* The gibbon in Figure 43-17 is one of the **anthropoid primates,** a group that also includes New World monkeys, Old World monkeys, apes, and humans. Anthropoid adaptations include rotating shoulder and elbow joints and an **opposable thumb,** which can touch the other fingers. Anthropoids can hold and manipulate objects precisely, as when a chimpanzee peels a banana or when a student holds a pencil. Nonhuman anthropoids also have grasping feet with an opposable big toe.

Humans, apes, and Old World monkeys have a similar *dental formula,* or number and arrangement of teeth. Each half of the upper and lower mouth includes two incisors, one canine, two premolars, and three molars, as shown in Figure 43-18. Compared to other primates, anthropoids have a more complex brain structure and a larger brain relative to body size.

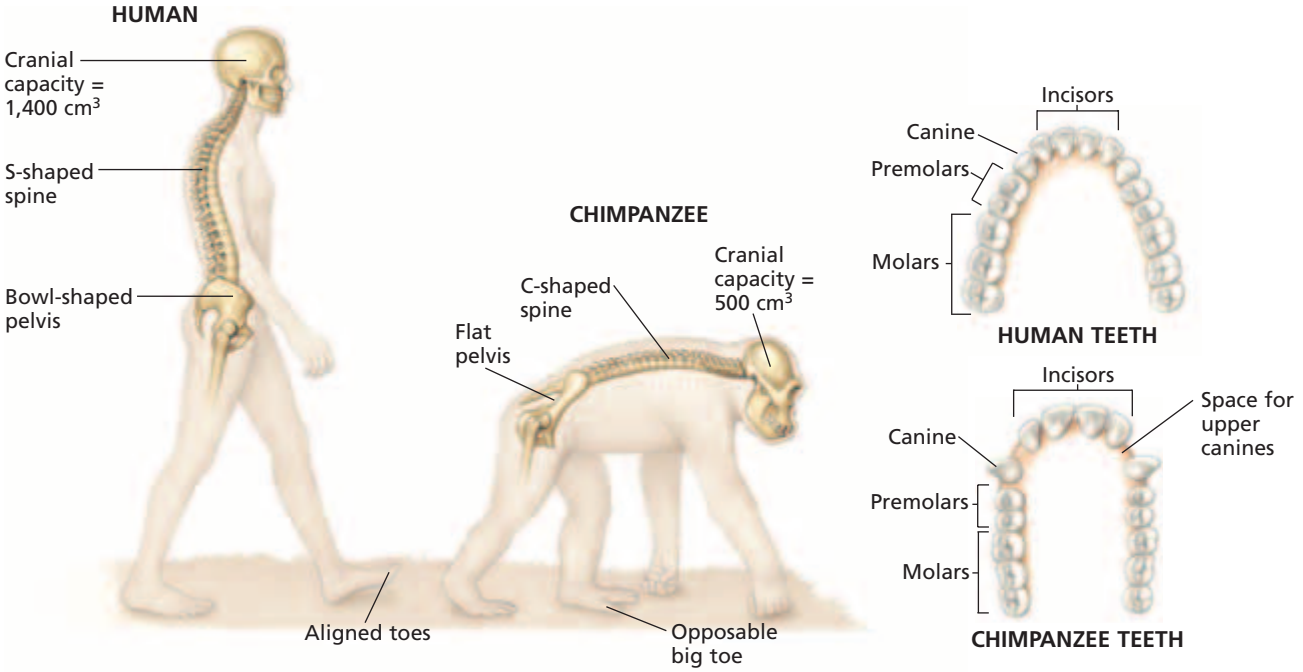
Orangutans, gorillas, chimpanzees, bonobos, and humans make up the **great apes.** Chimpanzee and human DNA is so similar that humans are thought to be more closely related to chimpanzees than to any other living primates. DNA and fossil evidence suggests that humans and chimpanzees share a common ancestor that lived about 6 million years ago. Humans, however, did not descend from chimpanzees. Rather, modern apes and humans both descended from an ancestral apelike species.

FIGURE 43-18

Humans have certain physical traits that differ markedly from those of the chimpanzee, a modern ape: the jaw, pelvis, spine, feet, and toes.

