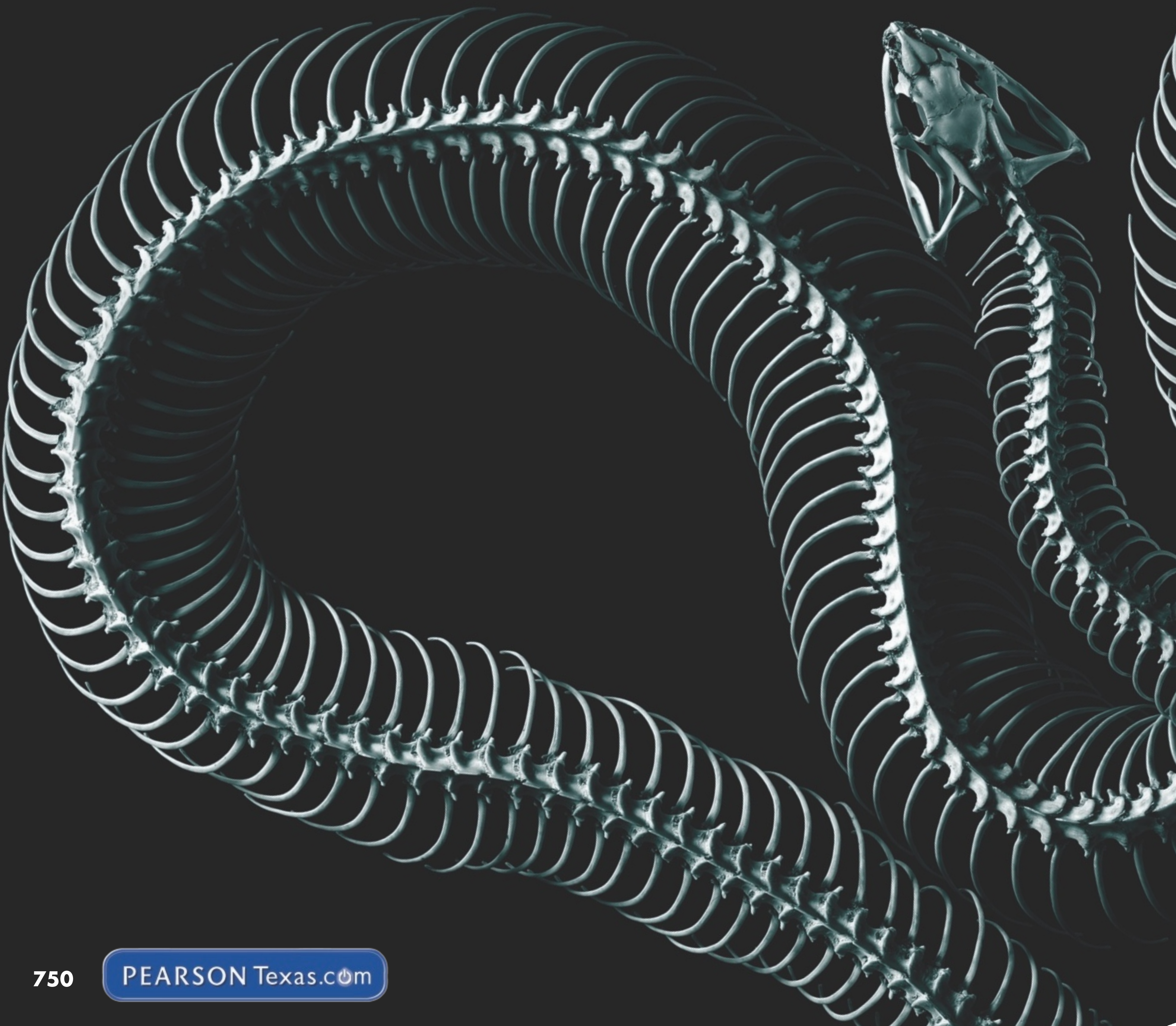
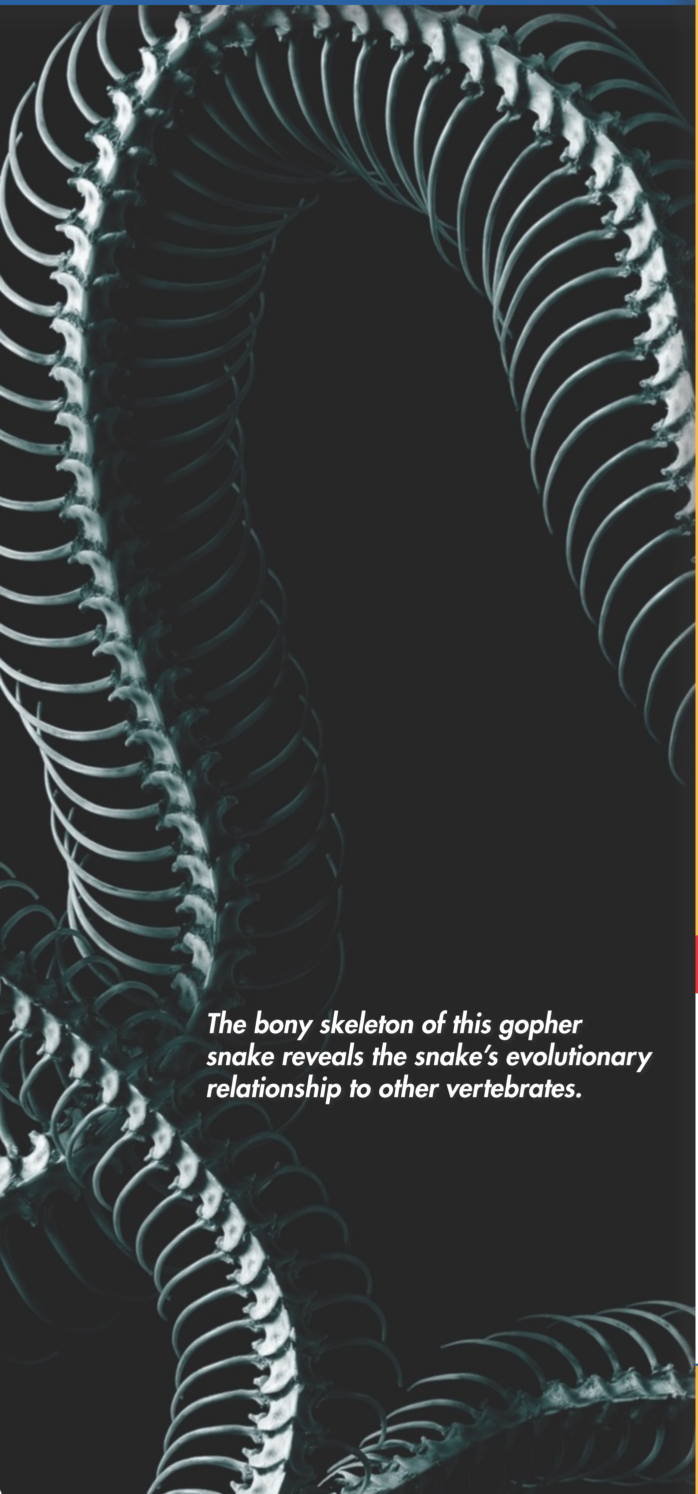
26 Animal Evolution and Diversity





The bony skeleton of this gopher snake reveals the snake's evolutionary relationship to other vertebrates.

FOCUS ON TEKS 7A

CHAPTER MYSTERY

FOSSIL QUEST

To Josh and Pedro, it sounded like a great summer trip: fossil hunting. They would be outside, and the trip would look awesome on college applications. Their parents were okay with the idea—if they stayed within the United States. Both boys liked learning about extinct animals, but for this trip, Josh wanted to search for the very *first* animals. Pedro, on the other hand, loved his pet parakeet, so he wanted to look for the ancestors of birds. But where could they find these fossils . . . and were any sites close enough to satisfy their parents?

Next, they needed to figure out in which periods their target animals lived. Then, they needed to figure out where they could find rocks of the appropriate ages. In this chapter, look for clues to the geologic time periods the boys' target animals might have lived in and where the two boys might expect to find their fossils. Then, solve the mystery.

UntamedScience™

Never Stop Exploring Your World.
Discovering where Josh and Pedro's "Fossil Quest" will take them is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

Texas Essential Knowledge and Skills

READINESS TEKS: 7A Analyze and evaluate how evidence of common ancestry among groups is provided by the fossil record, biogeography, and homologies, including anatomical, molecular, and developmental.

SUPPORTING TEKS: 7B Analyze and evaluate scientific explanations concerning any data of sudden appearance, stasis, and sequential nature of groups in the fossil record. **12B** Compare variations and adaptations of organisms in different ecosystems.

TEKS: 3B Communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials. **3F** Research and describe the history of biology and contributions of scientists.

26.1 Invertebrate Evolution and Diversity

In this lesson you will learn that evidence for invertebrate evolution is provided in the fossil record **(TEKS 7B)**, as well as about the classification of invertebrates **(TEKS 7A)**.

Key Questions

When did the first animals evolve?

What does the cladogram of invertebrates illustrate?

Vocabulary

appendage
larva
trochophore

Taking Notes

Preview Visuals Before you read, preview the cladogram of invertebrates in **Figure 26–3.** Take note of any questions you have about it, and try to answer them as you read.

THINK ABOUT IT Paleontologists have known since Darwin's time that many modern multicellular phyla seemed to appear in the fossil record suddenly during a period called the "Cambrian Explosion." We use the word "suddenly" in the geological sense, because the Cambrian Explosion itself occurred over 15 million years! Also, it looked like an "explosion" because, until recently, few older fossils had been found. That isn't surprising. Earlier animals—the first animals—would have been tiny and composed of soft tissues that are rarely preserved as fossils. So Cambrian life seemed to appear "explosively." But recent discoveries provide fossil evidence that this explosive evolution of multicellular organisms began millions of years earlier, and lasted millions of years longer than originally thought. So the Cambrian explosion was not a single event, but rather a series of events that took place over millions of years.

Origins of the Invertebrates TEKS 7A, 7B

When did the first animals evolve?

All life remained single-celled for roughly 3 billion years after the first prokaryotic cells evolved. We still don't know exactly when the first multicellular animals evolved. Current data support the hypothesis that the first animals evolved from ancestors they shared with living eukaryotes called choanoflagellates (koh AN uh FLAJ uh layts). Choanoflagellates are usually single-celled, but they sometimes grow in colonies. They share several characteristics with sponges, the simplest animals.

Traces of Early Animals Our oldest evidence of multicellular life comes from recently discovered microscopic fossils that are roughly 600 million years old. **The fossil record indicates that the first animals began evolving long before the Cambrian Explosion.** Some of these incredibly well preserved fossils are eggs and embryos, as shown in **Figure 26–1.** Others are parts of sponges and animals similar to jellyfish. Still others are "trace fossils"—tracks and burrows made by animals whose bodies weren't fossilized.

FIGURE 26–1 Fossil Evidence Fossils such as the 565-million-year-old embryo at left are among the rarest and most valuable treasures that the backbreaking work of hunting for microfossils can yield. (SEM 100×)

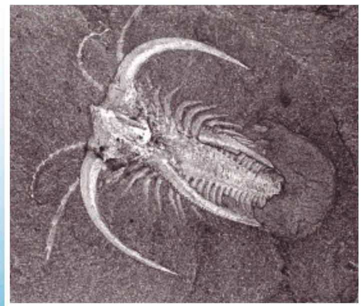
The Ediacaran Fauna Exciting and important fossil evidence of animal life before the Cambrian comes from the Ediacara Hills of Australia. These odd fossils date from roughly 565 to about 544 million years ago. Their body plans differ from those of anything alive today. They show little evidence of cell, tissue, or organ specialization, and no organization into a front and back end. Some may have had photosynthetic algae living within their bodies. Some were segmented and had bilateral symmetry. Some seem to be related to invertebrates such as jellyfishes and worms. Many of the organisms were flat and lived on the bottom of shallow seas.

The Cambrian Explosion Following sequentially in the fossil record after the Ediacaran fauna are fossils from the Cambrian Period, which began about 542 million years ago. Some of the best fossils from the Cambrian Period are found in Chengjiang, China, and in the Burgess Shale of Canada. These fossils show that animals evolved complex body plans, including specialized cells, tissues, and organs, over about 10–15 million years. Many had body symmetry; segmentation; a front and back end; and **appendages,** structures such as legs or antennae protruding from the body. Some Cambrian animals had also evolved shells, skeletons, and other hard body parts that fossilize well. That's one reason why Cambrian fossils are more numerous than, and were discovered before, Ediacaran fossils.

Some early Cambrian fossils represent extinct groups so peculiar that no one knows what to make of them! On the basis of anatomical homologies, however, some Cambrian fossils have been evaluated as ancient members of modern invertebrate phyla, such as the arthropod *Marrella* in **Figure 26–2.** Other Cambrian animals appear to be early chordates, and still others have been classified as mollusks. But this does not mean that we would recognize Cambrian organisms as modern members of these phyla. Many millions of years passed before evolutionary change over many sequential adaptive radiations produced the familiar body structures of modern animals.

