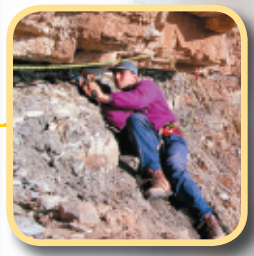
Chapter 9

A View of Earth's Past

Chapter Outline



Why It Matters

The rock and fossil records show that Earth's surface is constantly changing. Fossils provide valuable information about extinct organisms. This illustration shows an artist's idea of how a mother *Hypacrosaurus* might have looked as she fed her hatchlings. Because fossils do not record such characteristics as skin color, they are left to our imagination.

Inquiry Lab

20 min

Exploring Geologic Evidence

Obtain a **box** from your teacher. Use a **spoon** to dig carefully through the layers in the box to find "fossils." Transfer material removed from the box to a sheet of **newspaper.** Record the layer in which each fossil was found. Sketch the layers, including the number and type of each fossil found, to produce a geologic history.

Questions to Get You Started

1. Which fossils are the oldest? How do you know?
2. Which fossils are found only in older layers? What are possible reasons for this distribution?

READING TOOLBOX

These reading tools will help you learn the material in this chapter.

Word Parts

Prefixes Many scientific words contain prefixes or suffixes that come from Latin and Greek. You can use the meanings of prefixes and suffixes to help you figure out the meanings of science terms.

The term *Paleozoic Era* contains the prefix *paleo-,* from the Greek word *palaio,* meaning "ancient," and the suffix *-zoic,* from the Greek word *zoe,* meaning "life." The Paleozoic Era is the time in which many early forms of life became abundant.

Your Turn As you read this chapter, make a table of terms containing a prefix and the suffix *-zoic*. Using a dictionary, enter the meanings of the prefixes in the table.

TERM	PREFIX	MEANING OF PREFIX
Paleozoic Era	paleo-	ancient
Mesozoic Era	meso-	
Cenozoic Era		

Describing Time

Temporal Language Temporal language is language that is used to describe time. Paying careful attention to temporal language can help you understand events and processes in the environment.

Your Turn Make a two-column table. As you read this chapter, look for words and phrases that refer to time. Write these words and phrases in the first column of your table. In the second column, write whether each word or phrase describes a specific time, duration, frequency, or sequence of events.

TEMPORAL WORD	DESCRIBES . . .
19th century	specific time
timeline	sequence
rate	frequency

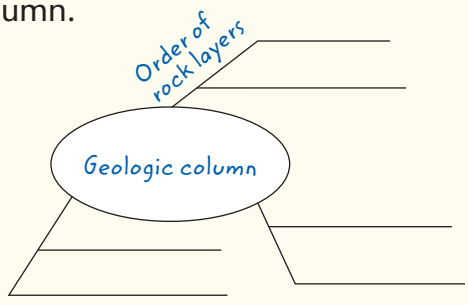
Graphic Organizers

Spider Maps Spider maps show how details are organized into categories that relate to a main idea.

To make a spider map, follow these steps.

1. Write a main topic title, and draw an oval around it.
2. From the oval, draw legs. Each leg represents a category of the main topic.
3. From each leg, draw horizontal lines. Write details about each category on these lines.

Your Turn As you read Section 1, complete a spider map like the one started here to organize the ideas you learn about the geologic column.



For more information on how to use these and other tools, see **Appendix A.**

SECTION 1

Geologic Time

Key Ideas	Key Terms	Why It Matters
❯ Summarize how scientists worked together to develop the geologic column. ❯ List the major divisions of geologic time.	**geologic column** **era** **period** **epoch**	The geologic time scale provides a framework for understanding the geologic processes that shape our planet.

Earth's surface is constantly changing. Mountains form and erode; oceans rise and recede. As conditions on Earth's surface change, some organisms flourish and then later become extinct. Evidence of these changes is recorded in the rock layers of Earth's crust. To describe the sequence and length of these changes, scientists have developed a *geologic time scale*. This scale outlines the development of Earth and life on Earth.

The Geologic Column

By studying fossils and applying the principle that old layers of rock are below young layers, 19th-century scientists determined the relative ages of sedimentary rock in different areas around the world. No single area on Earth contained a record of all geologic time. So, scientists combined their observations to create a standard arrangement of rock layers. As shown in the example in **Figure 1**, this ordered arrangement of rock layers is called a **geologic column.** A geologic column represents a timeline of Earth's history. The oldest rocks are at the bottom of the column.

geologic column an ordered arrangement of rock layers that is based on the relative ages of the rocks and in which the oldest rocks are at the bottom

Rock layers in a geologic column are distinguished by the types of rock the layers are made of and by the kinds of fossils the layers contain. Fossils in the upper, more-recent layers resemble modern plants and animals. Most of the fossils in the lower, older layers are of plants and animals that are different from those living today. In fact, many of the fossils discovered in old layers are from species that have been extinct for millions of years.

THINK central
INTERACT ONLINE
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Reading Check **Where would you find fossils of extinct animals on a geologic column?**
(See Appendix G for answers to Reading Checks.)

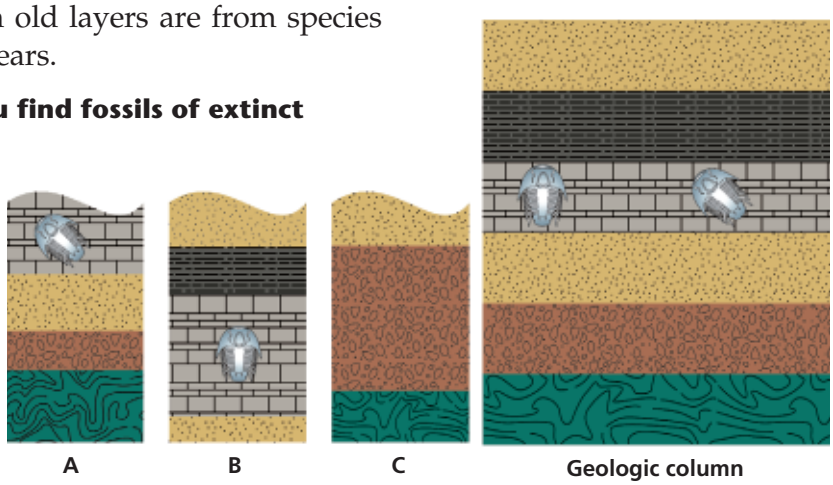


Figure 1 By combining observations of rock layers in areas A, B, and C, scientists can construct a geologic column. ***Why is relative position important for determining the ages of rock layers?***

Figure 2 This scientist is collecting rock samples that contain fossilized fungal spores that date the rock to the Triassic Period.

Academic Vocabulary

investigate (in VES ti geyt) to examine or study an object in detail in an attempt to learn the facts about it

READING TOOLBOX

Temporal Language

As you read in this section about the various divisions of geologic time, make a table that describes the temporal language that is used.

Using a Geologic Column

When the first geologic columns were being developed, scientists estimated the ages of rock layers by using factors such as the average rates of sediment deposition. The development of radiometric dating methods, however, allowed scientists to determine the absolute ages of rock layers with more accuracy.

Scientists can now use geologic columns to estimate the ages of rock layers that cannot be dated radiometrically. To determine the age of a given rock layer, scientists compare the rock layer with a similar layer in a geologic column that contains the same fossils or that has the same relative position. If the two layers match, they likely formed at about the same time. The scientist in **Figure 2** is investigating the ages of sedimentary rocks.

Divisions of Geologic Time

The geologic history of Earth is marked by major changes in Earth's surface, climate, and types of organisms. Geologists use these indicators to divide the geologic time scale into smaller units. Rocks grouped within each unit contain similar fossils. In fact, a unit of geologic time is generally characterized by fossils of a dominant lifeform. A simplified geologic time scale is shown in **Table 1.**

Because Earth's history is so long, geologists commonly use abbreviations when they discuss geologic time. For example, Ma stands for *mega-annum*, which means "million years."

Quick Lab

30 min

Geologic Time Scale

Procedure

1. Copy the table shown at right onto a piece of paper.
2. Complete the table by using the scale 1 cm is equal to 10 million years.
3. Lay a 5-m strip of adding-machine paper flat on a hard surface. Use a meterstick, a metric ruler, and a pencil to mark off the beginning and end of Precambrian time according to the time scale you calculated. Do the same for the three eras. Label each time division, and color each a different color with colored pencils.
4. Pick two periods from the geologic time scale. Using the same scale that was used in step 2, calculate the scale length for each period listed. Mark the boundaries of each period on the paper strip, and label the periods on your scale.