Modern Humans

Among living mammals, only we humans, *Homo sapiens,* have the trait of **bipedalism** (bie-PED'l-IZ-uhm), the tendency to walk upright on two legs. The human skeleton is adapted for bipedalism in several ways, as shown in Figure 43-18.



The bowl-shaped human pelvis supports internal organs during upright walking. The human spine curves in an S shape that allows for upright posture. Human toes are aligned with each other and are much shorter than ape toes. Because humans are the only primates that have this foot structure, the shape of the human foot is likely an adaptation for bipedalism.

The larger brain and smaller jaw in modern humans result in a flatter face than that found in apes. The modern human brain has an average size of about 1,400 cm^3 and the chimpanzee, about 400 cm^3. Among other unique structures, the human brain has extensive areas that function in the production and understanding of speech. Apes have similar areas of their brains that function in communication, and apes can learn to mimic certain forms of human sign language. Apes living in the wild, however, do not use the complexity of signals found in human language.

Word Roots and Origins

anthropoid

from the Greek *anthropos,* meaning "man," and *eidos,* meaning "shape"

Hominids

Hominids include humans and extinct humanlike anthropoid species. Bipedalism is the distinguishing characteristic of this group. All other living anthropoid primates are *quadrupedal,* meaning they tend to walk on all four limbs. Apelike ancestors of the first hominids were probably also quadrupedal. How long ago did the first bipedal hominid evolve? And did human traits such as upright walking and a larger brain evolve together or at different times? Fossil evidence has provided some clues to the answers.

FOSSIL HOMINIDS

Paleontologists and anthropologists (scientists who study humans) have unearthed sufficient fossil evidence to conclude that a variety of humanlike species lived on Earth within the past 10 million years. However, scientists continue to investigate and debate hypotheses about the evolutionary relationships among all known hominids. Even the species name of some fossils is a matter of debate.

One important fossil discovery was made in 1974 in the Afar Valley region of Africa by Donald Johanson and colleagues. The 3.2 million–year-old fossilized skeleton, shown in Figure 43-19, was of an anthropoid primate with the brain size of a chimpanzee. But the skeletal structure clearly showed that this organism was bipedal.

FIGURE 43-19

The original fossil find of *Australopithecus afarensis* consisted of a partial skeleton. The team of investigators who discovered it nicknamed the fossil "Lucy."

Australopithecines

Johanson and colleagues gave the new fossil the species name *Australopithecus afarensis* and the nickname "Lucy." Additional fossils of the same species have been discovered in other parts of Africa and date from about 2.5 million to 4 million years ago. A number of fossil organisms similar to Lucy have been classified as species of the genus *Australopithecus* within the subfamily of **australopithecines** (AW-struh-loh-PITH-uh-SEENZ), which may include other genera.