Modern Invertebrate Diversity Today, invertebrates are the most abundant animals. They live in nearly every ecosystem, participate in nearly every food web, and vastly outnumber so-called "higher animals," such as reptiles and mammals.

FIGURE 26–2 Cambrian Animals This Cambrian Period fossil of *Marrella splendens* was found in the Burgess Shale in Canada. The illustration shows what *Marrella* and other Burgess Shale animals may have looked like. **Infer** ***Why do scientists have more detailed data on Cambrian animals than they do on pre-Cambrian animals?***



Cladogram of Invertebrates TEKS 7A, 7B

What does the cladogram of invertebrates illustrate?

Major clades of living invertebrates are shown in **Figure 26–3.** **This cladogram shows current hypotheses about the sequential nature of, and evolutionary relationships among major living invertebrate groups. This branching, hierarchical classification system, based on similarities and differences shared among groups, also indicates the sequence in which some important features evolved.** These features include body symmetry, cephalization, segmentation, and formation of a coelom. Many of these features evolved in Cambrian animals.

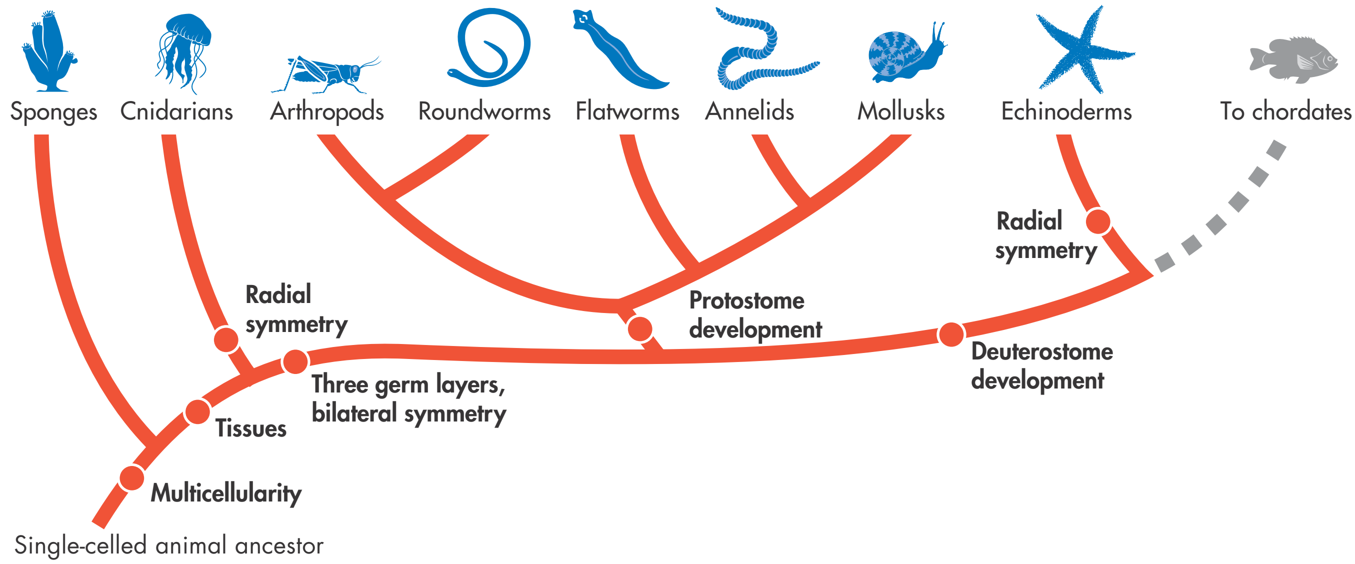
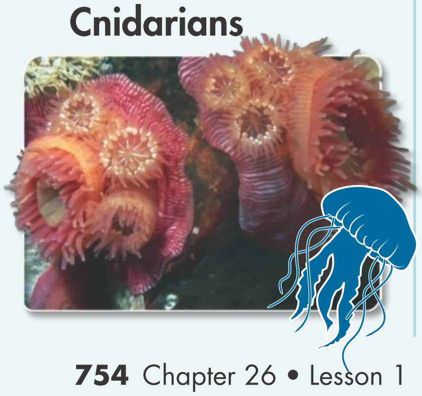
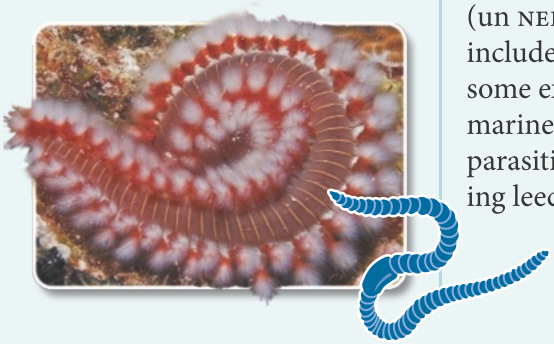
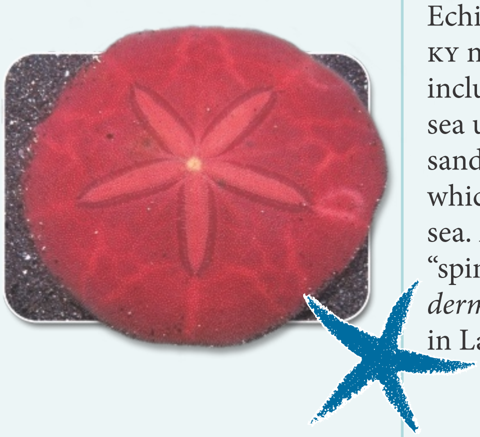


FIGURE 26–3 Cladogram of Invertebrates This diagram shows current hypotheses of evolutionary relationships among major groups of animals. During the course of evolution that produced these different groups, important traits evolved. These are shown by the red circles. Note that the nonvertebrate chordates, which you will learn about in the next lesson, are not shown. Also, note that invertebrates do not form a clade.

INVERTEBRATE	PHYLUM	DESCRIPTION
Sponges 	Sponges are members of the phylum Porifera (por IHF er uh), which means “pore bearers” in Latin, reflecting the fact that they have tiny openings, or pores, all over their bodies.	Sponges are classified as animals because they are multicellular, heterotrophic, lack cell walls, and contain a few specialized cells. Sponges are the most ancient members of the kingdom Animalia and are among the simplest organisms to be placed in the clade Metazoa, with all other multicellular animals.
Cnidarians 	Jellyfishes, sea fans, sea anemones, hydras, and corals are all members of the phylum Cnidaria (ny DAYR ee uh).	Cnidarians are aquatic, soft-bodied, carnivorous, radially symmetrical animals with stinging tentacles arranged in circles around their mouths. Some, such as corals, have skeletons. They are the simplest animals to have body symmetry and specialized tissues. Some cnidarians live as independent individuals. Others live in colonies composed of many individuals.

INVERTEBRATE	PHYLUM	DESCRIPTION
Arthropods 	Members of the phylum Arthropoda (ahr THRAHP oh duh) include spiders; centipedes; insects; and crustaceans, such as crabs. *Arthron* means "joint" in Greek, and *podos* means "foot."	Arthropods have bodies divided into segments, a tough external skeleton called an exoskeleton, cephalization, and jointed appendages. Arthropods appeared in the sea about 600 million years ago and have since colonized freshwater habitats, the land, and the air. At least a million species have been identified—more than three times the number of all other animal species combined!
Nematodes (Roundworms) 	Members of the phylum Nematoda range in size from microscopic to 1 meter in length.	Nematodes, or roundworms, are unsegmented worms with pseudocoeloms, specialized tissues and organ systems, and digestive tracts with two openings—a mouth and an anus. Some are free-living and inhabit soil or various aquatic habitats. Others are parasites that infect a wide range of plants and animals, including humans. Nematodes were once thought to be closely related to flatworms, annelids, and mollusks but have been found to be more closely related to arthropods.
Flatworms 	The phylum Platyhelminthes (plat ih hel MIN theez) contains the flatworms	Flatworms are soft, unsegmented, flattened worms that have tissues and internal organ systems. They are the simplest animals to have three embryonic germ layers, bilateral symmetry, and cephalization. Most flatworms are no more than a few millimeters thick. Flatworms do not have coeloms.
Annelids 	The phylum Annelida (un NEL ih duh) includes earthworms, some exotic-looking marine worms, and parasitic, bloodsucking leeches.	Annelids are worms with segmented bodies and a true coelom lined with tissue derived from mesoderm. The name Annelida is derived from the Latin *annellus*, which means "little ring." The name refers to the ringlike appearance of the body segments of annelids.

INVERTEBRATE	PHYLUM	DESCRIPTION
Mollusks 	The phylum Mollusca includes snails, slugs, clams, squids, and octopi.	Mollusks are soft-bodied animals that typically have an internal or external shell. Like annelids, mollusks have true coeloms surrounded by mesoderm. They also have complex organ systems. Why are animals as different-looking as snails, clams, and squid in the same phylum? One answer lies in the behavior of their **larvae** (singular: larva), or immature stages. Many mollusks have a free-swimming larval stage called a **trochophore** (TRAHK oh fawr). The trochophore is also characteristic of many annelids, indicating that annelids and mollusks are closely related.
Echinoderms 	The phylum Echinodermata (ee KY noh durm aht uh) includes sea stars, sea urchins, and sand dollars, all of which live only in the sea. *Echino-* means "spiny" in Greek, and *dermis* means "skin" in Latin.	Echinoderms have spiny skin and an internal skeleton. They also have a water vascular system—a network of water-filled tubes that include suction-cuplike structures called tube feet, which are used for walking and for gripping prey. Most adult echinoderms exhibit five-part radial symmetry. The skin of an echinoderm is stretched over an internal skeleton of calcium carbonate plates. Although radial symmetry is characteristic of simpler animals such as cnidarians, echinoderms are more closely related to humans and other chordates because they are deuterostomes.

26.1 Review Key Concepts TEKS 7B

1. a. Review What was the Cambrian Explosion?

b. Explain When does fossil evidence indicate that the first animals evolved?

c. Relate Cause and Effect What two characteristics of early animals explain the scarcity of animal fossils older than the Cambrian Period?

2. a. Review What is a cladogram?

b. Explain What does the cladogram of invertebrates show?

c. Sequence Which body plan feature evolved first—radial symmetry or deuterostome development?

VISUAL THINKING

3. Design a "new" invertebrate. Create an illustration on which you point out its body plan features. Then, show its place on the cladogram of invertebrates, and write a caption explaining how its features helped you decide where it belongs.

26.2 Chordate Evolution and Diversity

In this lesson you will learn about the evolution of chordates as shown in the fossil record **(TEKS 7B)**, as well as the evidence that shows how chordates are related **(TEKS 7A)**. You will also learn about adaptations chordates evolved that allow them to live in different ecosystems **(TEKS 12B)**. Also covered: **TEKS 12F**

Key Questions

What are the most ancient chordates?

What can we learn by studying the cladogram of chordates?

Vocabulary

cartilage
tetrapod

Taking Notes

Venn Diagram Construct a Venn diagram comparing and contrasting nonvertebrate chordates and vertebrates.

THINK ABOUT IT Fishes, amphibians, reptiles, birds, and mammals look very different. Some have feathers, others have fins. Some fly, others swim or crawl. Biologists use some of these differences to classify these animals into clades within the larger clade in which humans are placed—Chordata.

Origins of the Chordates TEKS 7A, 7B

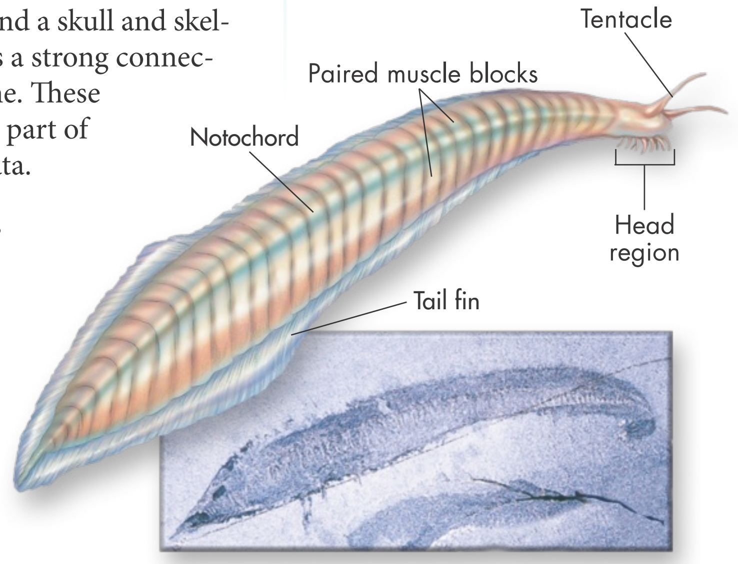
What are the most ancient chordates?