Era	Length of time (years)	Scale length
Precambrian	4,058,000,000	
Paleozoic	291,000,000	
Mesozoic	185,500,000	
Cenozoic	65,500,000 (to present)	

5. Decorate your strip by adding names or drawings of the organisms that lived in each division of time.

Analysis

1. When did humans appear? What is the scale length from that time to the present?
2. Add the lengths of the Paleozoic, Mesozoic, and Cenozoic Eras. What percentage of the geologic time scale do these combined eras represent? What percentage of the geologic time scale does Precambrian time represent?

Table 1 Geologic Time Scale

Era	Period	Epoch	Beginning of interval in Ma	Characteristics from geologic and fossil evidence
Cenozoic	Quaternary	Holocene	0.0115	The last glacial period ends; complex human societies develop.
		Pleistocene	1.8	Woolly mammoths, rhinos, and humans appear.
	Tertiary	Pliocene	5.3	Large carnivores (bears, lions) appear.
		Miocene	23.0	Grazing herds are abundant; raccoons and wolves appear.
		Oligocene	33.9	Deer, pigs, camels, cats, and dogs appear.
		Eocene	55.8	Horses, flying squirrels, bats, and whales appear.
		Paleocene	65.5	Age of mammals begins; first primates appear.
Mesozoic	Cretaceous		146	Flowering plants and modern birds appear; mass extinctions mark the end of the Mesozoic Era.
	Jurassic		200	Dinosaurs are the dominant life-form; primitive birds and flying reptiles appear.
	Triassic		251	Dinosaurs appear; ammonites are common; cycads and conifers are abundant; mammals appear.
Paleozoic	Permian		299	Pangaea comes together; mass extinctions mark the end of the Paleozoic Era.
	Carboniferous	Pennsylvanian Period	318	Giant cockroaches and dragonflies are common; coal deposits form; reptiles appear.
		Mississippian Period	359	Amphibians flourish; brachiopods are common in oceans; forests and swamps cover most land.
	Devonian		416	Age of fishes begins; amphibians appear; giant horsetails, ferns, and seed-bearing plants develop.
	Silurian		444	Eurypterids, land plants and animals appear.
	Ordovician		488	Echinoderms appear; brachiopods increase; trilobites decline; graptolites flourish.
	Cambrian		542	Shelled marine invertebrates appear; trilobites and brachiopods are common; first vertebrates appear; atmosphere reaches modern O_2-rich state.
Precambrian time			4,600	Earth forms; continental shields appear; fossils are rare; cyanobacteria are the most common organism.

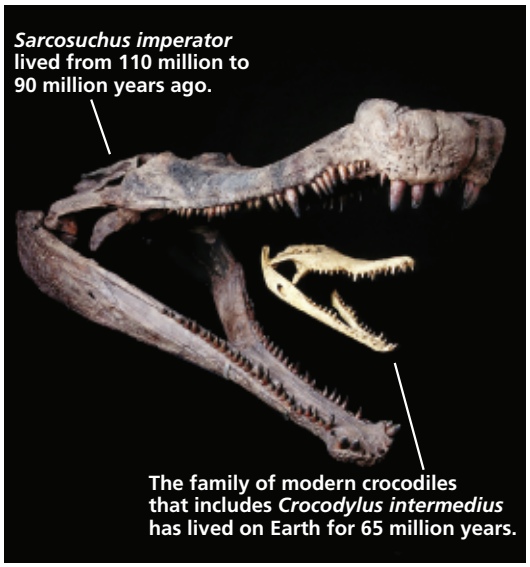


Figure 3 Crocodilians have lived on Earth for more than two geologic eras without major anatomical changes.

Eons and Eras

The largest unit of geologic time is an *eon*. Geologic time is divided into four eons: the Hadean Eon, the Archean Eon, the Proterozoic Eon, and the Phanerozoic Eon. The first three eons of Earth's history are part of a time interval commonly known as *Precambrian time*. This 4-billion-year interval contains most of Earth's history. Very few fossils exist in early Precambrian rocks, so dividing Precambrian time into smaller time units is difficult.

After Precambrian time, the Phanerozoic Eon began. This eon, as well as most eons, is divided into smaller units of geologic time called **eras.** The first era of the Phanerozoic Eon was the *Paleozoic Era,* which lasted about 291 million years. Paleozoic rocks contain fossils of a wide variety of marine and terrestrial life-forms. After the Paleozoic Era, the *Mesozoic Era* began and lasted about 186 million years. Mesozoic fossils include early forms of birds and reptiles, such as the giant crocodilian shown in **Figure 3.** The present geologic era is the *Cenozoic Era*, which began about 65 million years ago. Fossils of mammals are common in Cenozoic rocks.

era a unit of geologic time that includes two or more periods

period a unit of geologic time that is longer than an epoch but shorter than an era

epoch a subdivision of geologic time that is longer than an age but shorter than a period

Periods and Epochs

Eras are divided into shorter time units called **periods.** Each period is characterized by specific fossils and is usually named for the location in which the fossils were first discovered. Where the rock record is most complete and least deformed, a detailed fossil record may allow scientists to divide a period into shorter time units called **epochs.** An epoch may be divided into smaller units of time called *ages*. Ages are defined by the occurrence of distinct fossils in the fossil record.

Section 1 Review

Key Ideas

1. **Summarize** the reasons why many scientists had to work together to develop the geologic column.
2. **Describe** the major events in any one period of geologic time.
3. **Explain** why constructing geologic columns is useful to Earth scientists.
4. **List** the following units of time in order of length from shortest to longest: *year, period, era, eon, age,* and *epoch.*
5. **Name** the three eras of the Phanerozoic Eon, and identify how long each one lasted.
6. **Compare** geologic time with the geologic column.

Critical Thinking

7. **Analyzing Relationships** When a scientist discovers a new type of fossil, what characteristic of the rock around the fossil would he or she want to learn first?
8. **Predicting Consequences** How would our understanding of Earth's past change if a scientist discovered a mammal fossil from the Paleozoic Era?

Concept Mapping

9. Use the following terms to create a concept map: *geologic time, Precambrian time, Paleozoic Era, Mesozoic Era, Cenozoic Era, period,* and *epoch.*

SECTION 2

Precambrian Time and the Paleozoic Era

Key Ideas	Key Terms	Why It Matters
❯ Summarize how evolution is related to geologic change. ❯ Identify two characteristics of Precambrian rock. ❯ Identify one major geologic and two major biological developments during the Paleozoic Era.	**evolution** **Precambrian time** **Paleozoic Era**	The rock and fossil records show that Earth changes over time. One of these changes allowed the oxygen we breathe to begin accumulating in the atmosphere.

History is a record of past events. Just as the history of civilizations is written in books, the geologic history of Earth is recorded in rock layers. The types of rock and the fossils that occur in each layer reveal information about the environment when the layer formed. For example, the presence of a limestone layer in an area indicates that the area was once covered by water.

Evolution

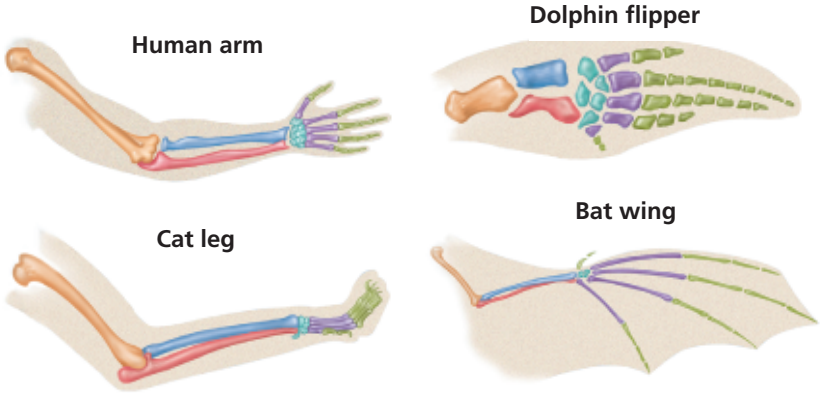
Fossils indicate the kinds of organisms that lived when rock formed. By examining rock layers and fossils, scientists have discovered evidence that species of living things have changed over time. Scientists call this process evolution. **Evolution** is the gradual development of new organisms from preexisting organisms. Scientists think that evolution occurs by means of natural selection. Evidence for evolution includes the similarity in skeletal structures of animals, as shown in **Figure 1.** The theory of evolution by natural selection was proposed in 1859 by Charles Darwin, an English naturalist.

evolution the process of change by which new species develop from preexisting species over time

Evolution and Geologic Change

Major geologic and climatic changes can affect the ability of some organisms to survive. For example, dramatic changes in sea level greatly affect organisms that live in coastal areas. By using geologic evidence, scientists try to determine how environmental changes affected organisms in the past. The fossil record shows that some organisms survived environmental changes, while other organisms disappeared. Scientists use fossils to learn why some organisms survived long periods of time without changing, while other organisms changed or became extinct.