MANY HOMINID SPECIES

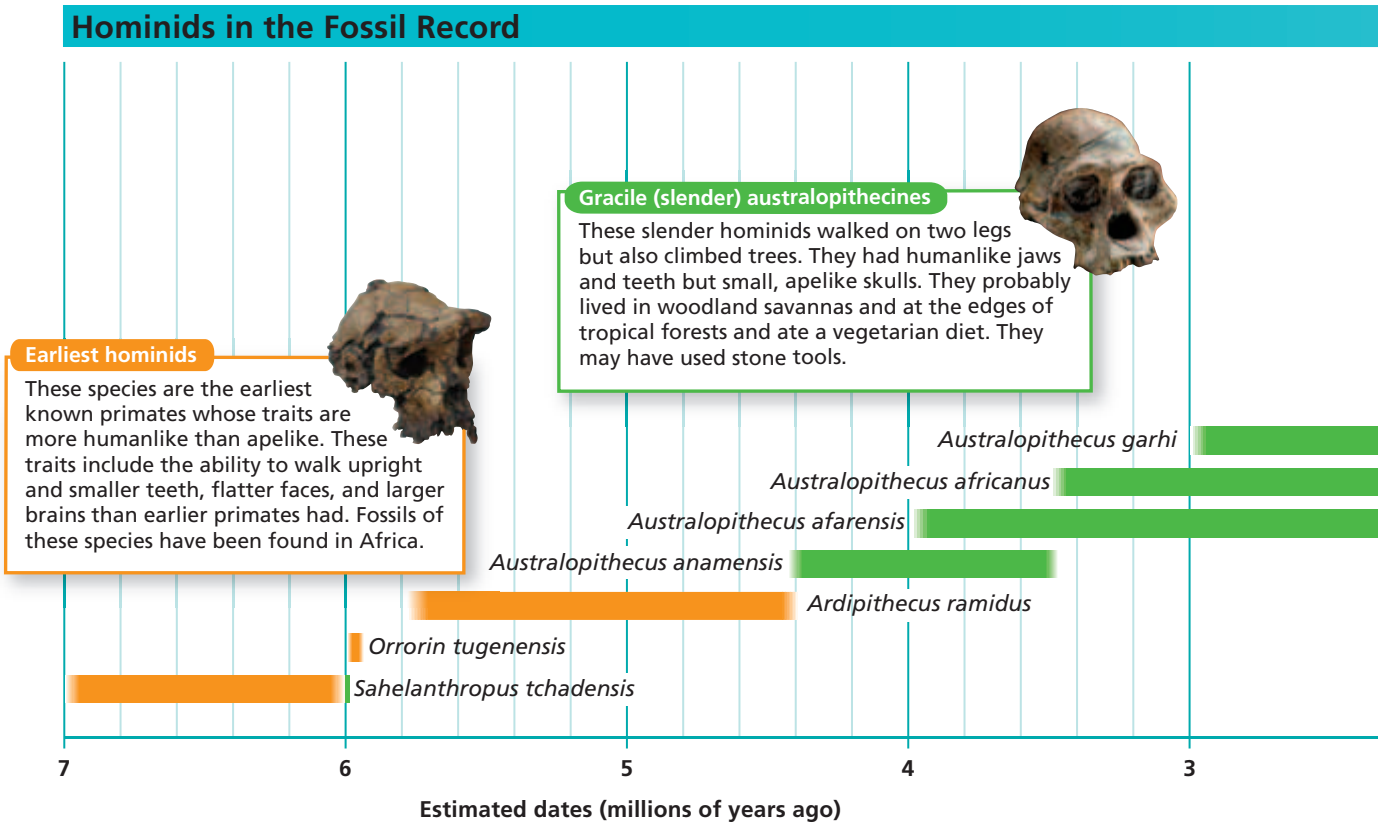
Paleontologists continue to find new hominid fossils. Although the exact classification of some fossils is strongly debated, it is clear that human evolution did not proceed as a single lineage of increasingly humanlike forms. Rather, several hominid forms arose, thrived, and became extinct over the past 7 million years, as shown in Figure 43-20. Furthermore, different species of hominids may have coexisted in time and possibly interacted.

In 1995, Mary Leakey and colleagues at the National Museums of Kenya announced the finding of a new hominid species, *Australopithecus anamensis,* that predated *A. afarensis* (Lucy's species) by about 300,000 years. Like Lucy's species, this species was also similar to a chimpanzee but probably bipedal. A possible descendant of Lucy's species was *A. africanus,* which lived about 2.3 to 3 million years ago. It was taller and heavier than Lucy's species and had a slightly larger brain capacity (430 to 550 cm^3).

Three more-recent species, *A. aethiopicus, A. robustus,* and *A. boisei,* date from about 2.6 million to 1 million years ago. The physical characteristics of these later species suggest that they were a different lineage from *A. afarensis.* For example, they had heavier skulls, larger molars, and generally thicker bodies than Lucy's species did. Their brain capacity ranged from 450 to 600 cm^3. Some scientists call these later hominids *robust australopithecines,* and some scientists place them in the genus *Paranthropus* instead of in the genus Australopithecus.

FIGURE 43-20

Many different species of hominids may have coexisted in time and possibly interacted during the past 7 million years. Scientists continue to find new hominid fossils and debate the exact classification of some fossils. This diagram represents one interpretation of the fossil record.