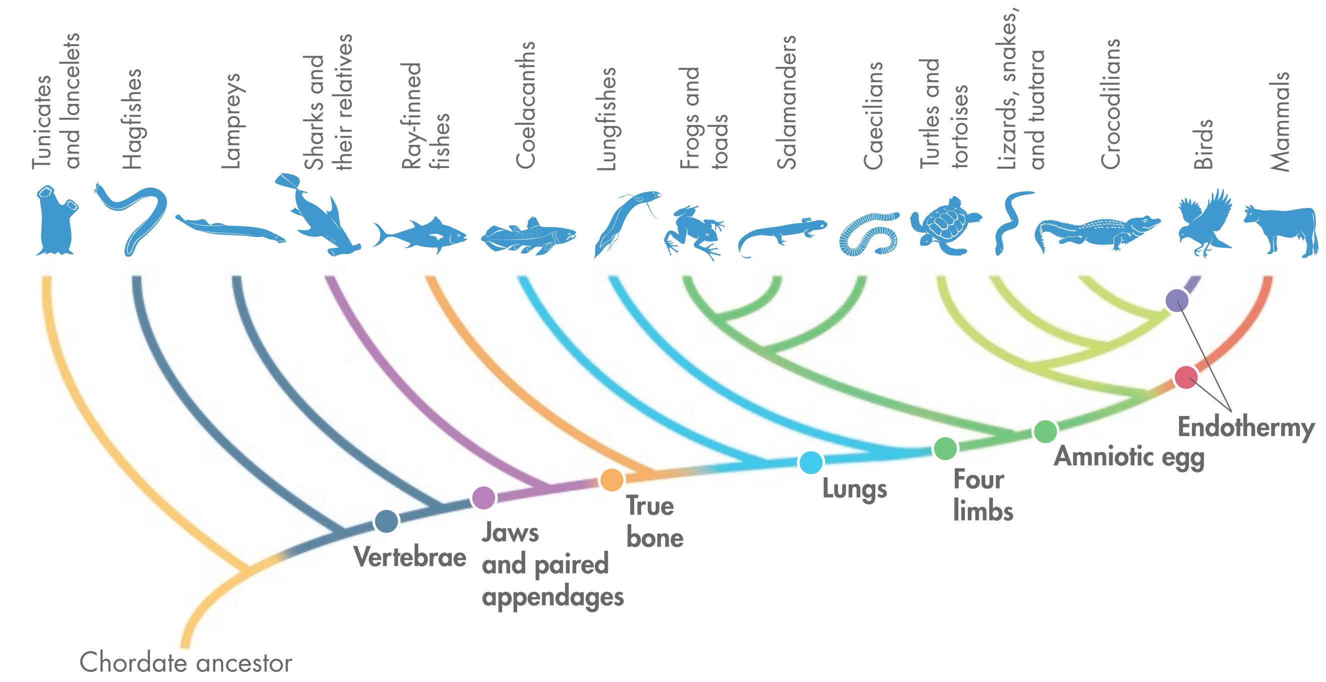
Chordates are the animals we know best because they are large (as animals go), often conspicuous, and strike us as beautiful, impressive, cute, or frightening. Some we keep as pets, others many of us eat. What combination of shared characteristics and evolutionary history unite us all?

The Earliest Chordates What were the earliest chordates like? **Embryological studies suggest that the most ancient chordates were related to the ancestors of echinoderms.** The rich Cambrian fossil deposits that record invertebrate history also include some early chordate fossils, such as *Pikaia* (pih KAY uh), shown in **Figure 26–4.** When *Pikaia* was first discovered, it was thought to be a worm. Then scientists determined that it had a notochord and paired muscles arranged in a series, like those of simple modern chordates. In 1999, fossil beds from later in the Cambrian Period yielded specimens of *Myllokunmingia* (MY loh kuhn min jee uh), the earliest known vertebrate. These fossils show muscles arranged in a series, traces of fins, sets of feathery gills, a head with paired sense organs, and a skull and skeletal structures likely made of cartilage. **Cartilage** is a strong connective tissue that is softer and more flexible than bone. These characteristics are shared—during at least at some part of the life cycle—by all members of the clade Chordata.

Modern Chordate Diversity Modern chordates consist of six familiar groups: the nonvertebrate chordates and five groups of vertebrates—fishes, amphibians, reptiles, birds, and mammals. About 96 percent of all living chordate species are vertebrates. Among vertebrates, fishes are the largest group by far. Yet, today's chordate species are only a small fraction of the total number of chordates that have existed over time.

FIGURE 26–4 *Pikaia*, an Early Chordate *Pikaia* is the earliest chordate known from the fossil record. **Classify** *Which chordate characteristics did* Pikaia *possess?*





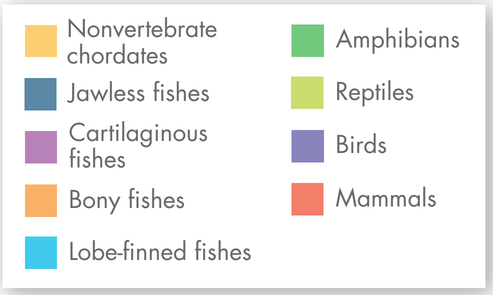


FIGURE 26–5 Cladogram of Chordates The phylum Chordata includes both vertebrates and nonvertebrate chordates. All groups (clades) share a common invertebrate ancestor. This cladogram shows current hypotheses about the evolutionary relationships among living chordate groups. The different colored lines represent the traditional groupings of these animals, as listed in the key. The circles indicate the evolution of some important chordate adaptations.

Cladogram of Chordates

TEKS 7A, 7B, 12B, 12F

What can we learn by studying the cladogram of chordates?

The hard body structures of many chordates fossilize well, so there is an excellent fossil record of chordate evolutionary history. **The cladogram of chordates presents current hypotheses about evolutionary relationships among chordate groups. It also shows the sequence in which important vertebrate features evolved.** The cladogram of chordates is shown in **Figure 26–5.**

The circles (nodes) in the cladogram represent the appearance of certain adaptive features during chordate evolution. Each time a new adaptation evolved in chordate ancestors, a major adaptive radiation occurred. One notable adaptation, for example, was the development of jaws, which jump-started the adaptive radiation of jawed fishes—now the most diverse chordate group. Other important adaptations include the development of true bone and paired appendages. Refer to the geologic time scale in Chapter 19 as you read about the evolutionary history of chordates.

Nonvertebrate Chordates Two chordate groups lack backbones. These nonvertebrate chordates are tunicates and lancelets. Fossil evidence from the Cambrian Period suggests that the ancestors of living nonvertebrate chordates diverged from the ancestors of vertebrates more than 550 million years ago. Adult tunicates (subphylum Urochordata) look more like sponges than like other chordates. They have neither a notochord nor a tail. But their larval forms have all key chordate characteristics. The small, fishlike lancelets (subphylum Cephalochordata) live on the sandy ocean bottom.

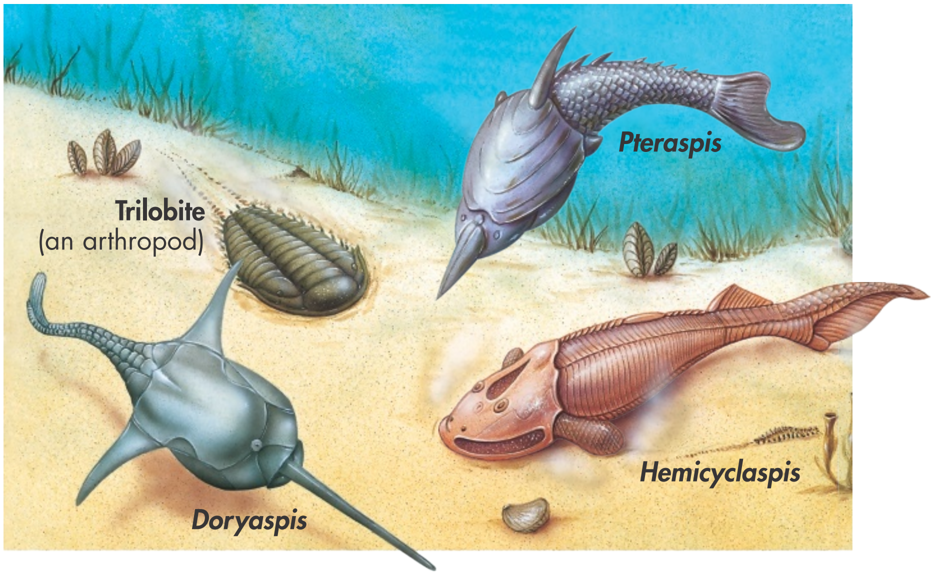


FIGURE 26–6 Ancient Jawless Fishes Ancient jawless fishes, some of which were armored, such as those shown here, lived during the early Devonian Period. Since they lacked jaws, they were limited in their ability to feed and defend themselves. Paired fins, however, gave these fishes control over their movement, and the lineage led to today's hagfishes and lampreys.

Jawless Fishes The earliest fishes appeared in the fossil record during the late Cambrian Period, about 510 million years ago. These odd-looking creatures had no true jaws or teeth, and their skeletons were made of cartilage. During the Ordovician and Silurian periods fishes had a major adaptive radiation. The products of this radiation ruled the seas during the Devonian Period, also called the Age of Fishes. Some armored jawless fishes, such as those in **Figure 26–6,** became extinct at the end of the Devonian, about 360 million years ago. Two other ancient clades of jawless fishes gave rise to the two clades, sometimes called classes, of modern jawless fishes: lampreys and hagfishes.

Lampreys and hagfishes both lack vertebrae and have notochords as adults. (They do have parts of what could be called a skull, which is one of the reasons they are still classified as vertebrates.) Lampreys are filter feeders as larvae and parasites as adults. Hagfishes have pinkish gray, wormlike bodies, secrete incredible amounts of slime, and tie themselves into knots!

Sharks and Their Relatives Other ancient fishes evolved a revolutionary feeding adaptation: jaws. Jaws hold teeth and muscles, which make it possible to bite and chew plants and other animals.

Early fishes also evolved paired pectoral (anterior) and pelvic (posterior) fins. These fins were attached to limb girdles, which are supporting structures made of cartilage or bone. Paired fins offered more control of body movement, while tail fins and powerful muscles gave greater thrust.

These adaptations launched the adaptive radiation of the class Chondrichthyes (kahn DRIK theez): the sharks, rays, and skates. The Greek word *chondros* means "cartilage," the tissue that makes up the skeletons of these "cartilaginous" fishes. There are hundreds of species of modern sharks, skates, and rays, ranging from predatory carnivores, such as the great white shark in **Figure 26–7,** to shy plankton feeders.

Online Journal *How did the evolution of paired fins help early fishes succeed in their environments?*

FIGURE 26–7 Jaws Though about 360 million years separate *Dunkleosteus* (fossil, top) and today's great white shark (bottom), you can easily see the important adaptation they have in common—jaws. But *Dunkleosteus* could have bitten "Jaws" the shark in half! **Pose Questions** ***What question would you ask a researcher about* Dunkleosteus?**

FIGURE 26–8 Bony Fishes Bony fishes, such as the perch this skeleton once belonged to, have skeletons made of true bone.
Compare and Contrast *List two ways that bony fishes differ from the fishes in Figure 26–6.*

Bony Fishes Another group of ancient fishes evolved skeletons made of hard, calcified tissue called true bone. This launched the radiation of the class Osteichthyes (ahs tee IK theez), the bony fishes. You can see the skeleton of a modern bony fish in **Figure 26–8.** Most modern bony fishes belong to a huge group called ray-finned fishes.