Figure 1 Bones in the front limbs of these animals are similar, even though the limbs are used in different ways. Similar structures indicate a common ancestor.



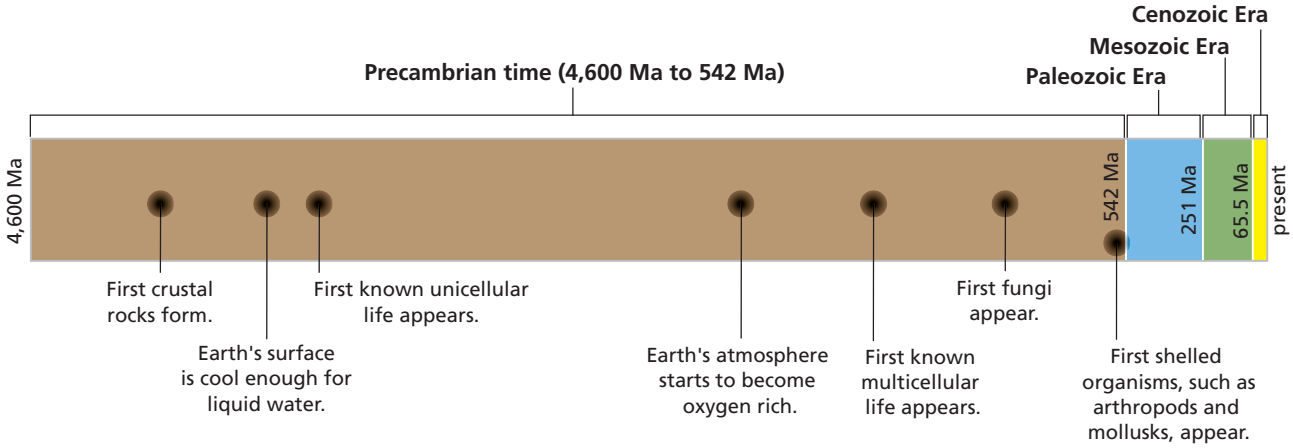


Figure 2 Precambrian Timeline *How many million years ago did the first unicellular life appear?*

Precambrian Time

Most scientists agree that Earth formed about 4.6 billion years ago as a large cloud, or *nebula*, spun around the newly formed sun. As material spun around the sun, particles of matter began to clump together and eventually formed Earth and the other planets of the solar system. The time interval that began with the formation of Earth and ended about 542 million years ago is known as **Precambrian time.** This division of geologic time makes up about 88% of Earth's history, as shown in **Figure 2.**

Precambrian time the interval of time in the geologic time scale from Earth's formation to the beginning of the Paleozoic era, from 4.6 billion to 542 million years ago

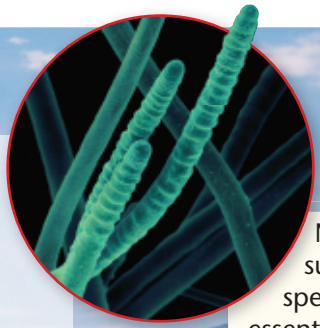
Even though Precambrian time makes up such a large part of Earth's history, we know relatively little about what happened during that time. We lack information partly because the Precambrian rock record is difficult to interpret. Most Precambrian rocks have been so severely deformed and altered by tectonic activity that the original order of rock layers is rarely identifiable.

Reading Check **How old is Earth?**

Why It Matters

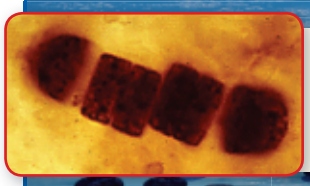
Long-Term Survivors

Some species alive today have survived for billions of years. Cyanobacteria—sometimes called blue-green bacteria—are one important example. Earth's early atmosphere contained no free oxygen, so it would be toxic to most organisms living today. Along with other photosynthetic organisms, cyanobacteria produced oxygen that built up in the atmosphere. This alteration of the atmosphere allowed oxygen-breathing animals to evolve.



EYE ON THE ENVIRONMENT

Modern cyanobacteria such as these belong to species that have survived essentially unchanged through the vast span of geologic time.



These cyanobacteria fossils come from rock that is one billion years old. Other cyanobacteria fossils are more than 3.5 billion years old.

YOUR TURN

UNDERSTANDING CONCEPTS

How did early photosynthetic organisms such as cyanobacteria affect Earth's atmosphere?

Precambrian Rocks

Large areas of exposed Precambrian rocks, called *shields*, exist on every continent except Antarctica. Precambrian shields are the result of several hundred million years of volcanic activity, mountain building, sedimentation, and metamorphism. After they were metamorphosed and deformed, the rocks of North America's Precambrian shield were uplifted and exposed at Earth's surface. Nearly half of the valuable mineral deposits in the world occur in the rocks of Precambrian shields. These valuable minerals include nickel, iron, gold, and copper.

Figure 3 Stromatolites contain layers of sediments that are cemented together by mats of cyanobacteria. Cyanobacteria are the most common Precambrian fossils.

Precambrian Life

Fossils are rare in Precambrian rocks, probably because Precambrian life-forms lacked bones, shells, or other hard parts that commonly form fossils. Also, Precambrian rocks are extremely old. Some date back nearly 3.9 billion years. Over this long period of time, volcanic activity, erosion, and extensive crustal movements, such as folding and faulting, probably destroyed most of the fossils that may have formed during Precambrian time.

Of the few Precambrian fossils that have been discovered, the most common are cyanobacteria in *stromatolites*, or layered, reef-like deposits. Stromatolites form today in warm, shallow waters, as shown in **Figure 3.** The presence of stromatolites in Precambrian rocks indicates that shallow seas covered much of Earth during intervals of Precambrian time. Fossils of marine worms, jellyfish, and single-celled organisms have also been discovered in rocks from late Precambrian time.

Academic Vocabulary

expose (eks POHZ) to present to view; to reveal; to uncover

Quick Lab Chocolate Candy Survival

10 min

Procedure

1. Lay a piece of colorful cloth on a table.
2. Randomly sprinkle a handful of candy-coated chocolate bits on the cloth.
3. Look away for 1 min; then look back.
4. For 10 s, pick up chocolate bits one at a time. Record the colors of candy you picked up.
5. Repeat steps 1–4 with a piece of colorful cloth that has a different pattern.

Analysis

1. What colors were you more likely to pick up in the first trial? What about those candies made you pick them up?
2. When you changed the color of the cloth, did the color of the candies you picked up change?
3. How could camouflage help an organism survive?

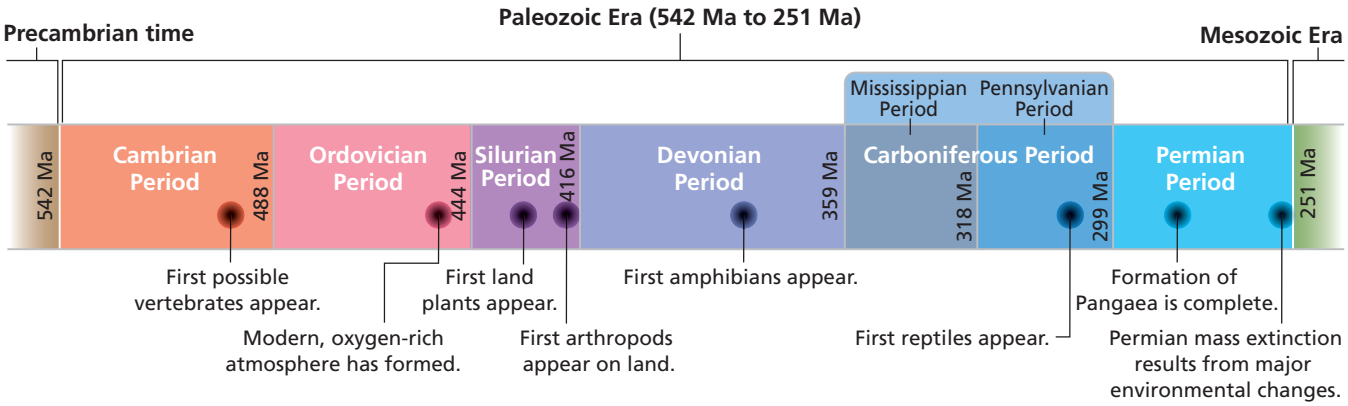


Figure 4 Paleozoic Timeline

The Paleozoic Era

Paleozoic Era the geologic era that followed Precambrian time and that lasted from 542 million to 251 million years ago

As shown in **Figure 4,** the geologic era that began about 542 million years ago and ended about 251 million years ago is called the **Paleozoic Era.** At the beginning of the Paleozoic Era, Earth's landmasses were scattered around the world. By the end of the Paleozoic Era, these landmasses had collided to form the supercontinent Pangaea. This tectonic activity created new mountain ranges and lifted large areas of land above sea level.