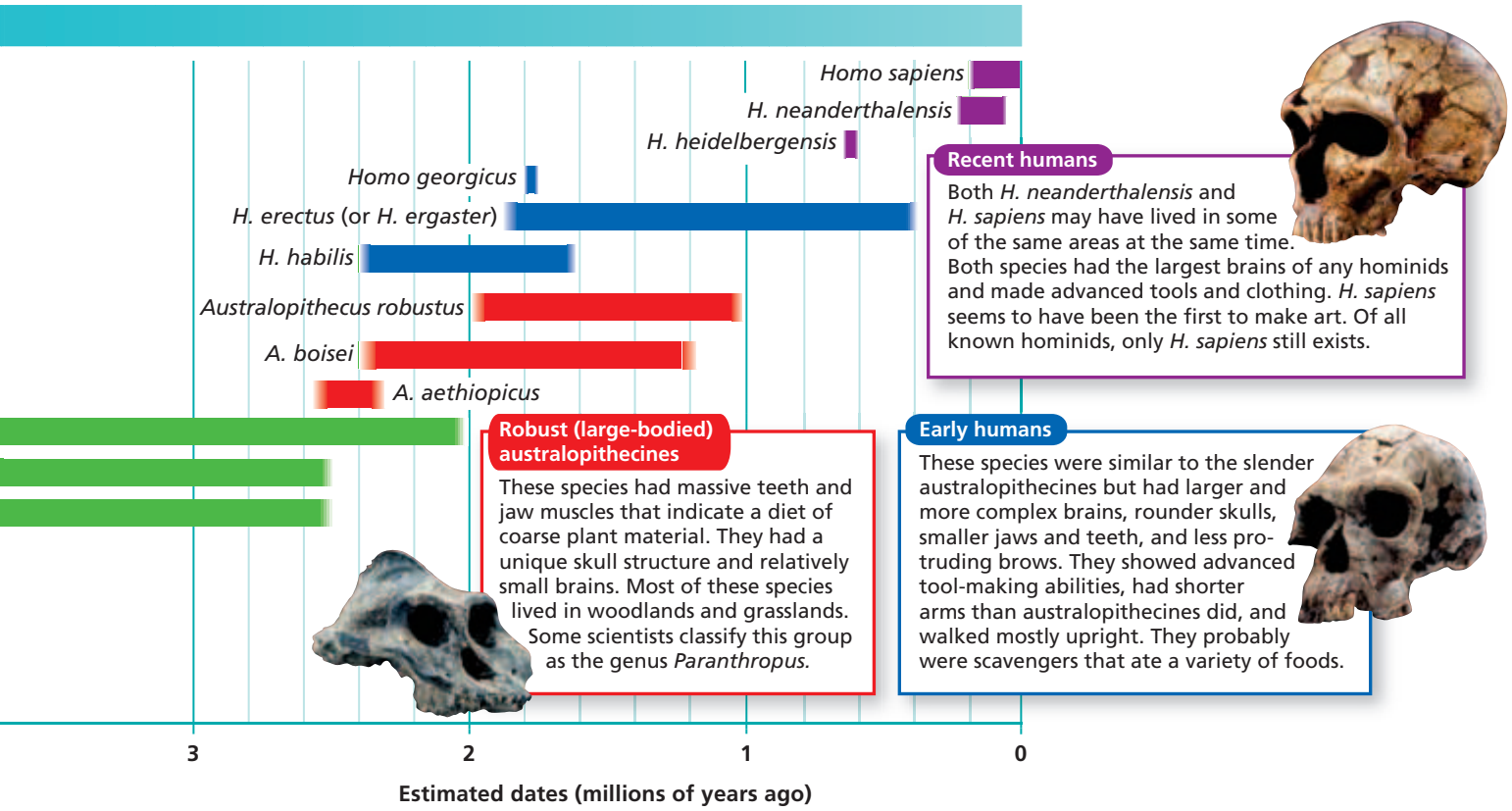
HUMANS

Sometime after the appearance of the australopithecines, new hominids appeared that are classified in the genus *Homo*. Extinct and living members of this genus are called **humans.** Many fossil humans have physical structures that are transitions between those of australopithecines and of modern humans.

Homo habilis and *Homo erectus*

In the early 1960s, scientists in East Africa found a hominid skull whose brain capacity was much larger than the brain capacity of Lucy's species but whose body was not much taller than Lucy's body. Importantly, the new fossils were found along with stone tools. Scientists named the new species *Homo habilis*, the "handy human." Fossils of *H. habilis* are between 1.6 million and 2.5 million years old and have a brain capacity of 590 to 690 cm^3.