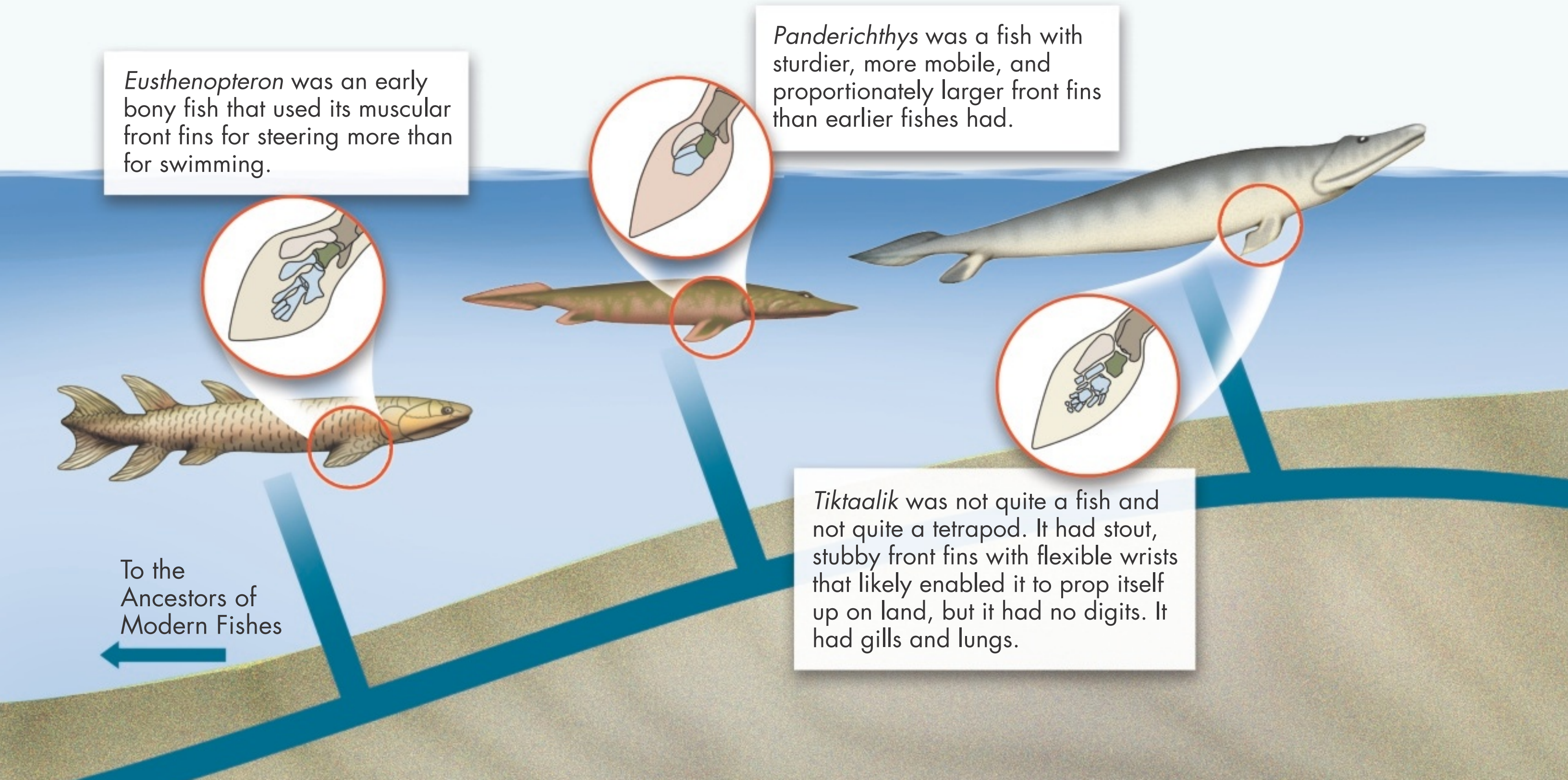
▶ ***Ray-Finned Fishes*** Ray-finned fishes are aquatic vertebrates with skeletons of true bone; most have paired fins, scales, and gills. The name "ray-finned" refers to bony rays connected by a layer of skin to form fins. The fin rays support the skin much as the thin rods in a handheld folding fan support the webbing of the fan. Most fishes you are familiar with, such as eels, goldfish, and catfish, are ray-finned fishes.

▶ ***Lobe-Finned Fishes*** Lobe-finned fishes are a different group of bony fishes that evolved fleshy fins supported by larger, more substantial bones. The few modern fishes that are descendants of ancient lobe-finned fishes include lungfishes and coelacanths (SEE luh kanths). Another group of ancient lobe-finned fishes evolved into the ancestors of four-limbed vertebrates, or **tetrapods.**

VISUAL SUMMARY

FROM FINS TO FEET

FIGURE 26–9 The cladogram shows a few of the animal groups in the evolution of the feet of tetrapods from the fins of ancient bony fish. All of the illustrated animal groups are extinct.



Amphibians The word *amphibian* means "double life," because most amphibians live in water as larvae but on land as adults. Most amphibians also require water for reproduction, breathe with lungs as adults, have moist skin with mucous glands, and lack scales and claws.

▶ ***The Unique "Fishapod"*** The general story of amphibian evolution has been known for years. Several fossils indicate that various lines of lobe-finned fishes sequentially evolved sturdier and sturdier appendages, which resembled the limbs of tetrapods. In recent years, a series of spectacular transitional fossils has filled in the details, as shown in **Figure 26–9.** One of these is *Tiktaalik* **(Figure 26–10).** An evaluation by its discovers noted that *Tiktaalik* has such a mix of fish and tetrapod features that it could be called a "fishapod"—part fish, part tetrapod.

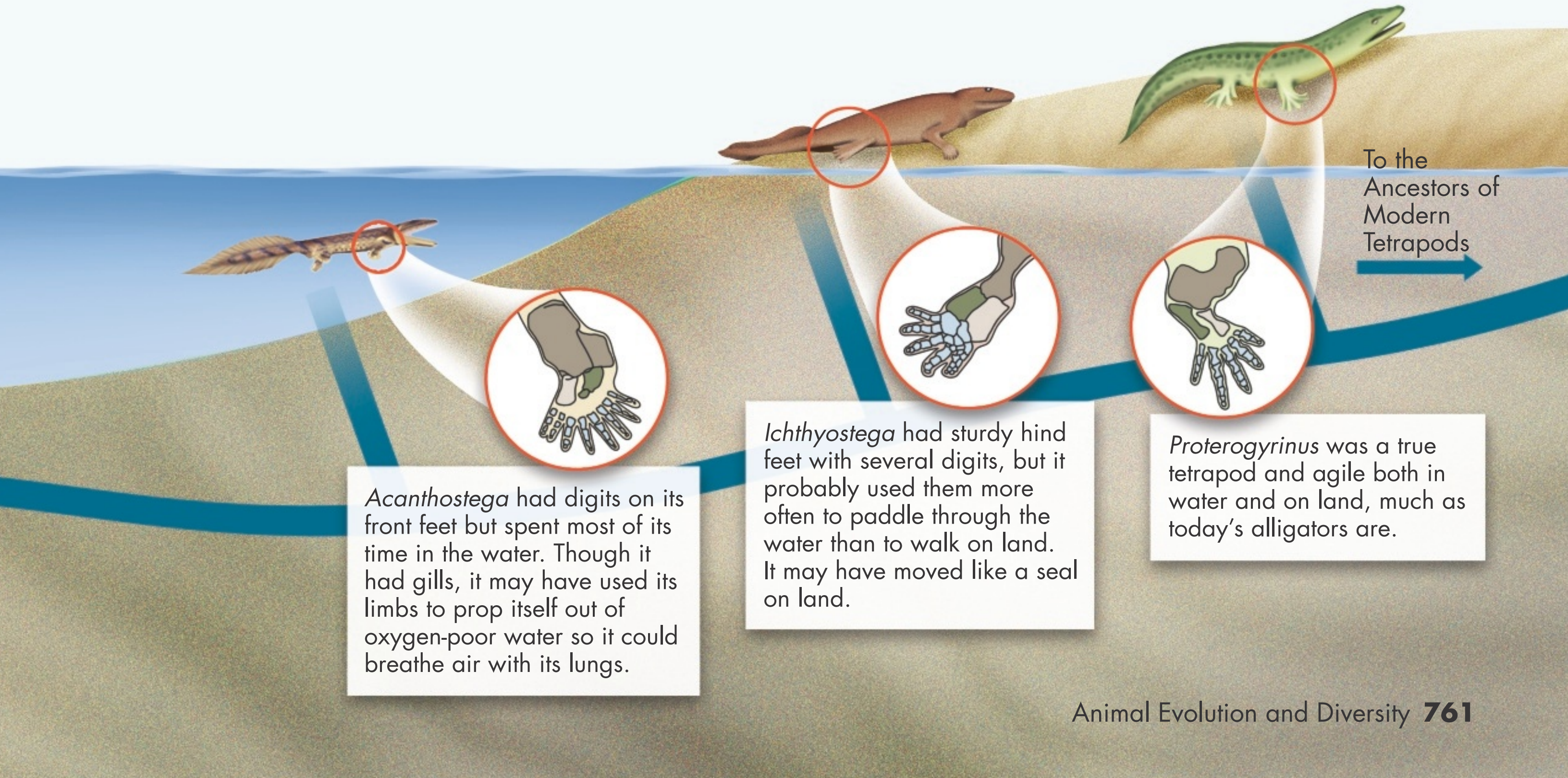
▶ ***Terrestrial Adaptations*** Evaluating the fact that these amphibians were the first tetrapods to appear in the fossil record, the judgment of paleontologists is that they were the ancestors of other vertebrate groups that appeared sequentially, including reptiles, birds, and mammals. Early amphibians also evolved ways to breathe air and protect themselves from drying out, as you will read in Chapters 27 and 28. These adaptations to terrestrial ecosystems fueled another adaptive radiation. Amphibians became the dominant vertebrates of the warm, swampy Carboniferous Period, about 359 to 300 million years ago. But this success didn't last. Climate changes caused many low, swampy habitats to disappear. Most amphibian groups became extinct by the end of the Permian Period, about 250 million years ago. Only three orders of amphibians survive today—frogs and toads, salamanders, and caecilians (see SIL ee unz).

Online Journal *Explain how the climate changes of the Permian Period could have caused the decline of amphibians.*

BUILD Vocabulary

WORD ORIGINS The word **tetrapod** comes from the Greek words "tetra," meaning *four*, and "pod," meaning *foot*.

FIGURE 26–10 ***Tiktaalik*, the Fishapod** The 375-million-year-old *Tiktaalik* fossil was discovered in Canada in 2004. It is considered a transitional fossil because it shows features of both tetrapods and the fish they evolved from—fins *with* wrist bones; gills *and* lungs. *Tiktaalik* could swim and breathe underwater like a fish OR crawl and breathe out of water like a tetrapod, so its discoverers called it a "fishapod."



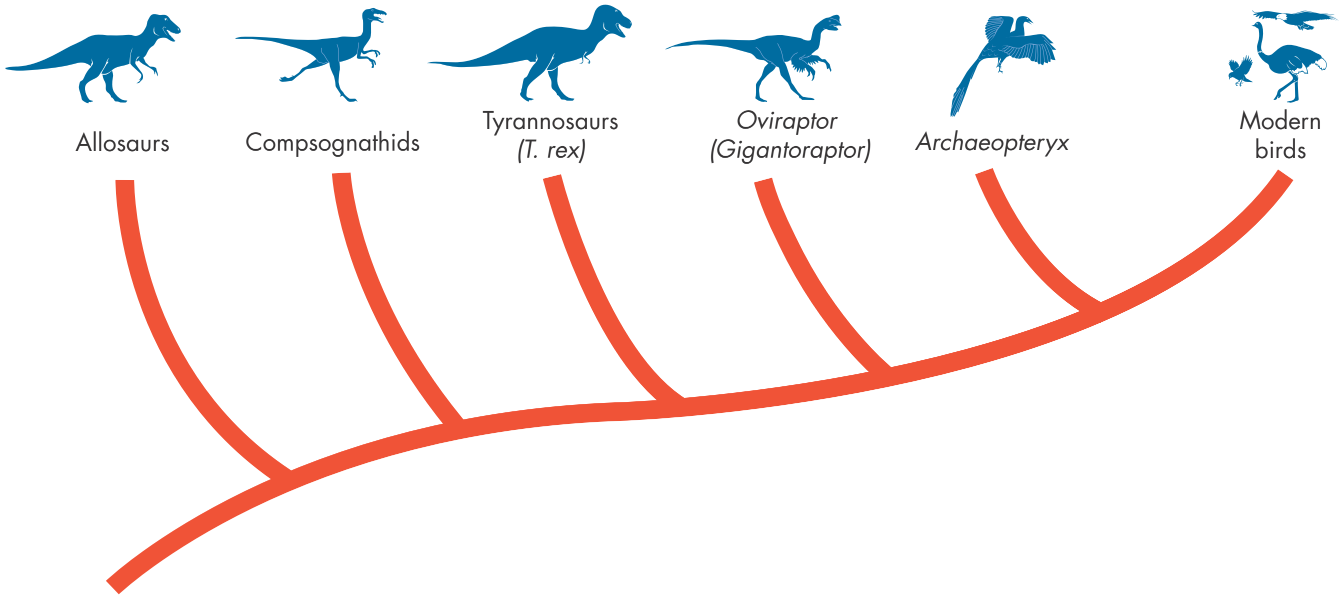


FIGURE 26–11 Evolution of Reptiles (including Birds) The diagram shows current hypotheses about the evolutionary relationships between living and extinct reptiles. None of the groups shown are direct ancestors of modern reptiles or modern birds.

Reptiles Reptiles evolved from ancient amphibians that continued to evolve adaptations to drier conditions. Reptiles have dry, scaly skin, well-developed lungs, strong limbs, and shelled eggs that do not develop in water. Living reptiles are represented by four groups: lizards and snakes, crocodilians, turtles and tortoises, the tuatara (too uh TAH ruh), and birds.

The first known reptile fossil dates back to the Carboniferous Period, 350 million years ago. As the Carboniferous ended and the Permian Period began, Earth's climate became cooler and less humid. Many lakes and swamps dried up. The first great adaptive radiation of reptiles began, as these animals evolved adaptations in response to environmental change to drier conditions. By the end of the Permian, about 250 million years ago, many diverse reptiles roamed Earth. The cladogram in **Figure 26–11** shows current hypotheses about the relationships between living and extinct reptiles.