Unlike Precambrian rocks, Paleozoic rocks hold an abundance of fossils. The number of plant and animal species on Earth increased dramatically at the beginning of the Paleozoic Era. Because of this rich fossil record, North American geologists have divided the Paleozoic Era into six periods.

The Cambrian Period

The Cambrian Period is the first period of the Paleozoic Era. A variety of marine life-forms appeared during this period. These Cambrian life-forms were more advanced than previous life-forms and quickly displaced the primitive organisms as the dominant life-forms. The explosion of Cambrian life may have been partly due to the warm, shallow seas that covered much of the continents during the time period. Marine *invertebrates*, or animals that do not have backbones, thrived in the warm waters. The most common of the Cambrian invertebrates were *trilobites*, such as the one shown in **Figure 5.** Scientists use many trilobites as *index fossils* to date rocks to the Cambrian Period.

Figure 5 During the early Paleozoic Era, various types of trilobites, such as this fossilized trilobite of the genus *Modocia*, flourished in the warm, shallow seas.

Another group of common animals in the Cambrian Period were the *brachiopods*, which are shelled animals. Fossils indicate that at least 15 different families of brachiopods existed during this period. A few kinds of brachiopods exist today, but modern brachiopods are rare. Other Cambrian invertebrates included worms, jellyfish, snails, and sponges. However, little evidence of land-dwelling plants or animals has been discovered in Cambrian rocks.

Reading Check **Name three common invertebrates from the Cambrian Period.**

Figure 6 During the Silurian Period, eurypterids lived in shallow lagoons. Eurypterids had one pair of legs for swimming and had four or five pairs for walking.

The Ordovician Period

During the Ordovician (AWR duh VISH uhn) Period, the number of trilobite species began to shrink. Brachiopods, bryozoans, and cephalopod mollusks became the dominant invertebrate lifeforms. Large numbers of corals appeared. Colonies of tiny invertebrates called *graptolites* also flourished in the oceans, and primitive fish appeared. By this period, *vertebrates*, or animals that have backbones, had appeared. The most primitive vertebrates were fish. Unlike modern fish, Ordovician fish did not have jaws or teeth, and their bodies were covered with thick, bony plates. During the Ordovician Period, as during the Cambrian Period, there was little plant life on land.

The Silurian Period

Vertebrate and invertebrate marine life continued to thrive during the Silurian Period. Echinoderms, relatives of modern sea stars, and corals became more common. Scorpion-like sea creatures called *eurypterids* (yoo RIP tuhr IDZ), such as the one shown in **Figure 6,** also existed during the Silurian Period. Fossils of giant eurypterids about 2 m long have been discovered in western New York. Near the end of this period, the earliest vascular land plants as well as animals, such as scorpions, evolved on land.

The Devonian Period

The Devonian Period is called the *Age of Fishes* because fossils of many bony fishes were discovered in rocks of this period. One type of fish, called a *lungfish*, had the ability to breathe air. Other air-breathing fish, called *rhipidistians* (RIE puh DIS tee uhnz), had strong fins that may have allowed them to crawl onto the land for short periods of time. Early amphibians probably evolved from rhipidistians. *Ichthyostega* (IK thee oh STEG uh), early amphibians that resembled huge salamanders, are thought to be the ancestors of modern amphibians such as frogs and toads. During the Devonian Period, land plants, such as giant horsetails, ferns, and seed-bearing plants, also began to develop. In the sea, brachiopods and mollusks continued to thrive.

READING TOOLBOX

Spider Map

Make a spider map that has six legs and several lines on each leg. Use the map to describe the six periods in the Paleozoic Era.

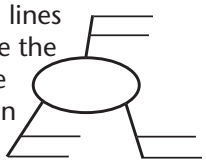


Figure 7 During the Carboniferous Period, crinoids, such as the one shown here, were common in the oceans. Crinoids are thought to be ancestors of modern animals called sea lillies.

The Carboniferous Period

During the Carboniferous Period, the climate was generally warm, and the humidity was at times very high over most of the world. Forests and swamps covered much of the land. Coal deposits in Pennsylvania, Ohio, and West Virginia are the fossilized remains of these forests and swamps. During this period, the rock in which some major oil deposits occur also formed. *Carboniferous* means "carbon bearing." In North America, the Carboniferous Period is divided into the Mississippian and Pennsylvanian Periods.

Amphibians and fish continued to flourish during the Carboniferous Period. *Crinoids*, like the one shown in **Figure 7,** were common in the oceans. Insects, such as giant cockroaches and dragonflies, were common on land. Toward the end of the Carboniferous Period, vertebrates that were adapted to life on land appeared. These early reptiles resembled large lizards.

The Permian Period

The Permian Period marks the end of the Paleozoic Era. A *mass extinction* of a large number of Paleozoic life-forms occurred at the end of the Permian Period. The continents had joined to form the supercontinent Pangaea. The collision of tectonic plates created the Appalachian Mountains. On the northwest side of the mountains, areas of desert and dry savanna climates developed. The shallow inland seas that had covered much of Earth disappeared. As the seas retreated, many species of marine invertebrates, including trilobites and eurypterids, became extinct. However, fossils indicate that reptiles and amphibians survived the environmental changes and dominated Earth in the millions of years that followed the Paleozoic Era.

Section 2 Review

Key Ideas

1. **Summarize** how evolution is related to geologic change.
2. **Identify** two characteristics of most Precambrian rocks.
3. **Explain** why fossils are rare in Precambrian rocks.
4. **Identify** one life-form from each of the six periods of the Paleozoic Era.
5. **Explain** why the Devonian Period is commonly called the *Age of Fishes*.
6. **Describe** the kinds of life-forms that became extinct during the mass extinction at the end of the Permian Period.

Critical Thinking

7. **Drawing Conclusions** Identify one way in which the formation of Pangaea affected Paleozoic life.
8. **Identifying Relationships** Why is Precambrian time—about 88% of geologic time—not divided into smaller units based on the fossil record?
9. **Analyzing Processes** Explain two ways in which the geologic record of the Paleozoic Era supports the theory of evolution.

Concept Mapping

10. Use the following terms to create a concept map: *Paleozoic Era, invertebrate, Cambrian Period, Ordovician Period, vertebrate,* and *Silurian Period.*

SECTION 3

The Mesozoic and Cenozoic Eras

Key Ideas	Key Terms	Why It Matters
❯ List the periods of the Mesozoic and Cenozoic Eras. ❯ Identify two major geologic and biological developments during the Mesozoic Era. ❯ Identify two major geologic and biological developments during the Cenozoic Era.	**mass extinction** **Mesozoic Era** **Cenozoic Era**	The movement of tectonic plates and the evolution and extinction of organisms have shaped the world we live in today. Our world continues to change as these processes continue.

At the end of the Permian Period, 90% of marine organisms and more than 70% of land organisms died. This episode during which an enormous number of species died, or **mass extinction,** left many resources available for the surviving life-forms. Because resources and space were readily available, an abundance of new life-forms appeared. These new life-forms evolved, and some flourished while others eventually became extinct.

The Mesozoic Era

As shown in **Figure 1,** the geologic era that began about 251 million years ago and ended about 65 million years ago is called the **Mesozoic Era.** Earth's surface changed dramatically during the Mesozoic Era. As Pangaea broke into smaller continents, the tectonic plates drifted and collided. These collisions uplifted mountain ranges such as the Sierra Nevada in California and the Andes in South America. Shallow seas and marshes covered much of the land. In general, the climate was warm and humid.