Later species, *Homo erectus* (meaning "upright human"), had a brain capacity of 800 to 1,250 cm^3, or about two-thirds that of a modern human. *H. erectus* had a thicker skull, larger brow ridges, a lower forehead, and larger, protruding teeth than modern humans have. Some individuals were as tall as modern humans. Because *H. erectus* fossils have been found on several continents, scientists think that this hominid was the first to travel out of Africa. Charred animal bones indicate that *H. erectus* hunted and cooked its food.



Word Roots and Origins

sapiens

from the Latin *sapere,* meaning "to taste" or "to know"

Homo sapiens and *Homo neanderthalensis*

Neanderthals, a distinctive type of human, lived in Europe and Asia from about 230,000 to 30,000 years ago. They had heavy bones, thick brows, protruding jaws, and brains of about the same size as the brains of modern humans. They lived in caves and made stone scraper tools. The reason for their extinction is an ongoing scientific question. This species had once been classified as a subspecies of *Homo sapiens* but is now mainly classified as *H. neanderthalensis*. Neanderthals may have interacted with *H. sapiens* in some places.

The first humans classified as *H. sapiens* appeared in Africa about 160,000 years ago. The first discovery of *H. sapiens* fossils was in Cro-Magnon cave in France, so some members of *H. sapiens* are referred to as *Cro-Magnons* (KROH-man-YAWNS). Other fossils are known from several continents. The earliest members of *H. sapiens* differed only slightly from modern humans. Their average brain and body size were about the same as modern human's.

As hominid fossils are discovered and studied, scientists revise the classification of some hominid species and debate hypotheses about the possible evolutionary relationship between these species. The ancestry of *H. sapiens* is one such topic of debate.

Modern Humans

How did modern humans come to occupy the entire globe? In one hypothesis, local populations of *H. erectus* gave rise to local populations of *H. sapiens* all over the world. According to this *multiregional hypothesis,* interbreeding among populations was sufficient to keep all of humanity as a single species. In contrast, the *recent-African-origin hypothesis* suggests that *H. sapiens* evolved from *H. erectus* uniquely in Africa about 100,000 to 200,000 years ago, then migrated out of Africa, and populated the globe. An analysis of mitochondrial DNA from people around the world suggests that humans did arise in Africa. It is possible that humans migrated out of Africa more than once. Also, interbreeding among populations around the world would have been possible during and after these migrations.

SECTION 4 REVIEW

1. Identify which characteristics humans share with primates and which are unique to humans.
2. What kind of evidence shows that chimpanzees are the closest living relatives of humans?
3. Identify several traits that differ among the variety of hominids known from fossils.
4. Describe how members of *Homo habilis* differ from australopithecines.
5. Contrast the multiregional hypothesis and the recent-African-origin hypothesis.

CRITICAL THINKING

6. **Analyzing Processes** Propose an explanation of the adaptive value of bipedalism in hominids.
7. **Analyzing Models** Using Figure 43-20, name the hominids that would have coexisted 2 million, 1 million, and 50,000 years ago.
8. **Calculating Information** From the information about hominid brain size and fossil ages in this section, construct a graph of how hominid brain sizes changed with time.

CHAPTER HIGHLIGHTS

SECTION 1 Origin and Evolution of Mammals

- Six key characteristics of mammals are endothermy, a fully divided heart, hair, milk production by females, a single jawbone, and a diversity of complex teeth.
- Mammals belong to an ancient group of animals called *synapsids.* Synapsids have a skull with one opening in a bone behind the eye socket.
- Mammals are probably descended from a subgroup of early synapsids called *therapsids.* Therapsids had legs that were positioned beneath their body and had complex teeth.
- Small mammals first appeared in the Triassic period. Mammals underwent adaptive radiation after the Cretaceous mass extinction of dinosaurs.