▶ ***Enter the Dinosaurs*** A great adaptive radiation of reptiles continued through the Triassic and Jurassic periods. Dinosaurs lived all over the world, and they ranged from small to enormous. They were diverse in appearance and in habit: Some, such as *Plateosaurus,* ate leafy plants; others, such as *Coelophysis,* were carnivorous. Duckbilled *Maiasaura* lived in family groups and cared for eggs and young. Some dinosaurs even had feathers, which may have first evolved as a means of regulating body temperature. The evolutionary lineage that led to modern birds came from one group of feathered dinosaurs.

▶ ***Exit the Dinosaurs*** At the end of the Cretaceous Period, about 66 million years ago, a worldwide mass extinction occurred. According to current hypotheses, this extinction was probably caused by a combination of natural disasters, including massive and widespread volcanic eruptions, a fall in sea level, and a huge asteroid smashing into what is now the Yucatán Peninsula in Mexico. That collision produced forest fires and dust clouds. These environmental changes reduced ecosystem stability and led to the extinction of most dinosaurs, along with many other animal and plant groups on land and in the sea.

Birds Birds, once considered to form a class (Aves) separate from the class Reptilia, are now recognized as members of a larger clade that includes birds and all their reptilian ancestors and relatives. Today's birds, which can regulate their internal body temperature, are extremely diverse. Birds have feathers; strong, lightweight bones; two legs covered with scales that are used for walking or perching; and front limbs modified into wings.

▶ ***Bird Roots*** Evaluations of recent fossil discoveries support the hypothesis that today's birds share common ancestry with a group of birdlike dinosaurs. The first birdlike fossil discovered was *Archaeopteryx* (ahr kee AHP tur iks), from the late Jurassic Period, about 150 million years ago. *Archaeopteryx* looked so much like a small, running dinosaur that it would be classified as a dinosaur except for its highly evolved feathers. You can see a fossil and an artist's conception of *Archaeopteryx* in **Figure 26–12.** A whole series of recently discovered, well-preserved ancient birds and feathered dinosaurs has "connected the dots" between modern birds and their dinosaur ancestors.

▶ ***Bird Classification*** Recall, that a clade is a branch of a cladogram that includes a single common ancestor and all descendants of that ancestor. If you look back at **Figure 26–11,** you will see that recognizing birds as descendants of dinosaurs changes their classification. Modern birds alone, the traditional class Aves, form a clade within the clade containing dinosaurs. And because the clade containing dinosaurs is part of a larger clade of reptiles, modern birds are also reptiles. The traditional class Reptilia, which includes living reptiles and dinosaurs but *not* birds, is not a clade.

FIGURE 26–12 *Archaeopteryx*, an Early Bird *Archaeopteryx*, shown both in the fossil and artist's conception, was a bird that showed both dinosaur characteristics (teeth, bony tail) and bird characteristics (flight feathers). Because of the their weight of its teeth and bony tail and its small breastbone, it might not have been able to fly very well.

Analyzing Data

Feather Evolution

The information in the table shows the evolution of feathers in some groups of dinosaurs that preceded modern birds.

1. Organize Data Recalling what you learned about drawing cladograms in Chapter 18, use the information to place these traits correctly on **Figure 26–11.** (Redraw the cladogram in your notebook.)

2. Draw Conclusions Which type of feathers would you expect modern birds to possess?

Group (listed alphabetically)	Feather Status
Allosaurs	None
Archaeopteryx	Flight feathers
Compsognathids	Hairlike feathers
Oviraptors	True feathers
Tyrannosaurs	Branched feathers

FIGURE 26–13 Early Mammal Look-Alike The first mammals appeared on Earth about 220 million years ago. They may have resembled this modern tree shrew and probably ate insects.

Mammals Members of the traditional class Mammalia include about 5000 species that range in size from mice to whales. Characteristics unique to mammals include mammary glands in females, which produce milk to nourish young, and hair. Mammals also breathe air, have four-chambered hearts, and regulate their internal body temperature.

▶ ***The First Mammals*** True mammals first appeared during the late Triassic Period, about 220 million years ago. They were very small and resembled modern tree shrews, like the one in **Figure 26–13.** While dinosaurs ruled, mammals remained generally small and were probably active mostly at night. New fossils and DNA analyses suggest, however, that the first members of modern mammalian groups, including primates, rodents, and hoofed mammals, evolved during this period. After the great dinosaur extinction at the end of the Cretaceous Period, about 65 million years ago, mammals underwent a long adaptive radiation. Over millions of years, mammals diversified, increased in size, and occupied many niches. The Cenozoic Era, which began at the end of the Cretaceous Period, is usually called the Age of Mammals.

▶ ***Modern Mammals*** By the beginning of the Cenozoic Era, three major groups of mammals had evolved—monotremes (MAHN oh treemz), marsupials (mahr SOO pee ulz), and placentals. These three groups differ in their means of reproduction and development.

Only five species of the egg-laying monotremes, including the duckbill platypus, exist today, all in Australia and New Guinea. Marsupials, which include kangaroos, koalas, and wombats, bear live young that usually complete their development in an external pouch. Placental mammals—which include most of the mammals you are familiar with—have embryos that develop completely while still inside the mother. After birth, most placental mammals care for their young and nurse them to provide nourishment.

26.2 Review Key Concepts TEKS 7A, 12B

1. a. Review Name the group of animals whose ancestors were related to the earliest chordates.

b. Compare and Contrast Why did scientists classify *Pikaia* as a chordate instead of as a worm?

2. a. Review What two aspects of evolutionary history does the cladogram of chordates show?

b. Explain How do nonvertebrate chordates differ from other chordates?

c. Interpret Visuals According to **Figure 26–5,** which chordate feature evolved earlier—endothermy or lungs?

3. Compare Recall what you learned about plant evolution in Chapter 22. Based on the evolutionary changes shown in the cladograms on pages 636 and 758, identify the first major adaptations that allowed plants and chordates to live on land. In what ways are chordate adaptations to life on land similar to plant adaptations to life on land?

26.3 Primate Evolution

In this lesson you will learn about the evolution of primates as found in the fossil record **(TEKS 7A).**

THINK ABOUT IT Carolus Linnaeus placed our species, *Homo sapiens,* in an order he named *Primates,* which means "first" in Latin. But what are primates "first" in? Little distinguished the earliest primates from other mammals, aside from an increased ability to use their eyes and front limbs together. As primates evolved, however, several other characteristics became distinctive.

What Is a Primate?

What characteristics do all primates share?

Primates, including lemurs, monkeys, and apes, share several adaptations for a life spent in trees. **In general, a primate is a mammal that has relatively long fingers and toes with nails instead of claws, arms that can rotate around shoulder joints, a strong clavicle, binocular vision, and a well-developed cerebrum.** The lemur in **Figure 26–14** shows many of these characteristics.

Fingers, Toes, and Shoulders Primates typically have five flexible fingers and toes on each hand or foot that can curl to grip objects firmly and precisely. This enables many primates to run along tree limbs and swing from branch to branch with ease. In addition, most primates have thumbs and big toes that can move against the other digits. This allows many primates to hold objects firmly in their hands or feet. Primates' arms are well suited for climbing because they can rotate in broad circles around a strong shoulder joint attached to a strong clavicle, or collar bone.

Binocular Vision Many primates have a broad face, so both eyes face forward with overlapping fields of view. This facial structure gives primates excellent binocular vision. **Binocular vision** is the ability to combine visual images from both eyes, providing depth perception and a three-dimensional view of the world. This comes in handy for judging the locations of tree branches, from which many primates swing.

Well-Developed Cerebrum In primates, the "thinking" part of the brain—the cerebrum—is large and intricate. This well-developed cerebrum enables more-complex behaviors than are found in many other mammals. For example, many primate species create elaborate social systems that include extended families, adoption of orphans, and even warfare between rival troops.

Key Questions

What characteristics do all primates share?

What are the major evolutionary groups of primates?

What adaptations enabled later hominine species to walk upright?

***What is the current scientific thinking about the genus* Homo?**

Vocabulary

binocular vision • anthropoid • prehensile tail • hominoid • hominine • bipedal • opposable thumb

Taking Notes

Outline Before you read, outline this lesson. As you read, add details to your outline.

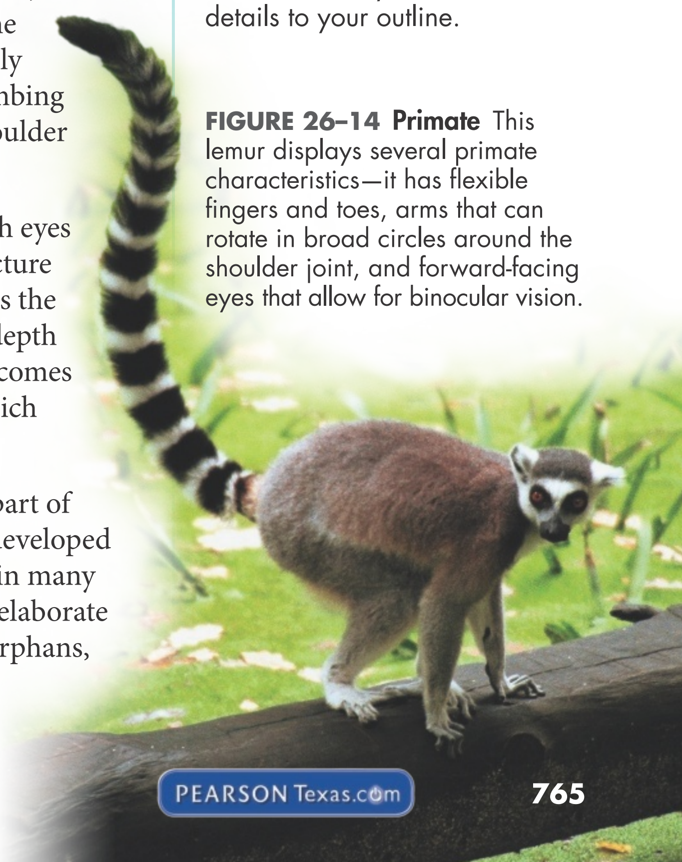


FIGURE 26–14 Primate This lemur displays several primate characteristics—it has flexible fingers and toes, arms that can rotate in broad circles around the shoulder joint, and forward-facing eyes that allow for binocular vision.

Quick Lab
EXPERIMENTAL INVESTIGATION

TEKS 2G

Binocular Vision

1. Throw a paper ball to your partner, who should try to catch the ball with one hand. Record whether your partner caught the ball.

2. Now have your partner close one eye. Repeat Step 1.

Analyze and Conclude

1. **Use Tables and Graphs** Exchange results with other groups. Make a bar graph for the class data comparing the results with both eyes open and one eye shut.

2. **Draw Conclusions** How is binocular vision useful to primates?

Evolution of Primates TEKS 7A

What are the major evolutionary groups of primates?

Humans and other primates evolved from a common ancestor that lived more than 65 million years ago. One recently discovered fossil, *Carpolestes,* which lived 56 million years ago in Wyoming, has been proposed as an example of the first primate. Early in their history, primates split into two groups. **Primates in one of these groups look very little like typical monkeys. This group contains the lemurs and lorises. The other group includes tarsiers and the anthropoids, the group that includes monkeys, great apes, and humans.** The cladogram in **Figure 26–15** shows current hypotheses about the evolutionary relationships and sequential nature of these groups.

Lemurs and Lorises With few exceptions, lemurs and lorises are small, nocturnal primates with large eyes adapted to seeing in the dark. Many have long snouts. Living members include the bush babies of Africa, the lemurs of Madagascar, and the lorises of Asia.

Tarsiers and Anthropoids Primates more closely related to humans than to lemurs belong to a different group, members of which have broader faces and widely separated nostrils. This group includes the tarsiers of Asia and the anthropoids. **Anthropoids** (AN thruh poydz), or humanlike primates, include monkeys, great apes, and humans. Anthropoids split into two groups around 45 million years ago, as the continents on which they lived moved apart.