Conditions during the Mesozoic Era favored the survival of reptiles. Lizards, turtles, crocodiles, snakes, and a variety of dinosaurs flourished during the Mesozoic Era. Thus, this era is also known as the *Age of Reptiles*. The Mesozoic Era has a rich fossil record and is divided into three periods.

mass extinction an episode during which large numbers of species become extinct

Mesozoic Era the geologic era that lasted from 251 million to 65.5 million years ago; also called the *Age of Reptiles*

Figure 1 Mesozoic Timeline

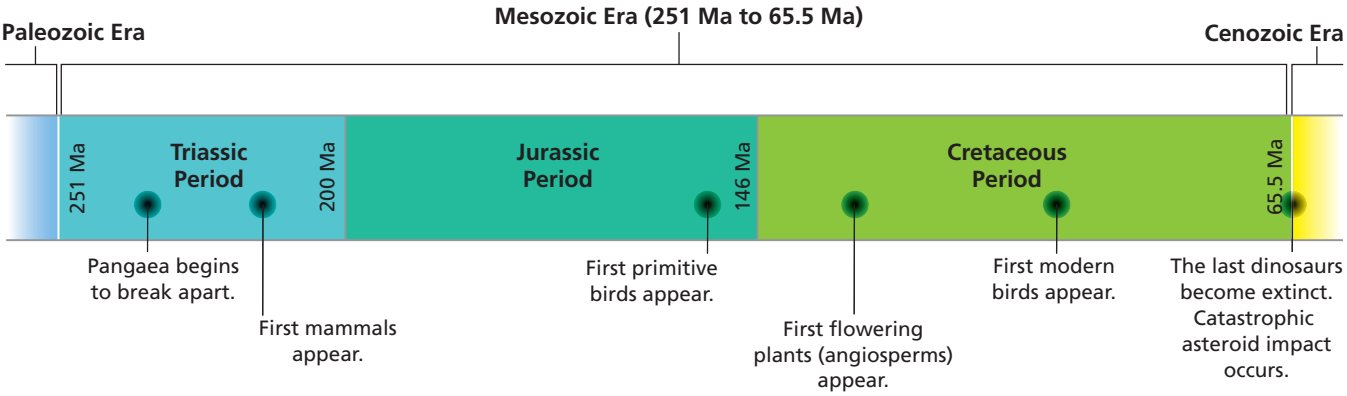


Figure 2 A group of dinosaurs of the genus *Coelophysis* race through a Triassic conifer forest in what is now New Mexico.

The Triassic Period

Dinosaurs flourished during the Triassic Period of the Mesozoic Era. Some dinosaurs were the size of squirrels. Others weighed as much as 15 tons and were nearly 30 m long. However, most of the dinosaurs of the Triassic Period were about 2 m to 5 m long and moved very quickly. As shown in **Figure 2,** these dinosaurs roamed through lush forests of cone-bearing trees and *cycads*, which are thick-stemmed plants with crowns of fern-like leaves.

Reptiles called *ichthyosaurs* lived in the Triassic oceans. New forms of marine invertebrates also evolved. The most distinctive was the ammonite, a type of shellfish that is similar to the modern nautilus. Ammonites serve as Mesozoic index fossils. The first mammals, small rodent-like forest dwellers, also appeared.

The Jurassic Period

Academic Vocabulary

dominant (DAHM uh nuhnt) having the greatest effect; most numerous

Dinosaurs became the dominant life-form during the Jurassic Period. Fossil records indicate that two major groups of dinosaurs evolved. These groups are distinguished by their hip-bone structures. One group, called *saurischians*, or "lizard-hipped" dinosaurs, included herbivores, which are plant eaters, and carnivores, which are meat eaters. Among the largest saurischians were herbivores of the genus *Apatosaurus*, once known as *Brontosaurus*, which weighed up to 50 tons and grew up to 25 m long.

The other major group of Jurassic dinosaurs, called *ornithischians*, or "bird-hipped" dinosaurs, were herbivores. Among the best known of the ornithischians were herbivores of the genus *Stegosaurus*, which were about 9 m long and about 3 m tall at the hips. In addition, flying reptiles called *pterosaurs* were common during the Jurassic Period. Like modern bats, pterosaurs flew on skin-covered wings. Fossils of the earliest birds, such as the one shown in **Figure 3,** also occur in Jurassic rocks.

Reading Check **Name two fossils that were discovered in the fossil record of the Jurassic Period.**

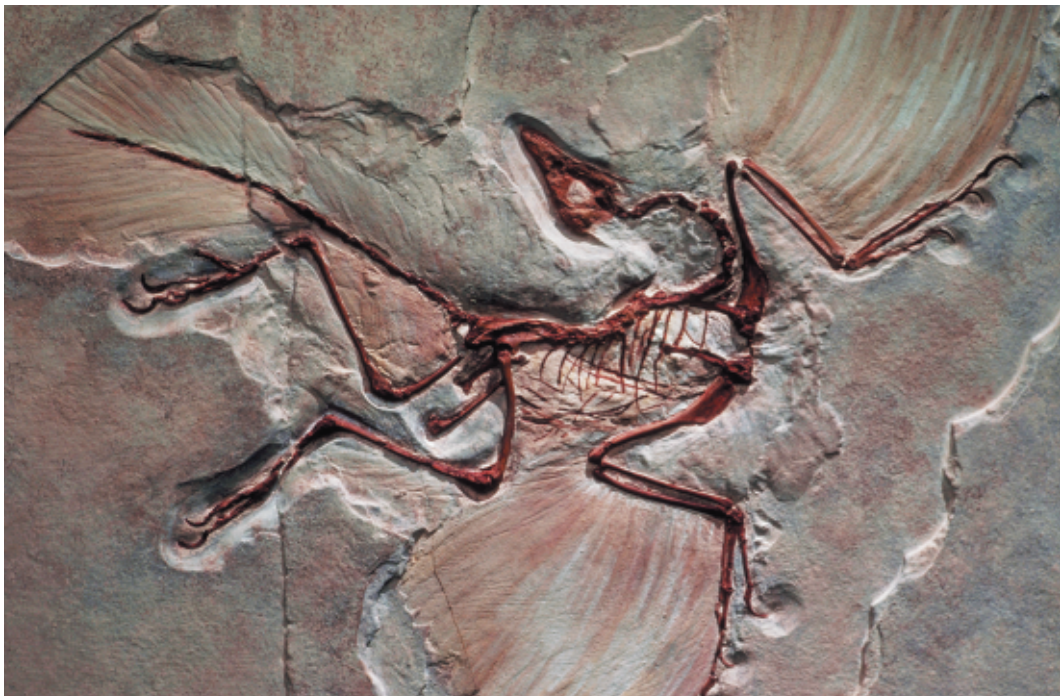


Figure 3 The *Archaeopteryx* (AWR kee AUP tuhr IKS) was one of the first birds that appeared during the Jurassic Period.

Figure 4 This 12.5-m-long *Tyrannosaurus rex* was discovered near Faith, South Dakota. This specimen, named Sue, was displayed in the Field Museum in Chicago in 2000.

The Cretaceous Period

Dinosaurs continued to dominate Earth during the Cretaceous Period. Among the most spectacular dinosaurs was the carnivore *Tyrannosaurus rex*, such as the one shown in **Figure 4.** The *Tyrannosaurus rex* stood nearly 6 m tall and had huge jaws with sharp teeth that were up to 15 cm long. Also, among the common Cretaceous dinosaurs were the armored *ankylosaurs*, horned dinosaurs called *ceratopsians*, and duck-billed dinosaurs called *hadrosaurs*.

Plant life had become very sophisticated by the Cretaceous Period. The earliest flowering plants, or *angiosperms*, appeared during this period. The most common of these plants were trees such as magnolias and willows. Later, trees such as maples, oaks, and walnuts became abundant. Angiosperms became so successful that they are the dominant type of land plant today.

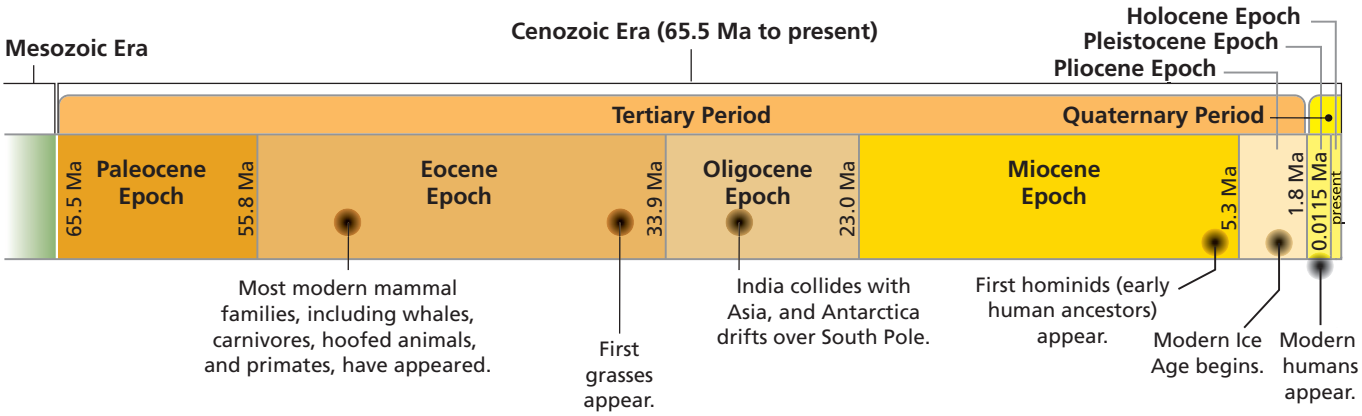
SCILINKS.
www.scilinks.org
Topic: Mass Extinctions
Code: **HQX0916**
Topic: Geologic Time Scale
Code: **HQX0669**

The Cretaceous-Tertiary Mass Extinction

The Cretaceous Period ended in another mass extinction. No dinosaur fossils have been found in rocks that formed after the Cretaceous Period. Some scientists think that this extinction was caused by environmental changes resulting from the movement of continents and increased volcanic activity.