Vocabulary

endothermy (p. 861)
mammary gland (p. 861)
synapsid (p. 862)
therapsid (p. 862)
monotreme (p. 863)
oviparous (p. 863)
marsupial (p. 863)
viviparous (p. 863)
placental mammal (p. 863)
placenta (p. 863)

SECTION 2 Characteristics of Mammals

- Mammals are endothermic. Endothermy enables mammals to occupy a range of habitats and sustain strenuous activity. Endothermy requires large amounts of food and oxygen.
- Mammals have a heart with two atria and two ventricles and have large lungs with a large internal surface area.
- Mammals, unlike most vertebrates, chew their food. Mammal teeth include incisors, canines, premolars, and molars.
- Some mammals digest cellulose with the aid of microorganisms. These mammals have either a rumen or a cecum that contains the symbiotic microorganisms.
- Monotremes lay eggs. Marsupials give birth to young that continue development in the mother's pouch. Placental mammals typically develop young within the uterus for longer periods than marsupials do before giving birth.

Vocabulary

diaphragm (p. 865)
incisor (p. 865)
canine (p. 865)
premolar (p. 865)
molar (p. 865)
baleen (p. 865)
rumen (p. 866)
cecum (p. 866)
echolocation (p. 866)

SECTION 3 Diversity of Mammals

- There are at least 26 living orders of mammals. The most ancient orders are Monotremata and seven orders of marsupials. The remaining orders are placental mammals.
- The major placental mammal orders are Xenarthra, Lagomorpha, Rodentia, Primates, Chiroptera, Insectivora, Carnivora, Artiodactyla, Cetacea, Perissodactyla, Sirenia, and Proboscidea.

Vocabulary

pinniped (p. 872)
ungulate (p. 872)

SECTION 4 Primates and Human Origins

- Most primates share several characteristics, including generalized teeth; dental formula; three-dimensional vision; large brains; and grasping hands, feet, and tails.
- Of all living primates, only humans are bipedal. Bipedalism is the defining characteristic of hominids.
- Paleontologists have found many hominid fossils, including a variety of now-extinct australopithecines and humans.
- The multiregional and recent-African-origin hypotheses seek to explain how humans came to occupy the entire globe.

Vocabulary

prehensile appendage (p. 875)
anthropoid primate (p. 876)
opposable thumb (p.876)
great ape (p. 876)
bipedalism (p. 876)
hominid (p. 877)
australopithecine (p. 877)
human (p. 879)

CHAPTER REVIEW

USING VOCABULARY

1. For each pair of terms, explain how the meanings of the terms differ.
   a. *viviparous* and *oviparous*
   b. *septum* and *diaphragm*
   c. *canine* and *molar*
   d. *rumen* and *cecum*
   e. *placenta* and *charion*
   f. *anthropoid primate* and *hominid*
2. Use the following terms in the same sentence: *mammals, synapsids, therapsids,* and *endothermy*.
3. **Word Roots and Origins** The word *incisor* is derived from the Latin *incidere,* which means "to cut into." Using this information, explain why the term *incisor* is a good name for the type of tooth that the term describes.

UNDERSTANDING KEY CONCEPTS

4. **Identify** six key characteristics of mammals.
5. **Relate** the characteristics of therapsids and synapsids to those of mammals.
6. **Relate** the evolution of mammals to the mass extinction of Cretaceous reptiles.
7. **Compare** the costs and benefits of endothermy for mammals.
8. **Explain** how the structure of the mammalian heart supports endothermy.
9. **Describe** the important adaptations of the teeth of mammals.
10. **Compare** the teeth of rodents to those of lagomorphs.
11. **Describe** two mammalian adaptations for digesting plants.
12. **Identify** the part of the brain that is relatively larger in mammals than in other animal groups.
13. **Describe** the distinguishing characteristic of placental mammals.
14. **Give** an example of an animal from each of the 12 orders of placental mammals.
15. **Compare** the characteristics of artiodactyls and perissodactyls.
16. **Compare** sirenians, pinnipeds, and cetaceans.
17. **Describe** the distinguishing characteristics of primates.
18. **Compare** fossil australopithecines with fossil humans.
19. **CONCEPT MAPPING** Use the following terms to create a concept map that compares the process of reproduction in different animal groups: *reptiles, monotremes, marsupials, placental mammals, oviparous, viviparous,* and *placenta*.