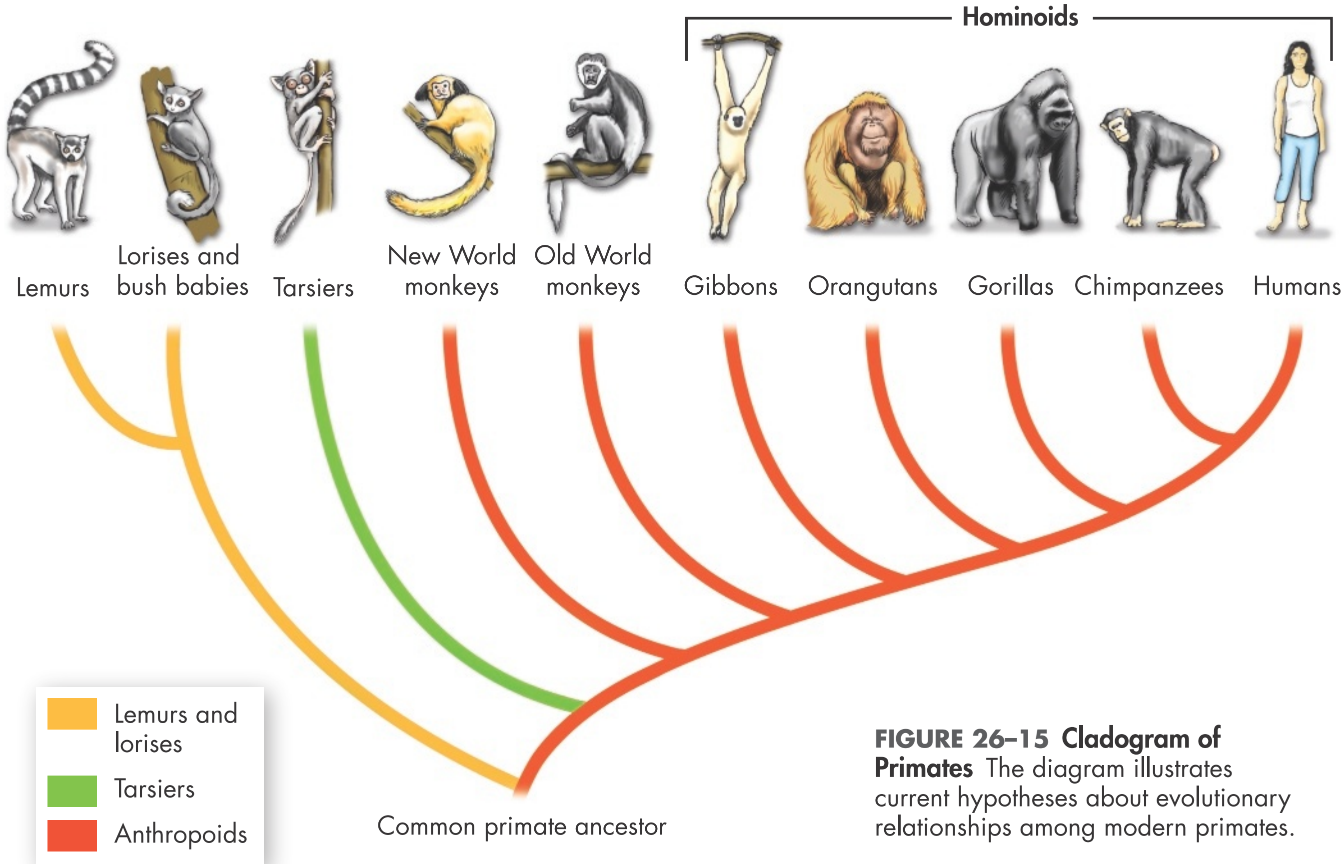


FIGURE 26–15 Cladogram of Primates The diagram illustrates current hypotheses about evolutionary relationships among modern primates.

▶ ***New World Monkeys*** Members of one anthropoid branch, the New World monkeys, are found in Central and South America. (Europeans once referred to North and South America as the "New World.") Members of this group, which includes squirrel monkeys and spider monkeys, live almost entirely in trees. They have long, flexible arms that enable them to swing from branch to branch. New World monkeys also have a long, **prehensile tail** that can coil tightly enough around a branch to serve as a "fifth hand."

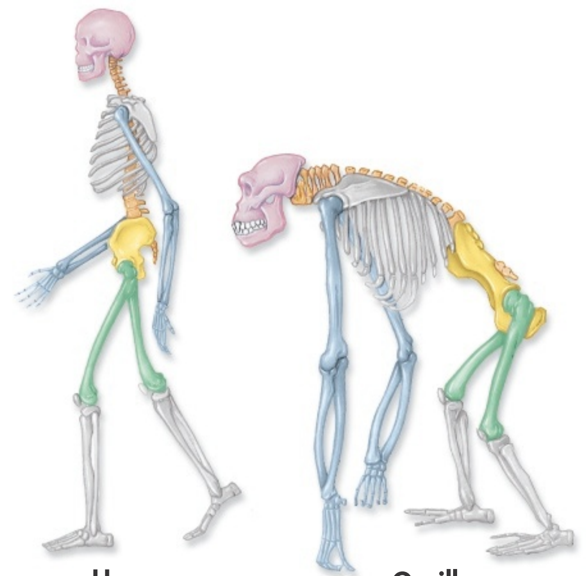
▶ ***Old World Monkeys and Great Apes*** The other anthropoid branch, which evolved in Africa and Asia, includes the Old World monkeys and great apes. Old World monkeys, such as langurs and macaques (muh KAHKS), spend time in trees but lack prehensile tails. Great apes, also called **hominoids,** include gibbons, orangutans, gorillas, chimpanzees, and humans. Recent DNA analyses confirm that, among the great apes, chimpanzees are humans' closest relatives.

Hominine Evolution TEKS 7A

What adaptations enabled later hominine species to walk upright?

Between 6 and 7 million years ago, the lineage that led to humans split from the lineage that led to chimpanzees. The hominoids in the lineage that led to humans are called **hominines.** Hominines include modern humans and all other species more closely related to us than to chimpanzees. Hominines evolved the ability to walk upright, grasping thumbs, and large brains. **Figure 26–16** shows some ways in which the skeletons of modern humans differ from those of hominoids such as gorillas. **The skull, neck, spinal column, hip bones, and leg bones of early hominine species changed shape in ways that enabled later species to walk upright.** The evolution of this **bipedal,** or two-footed, locomotion was very important, because it freed both hands to use tools. Meanwhile, the hominine hand evolved an **opposable thumb** that could touch the tips of the fingers, enabling the grasping of objects and the use of tools.

Hominines also evolved much larger brains. The brains of chimpanzees, our closest living relatives, typically range in volume from 280 to 450 cubic centimeters. The brains of *Homo sapiens,* on the other hand, range in size from 1200 to 1600 cubic centimeters! Most of the difference in brain size results from a radically expanded cerebrum.



Comparing Human and Gorilla Skeletons

Feature	Human	Gorilla
Skull	Atop S-shaped spine	Atop C-shaped spine
Spinal cord	Exits at bottom of skull	Exits near back of skull
Arms and hands	Arms shorter than legs; hands don't touch ground when walking	Arms longer than legs; hands touch ground when walking
Pelvis	Bowl-shaped	Long and narrow
Thigh bones	Angled inward, directly below body	Angled away from pelvis

FIGURE 26–16 Comparison of Hominoids Modern hominines walk upright on two legs; gorillas use all four limbs. The diagrams show many of the skeletal characteristics that allow hominines to walk upright. **Compare and Contrast** ***According to the chart and illustrations, what are the other skeletal differences between humans and gorillas?***

New Findings and New Questions The study of human ancestors is exciting and constantly changing. Since the 1990s, new discoveries in Africa have doubled the number of known hominine species. Those discoveries also doubled the length of the known hominine fossil record—from 3.5 million years to 7 million years, a time that corresponds closely to the time at which DNA studies suggest that the lineage that led to humans split from the lineage that led to chimpanzees. These new data have enhanced the picture of our species' past. Questions still remain as to how fossil hominines are related to one another—and to humans. In fact, the field is changing so rapidly that all we can present here is a sampling of current hypotheses.

Relatives Versus Ancestors Most paleontologists agree that the hominine fossil record includes seven genera—*Sahelanthropus, Orrorin*, *Ardipithecus, Australopithecus, Paranthropus, Kenyanthropus,* and *Homo*—and at least 20 species. These diverse hominine fossils stretch back in time roughly 7 million years. All these species are *relatives* of modern humans, but not all of them are human *ancestors*. To understand that distinction, think of your family. Your relatives may include aunts, uncles, cousins, parents, grandparents, and great-grandparents. All of these folks are your relatives, but only your parents, grandparents, and great-grandparents are your ancestors. Distinguishing relatives from ancestors in the hominine family is an ongoing challenge.

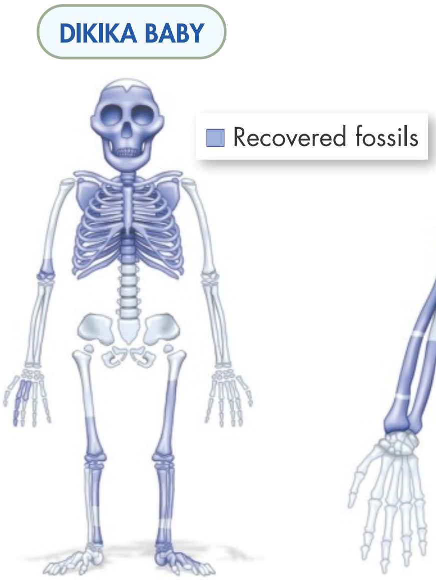
The Oldest Hominine? In 2002, paleontologists working in north-central Africa discovered a fossil skull roughly 7 million years old. This fossil, called *Sahelanthropus,* is one million years older than any known hominine. *Sahelanthropus* had a brain about the size of that of a modern chimp, but its short, broad face was more like that of a human. Scientists are still debating whether this fossil represents a hominine.

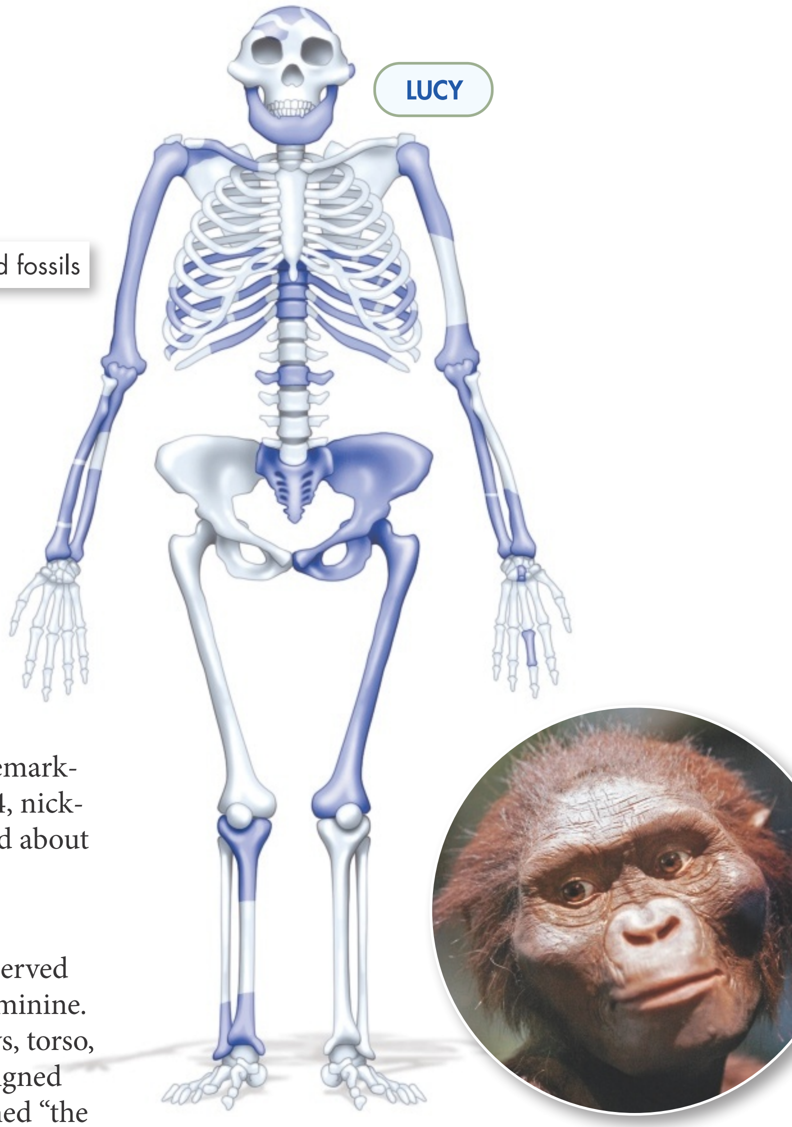
Australopithecus Some early hominine fossil species seem to belong to the lineage that led to modern humans, while others formed separate branches off the main hominine line. One early group of hominines, of the genus *Australopithecus,* lived from about 4 million to about 1.5 million years ago. These hominines were bipedal apes, but their skeletons suggest that they probably spent at least some time in trees. The structure of their teeth suggests a diet rich in fruit.

The best-known of these species is *Australopithecus afarensis,* which lived from roughly 4 million to 2.5 million years ago. The humanlike footprints in **Figure 26–17,** about 3.6 million years old, were probably made by members of this species. *A. afarensis* fossils indicate the species had small brains, so the footprints show that hominines walked bipedally long before large brains evolved. Other fossils of this genus indicate that males were much larger than females. You can see artists' conceptions of young female and adult female *A. afarensis* in **Figure 26–18.**

Online Journal *How long ago does DNA evidence suggest that the human lineage split from the chimpanzee lineage?*

FIGURE 26–17 Laetoli Footprints Between 3.8 and 3.6 million years ago, members of a species of *Australopithecus* made these footprints at Laetoli in Tanzania. The footprints show that hominines walked upright millions of years ago.