However, many scientists accept the *impact hypothesis* as the explanation for the extinction of the last dinosaurs. This hypothesis is that about 65 million years ago, an asteroid crashed into Earth. The impact of the collision raised enough dust to block the sun's rays for many years. As Earth's climate became cooler, plant life began to die, and many animal species became extinct. As the dust settled over Earth, the dust formed a layer of iridium-laden sediment. Iridium is a chemical element that is uncommon in rocks on Earth but that is common in meteorites.

Figure 5 Cenozoic Timeline



Cenozoic Era the current geologic era, which began 65.5 million years ago; also called the *Age of Mammals*

The Cenozoic Era

As shown in **Figure 5,** the **Cenozoic Era** is the division of geologic time that began about 65 million years ago and that includes the present period. During this era, the continents moved to their present-day positions. As tectonic plates collided, huge mountain ranges, such as the Alps and the Himalayas in Eurasia, formed.

During the Cenozoic Era, dramatic changes in climate have occurred. At times, continental ice sheets covered nearly one-third of Earth's land. As temperatures decreased during the ice ages, new species that were adapted to life in cooler climates appeared. Mammals became the dominant life-form and underwent many changes. The Cenozoic Era is thus commonly called the *Age of Mammals*.

READING TOOLBOX

Prefixes

Make a table that lists the names of the epochs of the Cenozoic Era. Give the meaning of each prefix attached to the suffix *-cene*.

The Tertiary and Quaternary Periods

The Cenozoic Era is divided into two periods. The Tertiary Period includes the time before the last ice age. The Quaternary Period began with the last ice age and includes the present. These periods have been divided into seven epochs. The Paleocene, Eocene, Oligocene, Miocene, and Pliocene Epochs make up the *Tertiary Period*. The Pleistocene and Holocene Epochs make up the *Quaternary Period*.

Figure 6 The *tarsier* is the sole modern survivor of a group of primates common during the earlier Cenozoic Era. ***Why are mammals better suited to cool climates than reptiles are?***

The Paleocene and Eocene Epochs

The fossil record indicates that during the Paleocene Epoch, many new mammals, such as small rodents, evolved. The first primates also evolved during the Paleocene Epoch. A modern survivor of an early primate group is shown in **Figure 6.**

Other mammals, including the earliest known ancestor of the horse, evolved during the Eocene Epoch. Fossil records indicate that the first whales, flying squirrels, and bats appeared during this epoch. Small reptiles continued to flourish. Worldwide, temperatures dropped by about 4 °C at the end of the Eocene Epoch.

The Oligocene and Miocene Epochs

During the Oligocene Epoch, the Indian subcontinent began to collide with the Eurasian continent, which caused the uplifting of the Himalayas. The worldwide climate became significantly cooler and drier. This change in climate favored grasses as well as cone-bearing and hardwood trees. Many early mammals became extinct. However, large species of deer, pigs, horses, camels, cats, and dogs flourished. Marine invertebrates, especially clams and snails, also continued to flourish.

During the Miocene Epoch, circumpolar currents formed around Antarctica, and the modern Antarctic icecap began to form. By the late Miocene Epoch, tectonic forces and dropping sea levels caused the Mediterranean Sea to dry up and refill several times. The largest known land mammals existed during this epoch. Miocene rocks contain fossils of horses, camels, deer, rhinoceroses, pigs, raccoons, wolves, foxes, and the earliest saber-toothed cats, which are now extinct. The earliest human ancestors may date to this epoch.

SCILINKS
www.scilinks.org
Topic: Geologic Periods and Epochs
Code: HQX0667

The Pliocene Epoch

During the Pliocene Epoch, predators—including members of the bear, dog, and cat families—evolved into modern forms. Herbivores, such as the giant ground sloth shown in **Figure 7,** flourished. The first modern horses also appeared in this epoch.

Toward the end of the Pliocene, dramatic climatic changes occurred, and the continental ice sheets began to spread. With more and more water locked in ice, sea level fell. The Bering land bridge appeared between Eurasia and North America. Changes in Earth's crust between North America and South America formed the Central American land bridge. Various species migrated between the continents across these two land bridges.

Reading Check **Why did sea level fall in the Pliocene Epoch?**

Figure 7 Giant ground sloths lived during the late Pliocene in parts of North America and South America. These slow-moving leaf-eaters could grow as large as an African bull elephant and weigh as much as 5 tons.

Figure 8 This painting from the Stone Age was made by early humans between 15,000 and 13,000 years ago in a cave in Lascaux, France.

The Pleistocene Epoch

The Pleistocene Epoch began 1.8 million years ago. In Eurasia and North America, ice sheets advanced and retreated several times. Some animals had characteristics that allowed them to endure the cold climate, such as the thick fur that covered woolly mammoths and woolly rhinoceroses. Many other species survived by moving to warmer regions. Some species, such as giant ground sloths and dire wolves, became extinct.

Fossils of the earliest modern humans (*Homo sapiens*) were discovered in Pleistocene sediments. Evidence of modern humans, such as the cave painting shown in **Figure 8,** indicates that early humans may have been hunters.

The Holocene Epoch

The Holocene Epoch, which includes the present, began about 11,500 years ago, as the last glacial period ended. As the ice sheets melted, sea level rose about 140 m, and the coastlines took on their present shapes. The North American Great Lakes also formed as the last ice sheets retreated. During the early Holocene Epoch, modern humans developed agriculture and began to make and use tools made of bronze and iron.

Human history is extremely brief. If you think of the entire history of Earth as one year, the first multicellular organisms would have appeared in September. The dinosaurs would have disappeared at 8 P.M. on December 26. Modern humans would not have appeared until 11:48 P.M. on December 31.

Section 3 Review

Key Ideas

1. **List** the periods of the Mesozoic Era, and describe one major life-form in each period.
2. **Identify** two major geologic and two major biological developments of the Mesozoic Era.
3. **List** the periods and epochs of the Cenozoic Era, and describe one major life-form in each division.
4. **Identify** two major geologic and two major biological developments of the Cenozoic Era.
5. **Explain** how the ice ages affected animal life during the Cenozoic Era.
6. **Identify** the era, period, and epoch we are in today.
7. **Describe** the worldwide environmental changes that set the stage for the Age of Mammals.

Critical Thinking

8. **Drawing Conclusions** Explain the criteria that scientists may have used to divide the Cenozoic Era into the Tertiary and Quaternary Periods.
9. **Identifying Relationships** Suppose that you are a geologist who is looking for the boundary between the Cretaceous and Tertiary Periods in an outcrop. What characteristics would you look for to determine the location of the boundary? Explain your answer.

Concept Mapping

10. Use the following terms to create a concept map: *Mesozoic Era, Age of Reptiles, Jurassic Period, Triassic Period, Cretaceous Period, Cenozoic Era, Age of Mammals, Tertiary Period,* and *Quaternary Period.*

Why It Matters

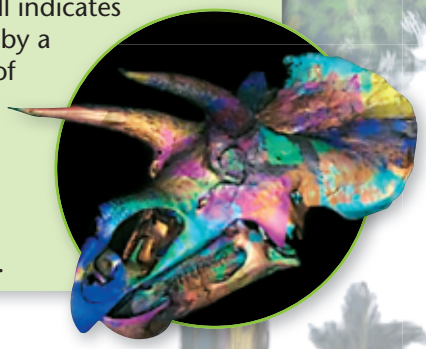
Reconstructing the Past

HISTORY IN SCIENCE

From films and books, most people can visualize the walk and long, swaying neck of an *Apatosaurus,* such as the one shown reaching for tree leaves. Dinosaurs became extinct millions of years ago. How do we know so much about them? Scientists use fossil evidence to reconstruct the bodies and lives of dinosaurs.