CRITICAL THINKING

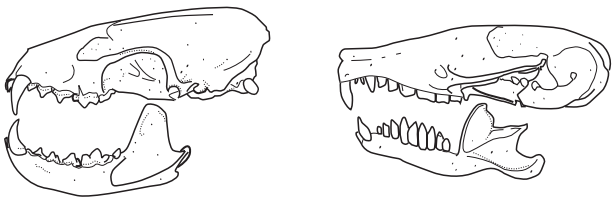
20. **Relating Structure and Function** Mammalian species that live in very cold environments are usually larger than species of the same genus that live in warmer climates. Propose an explanation for this. (Hint: Consider the effect that increasing size has on volume and surface area.)
21. **Analyzing Processes** Some kinds of mice give birth about 21 days after mating. Why might this characteristic make mice ideal laboratory animals for experiments dealing with mammalian development and heredity?
22. **Forming Hypotheses** Sloths are arboreal xenarthrans that spend most of their lives hanging upside down from tree branches as they feed in tropical forests. Most sloths have green algae growing in tiny pits in their hair. What advantage might each species gain from this relationship?
23. **Applying Concepts** In recent years, surgeons have tried transplanting baboon and pig hearts into humans. Explain why surgeons tried these hearts rather than a large turtle's heart.
24. **Analyzing Results** In a famous study conducted 200 years ago, the Italian scientist Lazzaro Spallanzani showed that a blinded bat could still fly and capture insects. However, a bat whose ears had been plugged with wax could neither fly nor hunt. Explain these results.
25. **Interpreting Graphics** Study the two skulls below. Which is more like a mammal skull? Justify your answer.

Standardized Test Preparation

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

1. Which of the following structures is found in all modern mammals and birds?
   - **A.** hair
   - **B.** skull with teeth
   - **C.** lungs with air sacs
   - **D.** heart with four chambers
2. What is the function of a mammalian diaphragm?
   - **F.** enables efficient breathing
   - **G.** provides nourishment for young
   - **H.** carries the young inside the uterus
   - **J.** keeps oxygenated blood separate in heart
3. Which of these animals is a marsupial?
   - **A.** lion
   - **B.** echidna
   - **C.** opossum
   - **D.** duckbill platypus
4. Which of these animals is a monotreme?
   - **F.** zebra
   - **G.** opossum
   - **H.** kangaroo
   - **J.** duckbill platypus
5. Which of the following structures is found in cats but not in opossums?
   - **A.** hair
   - **B.** uterus
   - **C.** placenta
   - **D.** mammary gland

INTERPRETING GRAPHICS: The illustration below shows the skulls of two different mammals. Use the illustration to answer the question that follows.



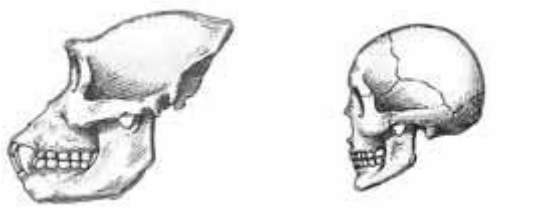
A B

6. What can be inferred about these mammals?
   - **F.** Mammal A has more fat than mammal B.
   - **G.** Mammal A has more hair than mammal B.
   - **H.** Mammal A eats more meat than mammal B.
   - **J.** Mammal A eats more grass than mammal B.

DIRECTIONS: Complete the following analogy.

7. hair : insulation :: milk :
   - **A.** armor
   - **B.** circulation
   - **C.** endothermy
   - **D.** nourishment

INTERPRETING GRAPHICS: The illustration below shows the skulls of two different mammals. Use the illustration to answer the question that follows.



A B

8. Which of the following accurately describes the differences between these skulls?
   - **F.** Skull A has more teeth than skull B does.
   - **G.** Skull A has more brain capacity than skull B does.
   - **H.** Skull A is the skull of a primate, and skull B is not the skull of a primate.
   - **J.** Skull A is the skull of an ape, and skull B is the skull of a human.

SHORT RESPONSE

Mammals and birds are endothermic vertebrates.

Describe the functional costs and benefits of endothermy.

EXTENDED RESPONSE

Scientists classify amniotes from 300 million years ago into two major groups: the diapsids and the synapsids. A unique subset of synapsids from 245 million years ago is made up of therapsids. Modern mammals are grouped into the monotremes, the marsupials, and the placental mammals.