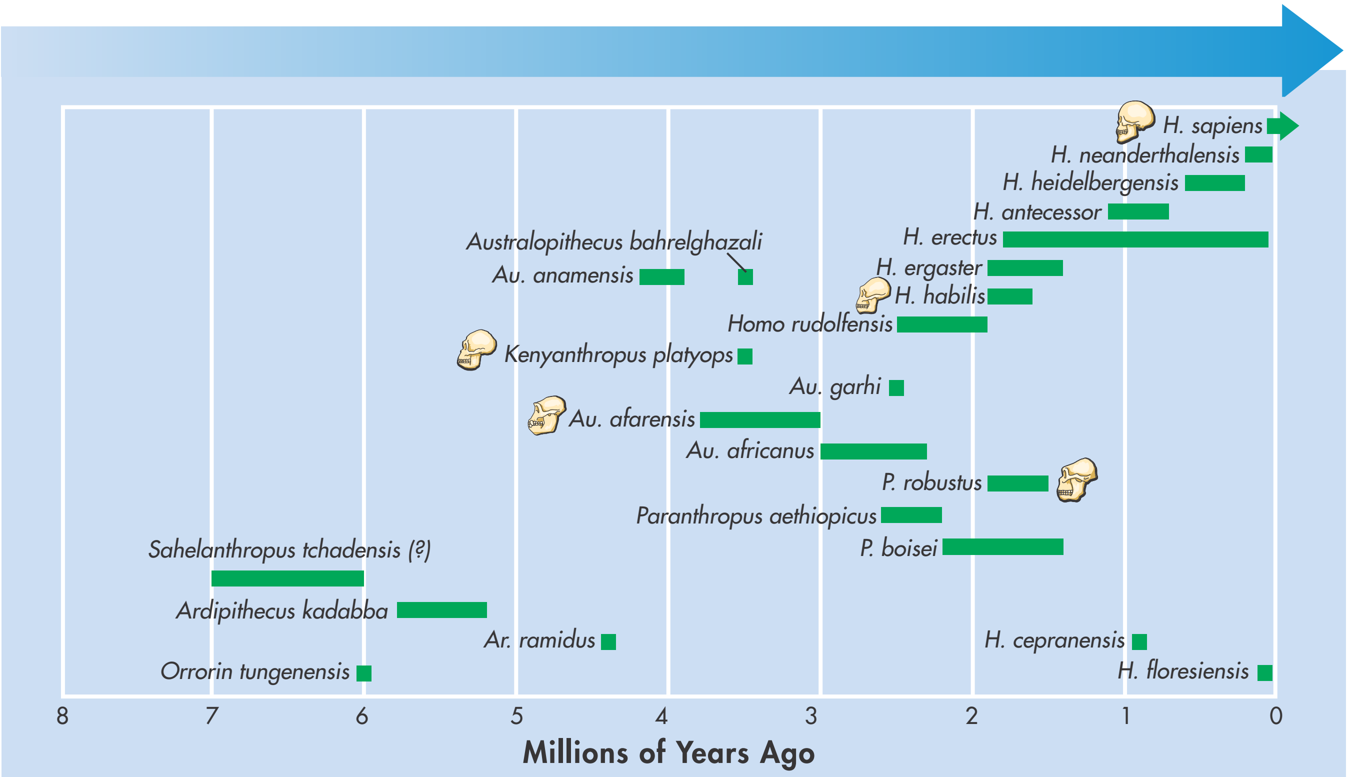
▶ ***Lucy*** The best-known *A. afarensis* specimen is a remarkably complete skeleton of a female discovered in 1974, nicknamed "Lucy." Lucy stood about 1 meter tall and lived about 3.2 million years ago.

▶ ***The Dikika Baby*** In 2006, an Ethiopian researcher announced the discovery of some incredibly well preserved 3.3 million-year-old fossils of a very young female hominine. The skeleton included a nearly complete skull and jaws, torso, spinal column, limbs, and left foot. This fossil was assigned to *A. afarensis*, the same species as Lucy, and nicknamed "the Dikika Baby," after the region in Africa where it was discovered. Leg bones confirmed that the Dikika Baby walked bipedally, while her arm and shoulder bones suggest that she would have been a better climber than modern humans. Researchers will be extracting information from these bones for years.

Paranthropus Three more-recent species, which grew to the size of well-fed football linebackers, have been placed in their own genus, *Paranthropus*. These *Paranthropus* species had huge, grinding back teeth. Their diets probably included coarse and fibrous plant foods like those eaten by modern gorillas. Paleontologists now place *Paranthropus* on a separate, dead-end branch of our family tree.

Hominine Relationships Researchers once thought that human evolution took place in relatively simple steps in which hominine species, over time, became gradually more humanlike. But it is now clear that a series of hominine adaptive radiations produced a number of species whose relationships are difficult to determine. As a result, what once looked like a simple hominine "family tree" with a single main trunk now looks more like a shrub with multiple trunks.

FIGURE 26–18 Lucy and the Dikika Baby "Lucy" and "the Dikika Baby" are nicknames of two very important fossils of the hominine *A. afarensis*. Lucy is a partial skeleton of an adult female. The Dikika Baby is the most-complete fossil yet found of this species. These two fossils were discovered just 6 miles apart in Ethiopia. **Interpret Visuals** ***Given the fossils recovered, which face shape would you expect scientists to be more confident about—the Dikika Baby's or Lucy's?***



VISUAL SUMMARY

HOMININE TIME LINE

FIGURE 26–19 The diagram shows hominine species known from fossils and the time ranges during which each species probably existed. These time ranges may change as paleontologists gather new data. At this writing, several competing hypotheses present different ideas about how these species are related to one another and to *Homo sapiens*. So far, there is no single, universally accepted hypothesis, so we present these data as a time line, rather than as a cladogram. The fossil record shows that hominine evolution did not proceed along a simple, straight-line transformation of one species into another. Rather, a series of adaptive radiations produced a number of species, several of which display a confusing mix of primitive and modern traits. **Interpret Graphs** ***According to this time line, which species in the genus* Homo *lived at the same time?***

The Road to Modern Humans TEKS 7A

***What is the current scientific thinking about the genus* Homo?**

The hominines discussed so far lived millions of years before modern humans. **Many species in our genus existed before our species, *Homo sapiens,* appeared in the fossil record. Furthermore, at least three other *Homo* species existed at the same time as early humans.** Paleontologists still do not completely understand the relationships among species in our genus.

The Genus *Homo* About 2 million years ago, a new group of hominine fossil species appeared. Several of these fossils resemble modern human bones enough that they have been classified in the genus *Homo.* One set of fossils from this time period was found with tools made of stone and bone, so it was named *Homo habilis* (HAB uh luhs), which means "handy man" in Latin. The earliest fossils that most researchers agree can be definitely assigned to the genus *Homo* have been called *Homo ergaster. H. ergaster* was larger than *H. habilis* and had a bigger brain and downward-facing nostrils that resemble those of modern humans. *Homo rudolfensis* appeared before *H. ergaster,* but some researchers choose to classify it in the genus *Australopithecus* instead of *Homo.*

Out of Africa—But When and Who? Researchers agree that our genus originated in Africa and migrated from there to populate the world. But questions remain. When did hominines first leave Africa? Did more than one species make the trip? Which of those species were human ancestors and which were merely relatives? You can see some of the current hypotheses in **Figure 26–20.**

▶ ***The First to Leave*** Fossil and molecular evidence suggest that some hominines left Africa long before *Homo sapiens* evolved. It also appears that more than one *Homo* species made the trip in waves. Again, researchers differ as to the identity of various fossils, but agree that hominines began migrating out of Africa at least 1.8 million years ago. Hominine remains from that period were found in the Republic of Georgia, which is north of Turkey and far from Africa. Some researchers who have examined those remains argue that they might belong to a smaller-brained *Homo* species, *Homo habilis*.

▶ **Homo erectus *in Asia*** According to some researchers, groups of *Homo erectus* left Africa and traveled all the way across India and through China to Southeast Asia. In fact, some of the oldest known specimens of *H. erectus* were uncovered on the Indonesian island of Java. This suggests that these ancient wanderers spread very rapidly once they left Africa. These *H. erectus* populations continued to survive and evolve across Asia for as long as 1.5 million years.

▶ ***The First* Homo sapiens** Paleontologists have long debated where and when *Homo sapiens* arose. One hypothesis, called the multiregional model, suggests that, in several parts of the world, modern humans evolved independently from widely separated populations of *H. erectus.* Another hypothesis, the "out-of-Africa" model, proposes that modern humans evolved in Africa about 200,000 years ago, migrated out of Africa through the Middle East, and replaced the descendants of earlier hominine species.

Recently, molecular biologists analyzed mitochondrial DNA from living humans around the world to determine when we last shared a common ancestor. The estimated date for that African common ancestor is between 200,000 and 150,000 years ago. More recent DNA data suggest that a small subset of those African ancestors left northeastern Africa between 65,000 and 50,000 years ago to colonize the world. These data strongly support the out-of-Africa model.

BUILD Vocabulary

MULTIPLE MEANINGS The word *sapient* means "wise." It is also used as an adjective referring to *Homo sapiens*.

FIGURE 26–20 Out of Africa Data show that relatives and ancestors of modern humans left Africa in waves. But when—and how far did they travel? By comparing the mitochondrial DNA of living humans and by continuing to study the fossil record, scientists hope to improve our understanding of the complex history of *Homo sapiens*. (Note: Skulls on the map do not indicate that skulls were found at each location.)

FIGURE 26–21 Cro-Magnon Art This ancient cave painting from France shows the remarkable artistic abilities of Cro-Magnons. **Infer** ***How might these painted images be related to the way in which these early humans lived?***

Modern Humans The story of modern humans over the past 200,000 years involves two main species in the genus *Homo*.

▶ **Homo neanderthalensis** Neanderthals flourished in Europe and western Asia beginning about 200,000 years ago. Evidence suggests that they made stone tools, lived in complex social groups, had controlled use of fire, and were excellent hunters. They buried their dead with simple rituals. Neanderthals survived in parts of Europe until about 28,000 to 24,000 years ago.

▶ ***Modern* Homo sapiens** Anatomically modern *Homo sapiens,* whose skeletons look like those of today's humans, arrived in the Middle East from Africa about 100,000 years ago. By about 50,000 years ago, *H. sapiens* populations were using new technology to make more sophisticated stone blades. They also began to make elaborately worked tools from bones and antlers. They produced spectacular cave paintings and buried their dead with elaborate rituals. In other words, these people, including the group known as Cro-Magnons, began to behave like modern humans.

When *H. sapiens* arrived in the Middle East, they found Neanderthals already living there. Neanderthals and *H. sapiens* lived side by side in the Middle East for about 50,000 years. Groups of modern humans moved into Europe between 40,000 and 32,000 years ago. There, too, *H. sapiens* coexisted alongside Neanderthals for several thousand years. For the last 24,000 years, however, our species has been Earth's only hominine. Why did Neanderthals disappear? Did they interbreed with *H. sapiens*? No one knows for sure. What we do know is that our species, *Homo sapiens,* is the only surviving member of the once large and diverse hominine clade.

26.3 Review Key Concepts TEKS 7A

1. a. **Review** What are the characteristics of primates?
   b. **Apply Concepts** How does each characteristic benefit primates?
2. a. **Review** List the two major groups of primates.
   b. **Sequence** At what point did the two groups of anthropoids split, and why?
3. a. **Review** Which early hominine bones changed shape over time, allowing later hominines to walk upright?
   b. **Relate Cause and Effect** How was bipedal locomotion important to hominine evolution?
4. a. **Review** Which two species are considered members of the genus *Homo?*
   b. **Compare and Contrast** List two ways in which *Homo neanderthalensis* differed from *Homo sapiens.*

WRITE ABOUT SCIENCE

Creative Writing

5. Create a "Lost Hominine" poster for *Homo neanderthalensis.* Include its known characteristics and approximately when and where it was last seen. Illustrate the poster with a drawing or clipping.

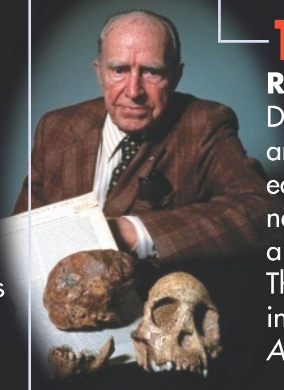
BIOLOGY & History

TEKS 3B, 3F

Human-Fossil Seekers **The study of human origins is an exciting search for our past. Piecing together this complicated story requires the skills of many scientists.**

1855 1885 1915 1945 1955 1975 2005 2035

1868
Edouard Lartet
Henry Christy
French geologist Lartet and English banker Christy unearth several ancient human skeletons in a rock shelter called Cro-Magnon in France. These hominine fossils are the first to be classified as *Homo sapiens.*



1924
Raymond Dart
Dart, an Australian anatomist, finds an early hominine fossil—a nearly complete skull of a child—in South Africa. This specimen was placed in a new genus called *Australopithecus.*

1974
Donald Johanson
An American paleontologist and his team find 40 percent of a skeleton of *Australopithecus*, which they call Lucy, in the Afar region of Ethiopia. The skeleton is about 3.2 million years old.