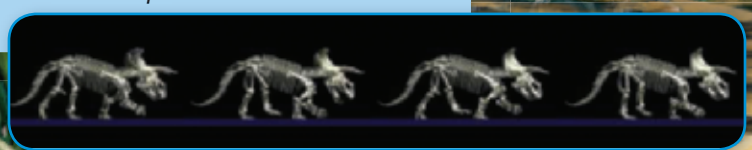
Scanning technology lets scientists analyze fossil evidence in a new way. By digitizing bones using CT and X-ray scanners, researchers can build detailed computer models of dinosaur skeletons. These models show how dinosaur bones functioned in living animals, helping us understand how dinosaurs looked and behaved, without resorting to cutting or slicing up the specimens.

Scientists have digitized a *Triceratops* skeleton for study and to replace missing bones.



Each color of the digital *Triceratops* skull indicates data collected by a different pass of a 3D surface scanner. The passes were combined to "build" a complete skull.

Fossilized dinosaur tracks show that *Apatosaurus* behaved like modern herd animals, with the youngest animals in the center for protection.



Scientists use a digitized *Triceratops* skeleton to study the mechanics of this huge creature. This sequence shows how *Triceratops* moved as it walked.

YOUR TURN

UNDERSTANDING CONCEPTS
How has technology aided in the study of dinosaurs?

ONLINE RESEARCH
Research techniques used to digitize a *Triceratops* at the National Museum of Natural History. Describe the importance of this work.

Skills Practice Lab

45 min

History in the Rocks

Geologists have discovered much about the geologic history of Earth by studying the arrangement of fossils in rock layers, as well as by studying the arrangement of the rock layers themselves. Fossils provide clues about the environment in which the organisms that formed the fossils existed. Scientists can determine the age of the rocks in which fossils occur because the ages of many fossils have been determined by radiometric dating of associated igneous rocks. Radiometric dating, fossil age, and rock arrangement are all used to determine changes that have occurred in the arrangement of the rock layers through geologic time. In this lab, you will discover how the geologic history of an area can be determined by examining the arrangement of fossils and rock layers.

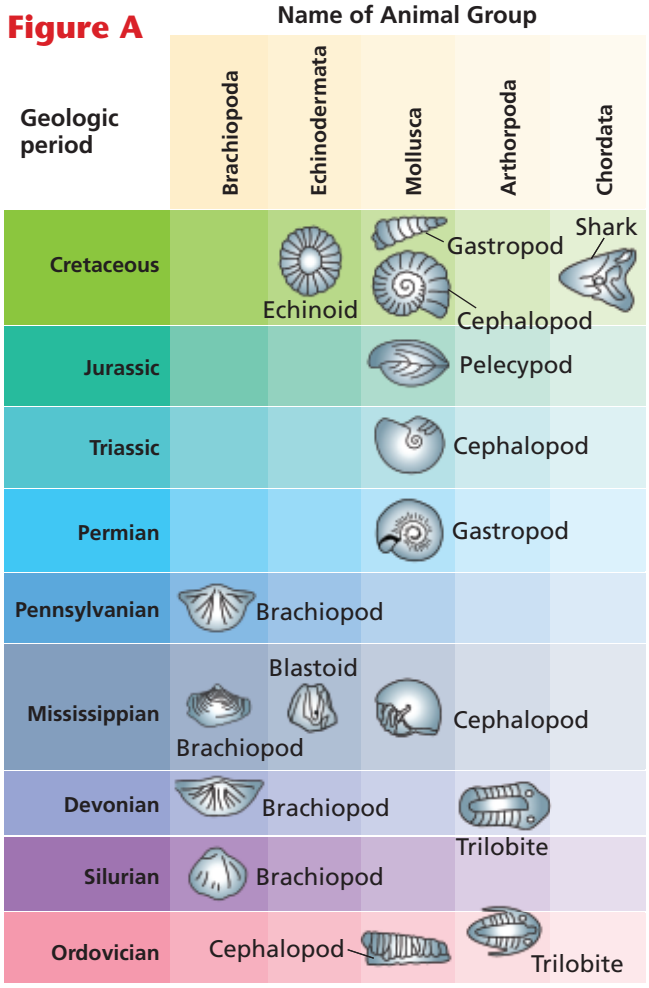
What You'll Do

- **Apply** the law of superposition to sample rock columns.
- **Demonstrate** the use of index fossils for determining relative and absolute ages.
- **Evaluate** the usefulness of different methods for determining relative and absolute ages.

What You'll Need

paper
pencil

Figure A



Procedure

1. Study the index fossils shown in **Figure A.** Note their placement in related groups and the geologic periods in which they lived.
2. Select one of the four rock columns shown in **Figure B.** This figure shows how some of these fossils may occur in a series of rock layers. Record the number of the arrangement that you are using.
3. Using **Figure A,** identify all the fossils in your column and the geologic time in which the organisms that formed the fossils lived.
4. List the fossil names in order from bottom to top.
5. Do the fossils in your column appear in the order of geologic time?
6. Do the fossils in your column show a complete sequence of geologic periods? If not, which periods are missing?
7. Repeat steps 2–6 with each of the other three rock columns.

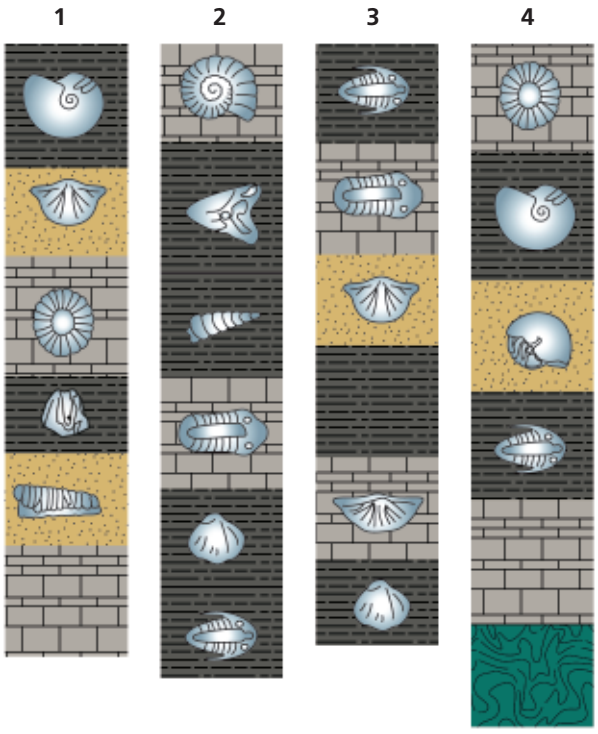


Figure B

Analysis

1. **Analyzing Processes** What processes or events might explain the order of the fossils in each of the rock columns?
2. **Evaluating Assumptions** Based on your observations in the procedure, why is it necessary that a fossil be found in a wide variety of geographic areas for it to be considered an index fossil?
3. **Explaining Events** Study arrangement 3 in **Figure B**. Note that there is a rock layer that contains no fossils between two rock layers that contain fossils. How might this have occurred?