Part A Describe modern scientific hypotheses about the evolutionary relationships among these groups of amniotes.

Part B Describe the kinds of evidence that scientists examine to test these hypotheses.

Test TIP For questions requiring an extended response, make an outline listing the key points of your response before you begin writing.

Examining Mammalian Characteristics

OBJECTIVES

- Observe examples of mammals.
- Examine the distinguishing characteristics of mammals.

PROCESS SKILLS

- observing
- inferring

MATERIALS

- hand lens or stereomicroscope
- microscope slide of mammalian skin
- compound light microscope
- mirror
- selection of vertebrate skulls (some mammalian, some nonmammalian)
- field guide to mammals

Background

1. List the distinguishing characteristics of mammals.
2. Define the term *endothermy.*
3. Mammalian skin is characterized by cutaneous glands, such as sebaceous glands and sweat glands, that develop as ingrowths from the epidermis into the dermis.

PART A Mammalian Hair and Skin

1. Use a hand lens to examine several areas of your skin that appear to be hairless. Record your observations in your lab report.
2. Compare the amount of hair on humans with the amount on other mammals that you have seen or read about. What role does hair or fur play in endothermy? What other roles does hair (or whiskers) play in mammals?
3. Examine a slide of mammalian skin under low power. Notice the glands in the skin.
4. Identify the sebaceous glands and the sweat glands in the skin. Sweat glands are found only in mammals, but some mammals do not have them or have few of them. What mechanism for cooling might these other animals have? Which other glands are unique to mammals?

PART B Mammalian Reproduction

5. Look at the photographs of mammals on this page. Which characteristics do these animals share?
6. Name the two orders of mammals represented in the photographs on this page.

PART C Mammalian Mouth and Teeth

7. Use a mirror to look in your mouth, and identify the four kinds of mammalian teeth. Count how many of each you have on one side of your lower jaw.
8. Look at the skulls of several mammals. Identify the four kinds of teeth in each skull, and count them as you counted your own. How are the four types of teeth different from yours?
9. Look at the skulls of several nonmammalian vertebrates. Describe the teeth in each one, and compare them with mammalian teeth.
10. Breathe through your nose with your mouth closed. Do you feel a flow of air into your mouth? You have a hard palate (the roof of your mouth) that separates your mouth from your nose.
11. Look again at the different skulls. In which vertebrates do you see a hard palate? What is an advantage of having a hard palate?
12. Compare the jaws of the mammalian skulls with those of the nonmammalian skulls. Notice how the upper jawbone and the lower jawbone connect in each skull. Is there a similarity in the mammalian jaws that distinguishes them from the nonmammalian jaws? Explain.
13. Create a data table, similar to the model below, to record your observations for your lab report. For example, the table below is designed to record observations of differences that you will find among the animal skulls. Remember to allow plenty of space to record your observations.

PART D Vertebrate Diversity

14. Use a field guide to find out more about the following mammalian orders: Cetacea, Xenarthra, Pholidota, and Chiroptera. Answer the following questions about these mammals in your lab report:
    a. Cetaceans, such as whales and dolphins, are marine mammals. Cetaceans are hairless except for a few bristles. Why are cetaceans classified as mammals?
    b. Some mammals—including some members of Xenarthra (anteaters and armadillos) and Pholidota (pangolins)—lack teeth. Which characteristics do these animals share with other mammals?
    c. Like many birds, chiropterans (bats) have wings, fly, and are endotherms. Which characteristics distinguish these mammals from birds?

Analysis and Conclusions

1. List the characteristics that distinguish mammals from other vertebrates.
2. List several characteristics you observed that most mammals share.
3. Birds are also endotherms. Which structure in birds serves the same function as hair in mammals? Explain.
4. Compare the data you collected on the teeth from different animal skulls with the diet of each of those animals. How does the type of teeth that it has help with the particular diet that each animal has?

Further Inquiry

Find out how mammalian brains are different from the brains of other vertebrates. What adaptive advantage might these differences provide mammals?

OBSERVATIONS OF ANIMAL SKULLS

Animal	Mammal?	Number of incisors	Number of canines	Number of premolars	Number of molars	Hard palate?	Jaw