2001
Meave Leakey
Nature publishes Meave Leakey's discovery of a 3.5–3.2 million year old skull that may be a human ancestor other than *Australopithecus.*

2002
Ahounta Djimdoumalbaye
Djimdoumalbaye, a college student in Chad, discovers the cranium of what may be the oldest known hominine, *Sahelanthropus tchadensis.*

1886
Marcel de Puydt
Max Lohest
De Puydt and Lohest describe two Neanderthal skeletons found in a cave in Belgium. Their detailed description shows that Neanderthals were an extinct human form, not an abnormal form of modern human.

1978
Mary Leakey
Mary Leakey, a British anthropologist, discovers a set of 3.6 million-year-old fossil hominine footprints at Laetoli in Tanzania. The footprints provide evidence that early hominines walked erect on two legs.

2006
Zeresenay Alemseged
Zeresenay, an Ethiopian paleoanthropologist, announces his discovery of the fossilized skeleton of a young hominine in the Dikika region of Ethiopia. It is the most complete example of *A. afarensis* ever discovered and is about 3.3 million years old.

WRITING **Use reference sources suggested by your teacher to research one of these discoveries. Assess the usefulness of each source. Communicate your research in a poster with images and captions.**

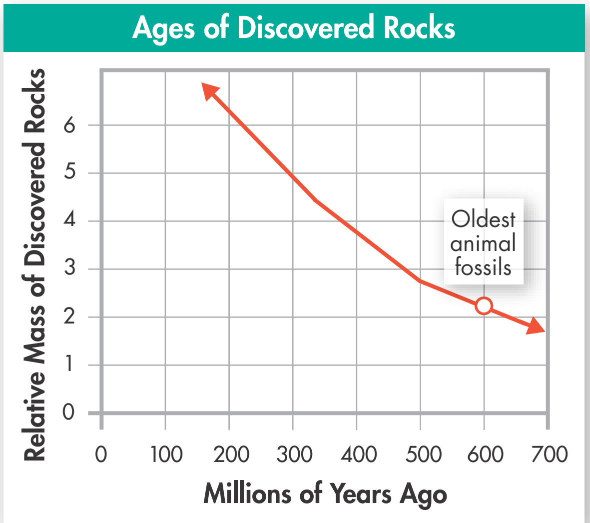
APPLY THE TEKS 7A

solve the CHAPTER MYSTERY

FOSSIL QUEST

Josh was working against great odds. "His" fossils would be about 600 million years old. He learned that there are few places where the fossil record in rocks of that age hasn't been destroyed by geological activity. Most known sites are in China and Australia—none are in the United States. Pedro found better news. Dinosaurs related to bird ancestors lived during the Cretaceous Period. There are a number of places where fossils of that age have been found—including the Green River area in Utah. Because both boys like dinosaurs, they joined an Earthwatch teen expedition to the Green River to search for bird ancestors!

1. Analyze Data Why is it so much harder to find fossils from the Proterozoic Eon, when the earliest known animals lived, than it is to find fossils from the Cretaceous Period, when the ancestors of birds lived? (*Hint:* See the graph below.)



2. Analyze Data *Birds are modern dinosaurs.* Evaluate this statement based on the dinosaur fossil record and phylogenetic information on birds discussed in this mystery and in the chapter.

3. Investigate Starting at the Earthwatch Web site, do an Internet search for fossil hunting expeditions you could join.

26 TEKS Practice

TEKS 2G, 7A, 7B, 12B

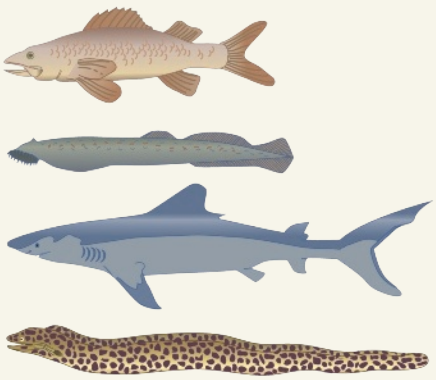
Review Content

1. The ancestors of many modern animal phyla first appeared during the
a. Burgess Period.
b. Cambrian Period.
c. Precambrian Era.
d. Ediacaran Period.

2. Of the following groups, which has the largest number of species by far?
a. arthropods
b. annelids
c. mollusks
d. echinoderms

3. The evolution of jaws and paired fins was an important development during the rise of
a. tunicates.
b. lancelets.
c. fishes.
d. amphibians.

4. Examine the diagrams below. Which of these is a jawed cartilaginous fish?



a. b. c. d.

5. Which adaptation is NOT characteristic of reptiles?
a. scaly skin
b. shelled egg
c. gills
d. lungs

6. Dinosaurs became extinct at the end of the
a. Cretaceous Period.
b. Triassic Period.
c. Carboniferous Period.
d. Permian Period.

7. The single most important characteristic that separates birds from other living animals is the presence of
a. hollow bones.
b. feathers.
c. two legs.
d. wings.

8. Which of the following is a placental mammal?
a. duckbill platypus
b. whale
c. kangaroo
d. koala

9. Anthropoids include monkeys and
a. lemurs.
b. lorises.
c. tarsiers.
d. humans.

10. Which of the following is a characteristic specific to primates?
a. body hair
b. rotation at the shoulder joint
c. notochord
d. ability to control body temperature

11. The first hominines appear in the fossil record about
a. 30,000 years ago.
b. 100,000 years ago.
c. 6 to 7 million years ago.
d. 120 million years ago.

Understand Concepts

12. What body plan features did Cambrian animals evolve over 10 to 15 million years?

13. What evidence exists to indicate that annelids and mollusks are closely related?

14. Which two major groups of fishes evolved from the early jawed fishes and still survive today?

15. What adaptation enables birds to live in environments that are colder than those in which most reptiles live?

16. Describe how the young of monotremes, marsupials, and placental mammals obtain nourishment.

17. What anatomical characteristic allows for the binocular vision that occurs in primates?

18. Describe the adaptations that make some primates successful tree dwellers.

19. List the unique characteristics of hominines. Give an example of a hominine.

Think Critically

20. **Infer** Most cnidarians do not swim toward their prey. Instead, they capture prey carried by water currents. How is this behavior related to their body plan? Cite textual evidence to support your answer.

21. **Compare and Contrast** How are echinoderms structurally different from arthropods?

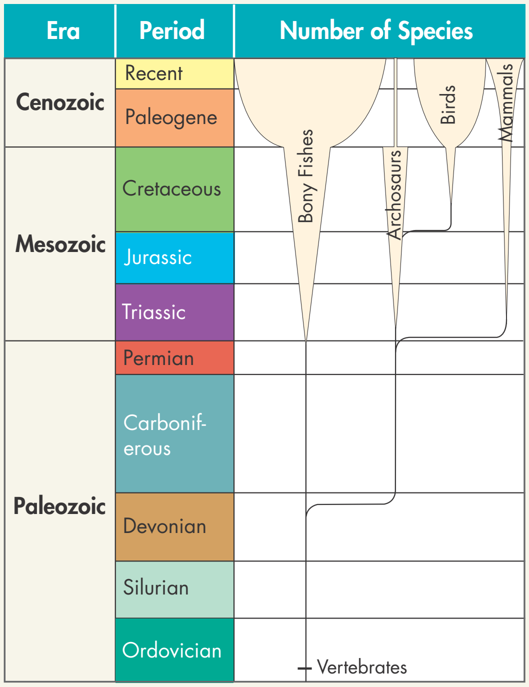
TEKS Practice

22. **Apply Concepts** Which anatomical characteristics of nonvertebrate chordates suggest that, in terms of evolutionary relationships, these animals are more closely related to vertebrates than to other groups of animals? Draw evidence from the text to support your answer.

23. **Explain** Life on Earth began in water. What were some of the major adaptations that animals evolved that allowed them to survive out of water?

Use Science Graphics

The chart below shows the relative numbers of species in four groups of vertebrates over time. The thickness of each band shows the relative number of species in that group. Use the chart to answer questions 24–27.



24. **Compare** How is this diagram similar to a traditional cladogram? What additional information can be learned from it?

25. **Interpret Visuals** Which of the groups shown has the greatest number of species today?

26. **Infer** Archosaurs are a group of reptiles that includes the dinosaurs, pterosaurs, modern crocodiles, and birds. Why do you think that birds are shown separately from the other archosaurs in the diagram?

27. **Apply Concepts** Describe the trend for each group shown from the beginning of the Mesozoic to today. Which groups were affected by the mass extinction at the end of the Mesozoic? Which groups have experienced adaptive radiations?

REVIEW THE TEKS

Biology Chapter 26

Lesson 1

In Lesson 26.1, you learned about the origin of the invertebrates based on evidence in the fossil record. Such evidence indicates that the first animals began evolving long before the Cambrian Explosion. You also learned about the invertebrates that are alive today, including sponges, cnidarians, arthropods, nematodes, flatworms, annelids, mollusks, and echinoderms. Based on current hypotheses of evolutionary relationships among these major groups, scientists have developed a cladogram that shows the evolutionary relationships. The cladogram also indicates the sequence in which important features such as body symmetry, cephalization, segmentation, and formation of a coelom evolved in Cambrian animals.

Readiness TEKS: 7A
Supporting TEKS: 7B

Lesson 2

In Lesson 26.2, you learned about the origin of the chordates. Embryological studies suggest that the most ancient chordates were related to the ancestors of echinoderms. You also learned about the chordates that are alive today, including fishes, amphibians, reptiles and birds, and mammals. The cladogram of chordates shows current hypotheses about the relationships among chordates groups It also shows at which points important vertebrate features, such as jaws and limbs, evolved.

Readiness TEKS: 7A
Supporting TEKS: 7B, 12B

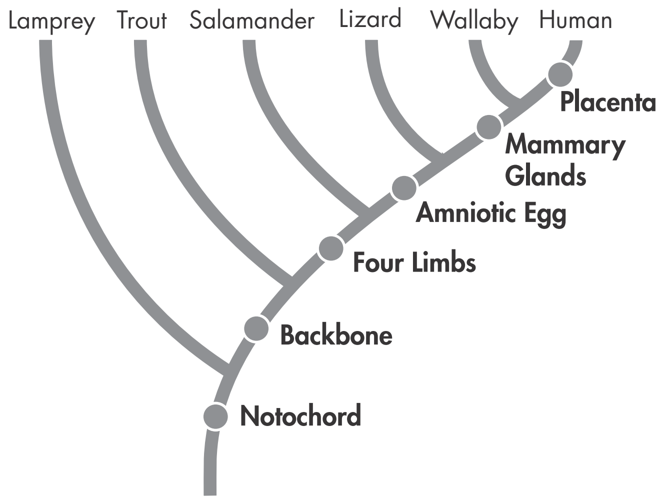
Lesson 3

Lesson 26.3 discusses the evolution of primates. Primates are mammals that have relatively long fingers and toes with nails instead of claws, arms that can rotate around shoulder joints, a strong clavicle, binocular vision, and a well-developed cerebrum. The skull, neck, spinal column, hip bones, and leg bones of early hominine species changed shape in ways that enabled later species to walk upright. Many species in our genus existed before our species, *Homo sapiens,* appeared. Furthermore, at least three other *Homo* species existed at the same time as early humans.

Readiness TEKS: 7A

★ TEKS Practice: Chapter Review

1 The diagram shows relationships between organisms.



According to the diagram, which anatomical feature do modern humans and trout share with a common ancestor?

A Notochord

B Placenta

C Four limbs

D Amniotic egg

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2 A well-developed cerebrum in a forest primate is an adaptation that allows for

F better balance.

G better depth perception.

H better handling of objects.

J a complex social system.

3 The image shows two different organisms, a scorpion and a lizard.

What trait was found in the common ancestor of these two organisms?

A Vertebrae

B Lungs

C Four limbs

D None of the above

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4 What is the best explanation of how the dinosaur extinction at the end of the Cretaceous Period allowed an adaptive radiation of mammals?

F Many new niches would have opened up with the extinction of the dinosaurs, so mammals could diversify and fill them.

G The dinosaur extinction would have removed many predators of mammals, so populations could increase.

H Environmental devastation occurred with the dinosaur extinction, so both mammals and environmental systems were able to develop together.

J The dinosaur extinction led to an adaptive radiation of birds, whose eggs provided food that fueled an adaptive radiation of mammals.

★ TEKS Practice: Cumulative Review

5 The table shows some of the characteristics of plants.

Characteristics of Plants
Eukaryotic Autotrophic Multicellular

Which characteristic or characteristics from this table could also be used to describe animals?

A Multicellular

B Eukaryotic, autotrophic

C Eukaryotic, multicellular

D Eukaryotic, autotrophic, multicellular

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6 Wilting is a plant response that is related to maintaining homeostasis. Which environmental condition is most likely to trigger wilting?

F Change of season

G Hot, dry weather

H Cloudy, humid weather

J Nutrient-poor soil

If You Have Trouble With . . .

Question	1	2	3	4	5	6
See Lesson	26.2	26.3	26.1	26.2	25.1	23.4
TEKS	7A, 2H	12B	7A	12B	8C	11A