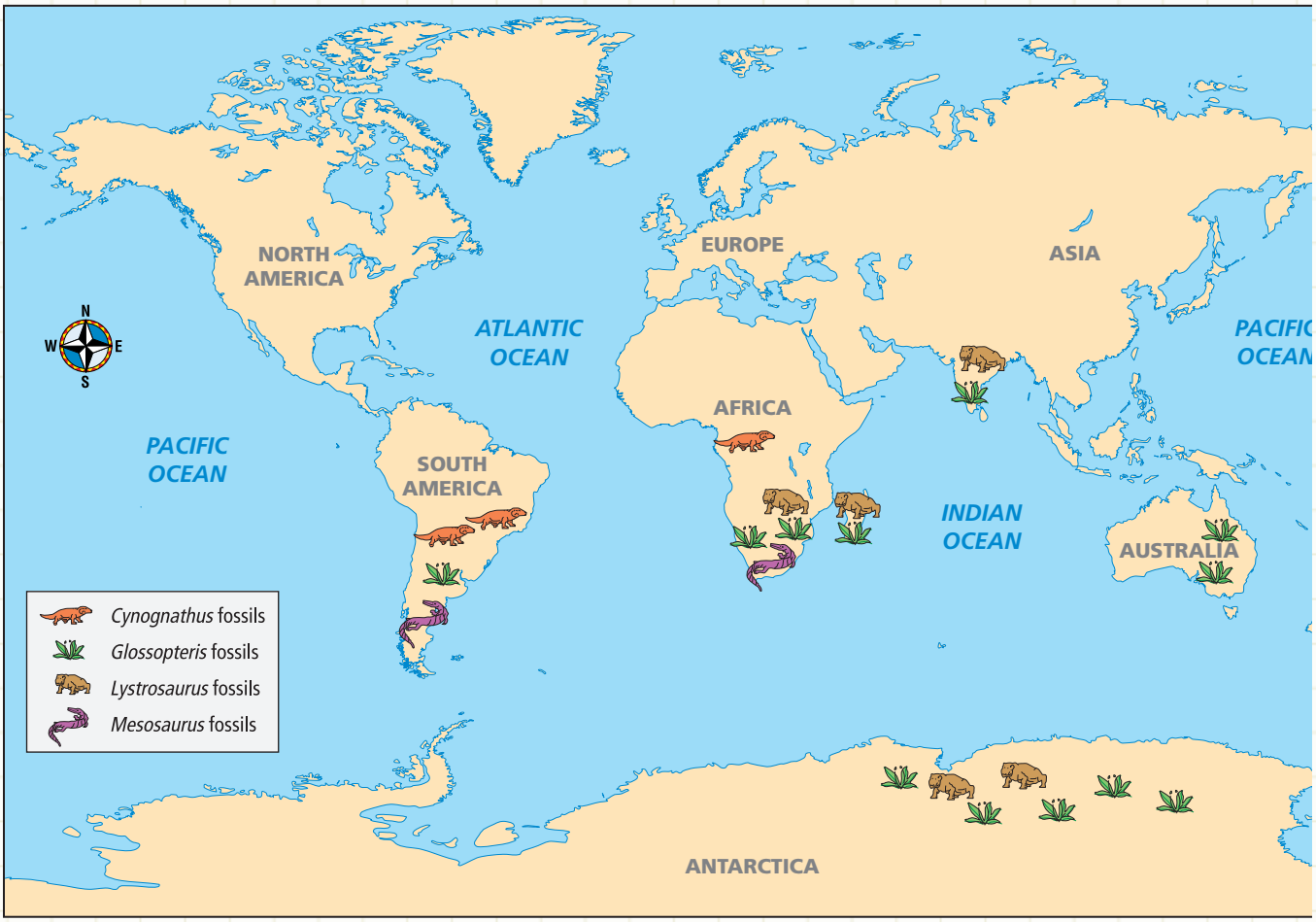
Extension

Examining Data Collect fossils in your area. Identify the fossils you have collected, and describe what your area was like when the organisms existed.

Research Find out how index fossils are used to help petroleum geologists locate oil reservoirs. Then, use that information to give an oral report to your class.

MAPS in Action

Fossil Evidence for Gondwanaland



Map Skills Activity

This map shows areas where selected fossils have been found. Use the map to answer the questions below.

1. **Using a Key** On which continents have fossils of plants of the genus *Glossopteris* been found?
2. **Using a Key** On which continents have fossils of organisms of the genus *Lystrosaurus* been found?
3. **Making Comparisons** Which fossil shown on the map was spread over the smallest area?
4. **Inferring Relationships** Based on the map, which continents were connected to Africa when the continents formed a supercontinent?
5. **Inferring Relationships** Based on the map, which continents were connected to Antarctica when the continents formed a supercontinent?
6. **Analyzing Relationships** How would you argue against a claim that plants of the genus *Glossopteris* evolved independently on separate continents or were transported between continents that were not connected? Explain your answer.
7. **Identifying Trends** If the continents were to continue the motion they have had since the time when they formed Gondwanaland, would you expect the east coast of South America and the west coast of Africa to be moving closer together or farther apart? Explain your answer.

Chapter 9

Summary

THINK central
SUPER SUMMARY
Keyword: HQXVEPS

Key Ideas | **Key Terms**

Section 1

Geologic Time

- Scientists developed the geologic column based on observations of the relative ages of rock layers throughout the world.
- Scientists used major changes in Earth's climate and extinctions recorded in the fossil record to divide the geologic time scale into smaller units. Geologic time is subdivided into eons, eras, periods, epochs, and ages.

geologic column, p. 229
era, p. 232
period, p. 232
epoch, p. 232

Section 2

Precambrian Time and the Paleozoic Era

- Evolution is the gradual development of organisms from other organisms. Evidence for the theory of evolution occurs throughout the fossil record.
- Precambrian rock contains valuable minerals but few fossils.
- The rock record reveals the formation of Pangaea and the evolution of marine invertebrates and vertebrates during the Paleozoic Era.

evolution, p. 233
Precambrian time, p. 234
Paleozoic Era, p. 236

Section 3

The Mesozoic and Cenozoic Eras

- The periods of the Mesozoic Era are the Triassic, Jurassic, and Cretaceous Periods; the periods of the Cenozoic Era are the Tertiary and Quaternary Periods.
- During the Mesozoic Era, Pangaea began to break apart, mountain ranges such as the Sierra Nevada formed, and the first mammals and flowering plants appeared.
- During the Cenozoic Era, India collided with Asia, Antarctica moved over the South Pole, and most modern mammal families, including humans, appeared.

mass extinction, p. 239
Mesozoic Era, p. 239
Cenozoic Era, p. 242

Chapter 9 Review

1. **Spider Map** Make a spider map for mass extinctions. Add one leg for the Permian mass extinction and one leg for the Cretaceous-Tertiary mass extinction. To each leg, add details about the mass extinction.

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *evolution*
3. *geologic column*
4. *period*

For each pair of terms, explain how the meanings of the terms differ.

5. *era* and *epoch*
6. *period* and *era*
7. *Mesozoic Era* and *Cenozoic Era*
8. *Precambrian time* and *Paleozoic Era*

UNDERSTANDING KEY IDEAS

9. The geologic time scale is a
   a. scale for weighing rocks.
   b. scale that divides Earth's history into time intervals.
   c. rock record of Earth's past.
   d. collection of the same kind of rocks.
10. Scientists are able to determine the absolute ages of most rock layers in a geologic column by using
    a. the law of superposition.
    b. radiometric dating.
    c. rates of deposition.
    d. rates of erosion.
11. To determine the age of a specific rock, scientists might correlate it with a layer in a geologic column that has the same relative position and
    a. fossil content.
    b. weight.
    c. temperature.
    d. density.
12. Geologic periods can be divided into
    a. eras. **c.** days.
    b. epochs. **d.** months.
13. Precambrian time ended about
    a. 4.6 billion years ago.
    b. 542 million years ago.
    c. 65 million years ago.
    d. 25 thousand years ago.
14. The most common fossils that occur in Precambrian rock are
    a. graptolites. **c.** eurypterids.
    b. trilobites. **d.** cyanobacteria.
15. The first vertebrates appeared during
    a. Precambrian time. **c.** the Mesozoic Era.
    b. the Paleozoic Era. **d.** the Cenozoic Era.
16. The *Age of Reptiles* is the name commonly given to
    a. Precambrian time. **c.** the Mesozoic Era.
    b. the Paleozoic Era. **d.** the Cenozoic Era.
17. The first flowering plants appeared during the
    a. Cretaceous Period.
    b. Triassic Period.
    c. Carboniferous Period.
    d. Ordovician Period.
18. The *Age of Mammals* is the name commonly given to
    a. Precambrian time. **c.** the Mesozoic Era.
    b. the Paleozoic Era. **d.** the Cenozoic Era.

SHORT ANSWER

19. Write a short paragraph describing the evolution of plants that is indicated by the fossil record.
20. Describe the events that may have led to the Cretaceous-Tertiary mass extinction. What evidence have scientists discovered that supports their hypothesis?
21. Describe the criteria that scientists use to divide a geologic column into different layers.
22. Identify two organisms that are found in the fossil record of a different geologic era but that are still living on Earth today. Identify what characteristic(s) have given them their long-term success.

CRITICAL THINKING

23. Analyzing Ideas Why can Precambrian time not be divided into periods by using fossils?

24. Applying Ideas Many coal and oil deposits formed during the Carboniferous Period. What element would you expect to find in both oil and coal?

25. Identifying Relationships What information in the geologic record might lead scientists to infer that shallow seas covered much of Earth during the Paleozoic Era?

26. Making Comparisons Compare the causes of the Permian mass extinction with those of the Cretaceous mass extinction.

CONCEPT MAPPING

27. Use the following terms to create a concept map: *geologic time, Paleozoic Era, Mesozoic Era, stromatolite, Precambrian time, eurypterid, crinoid, Cenozoic Era, trilobite, saurischian, ornithischian, dinosaur, mammal,* and *human*.

MATH SKILLS

Math Skills

28. Scientific Notation Write the beginning and end dates of each geologic era in scientific notation.

29. Making Calculations The Methuselah tree in California is 4.6×10^3 years old. How many times older than this tree is Earth ?

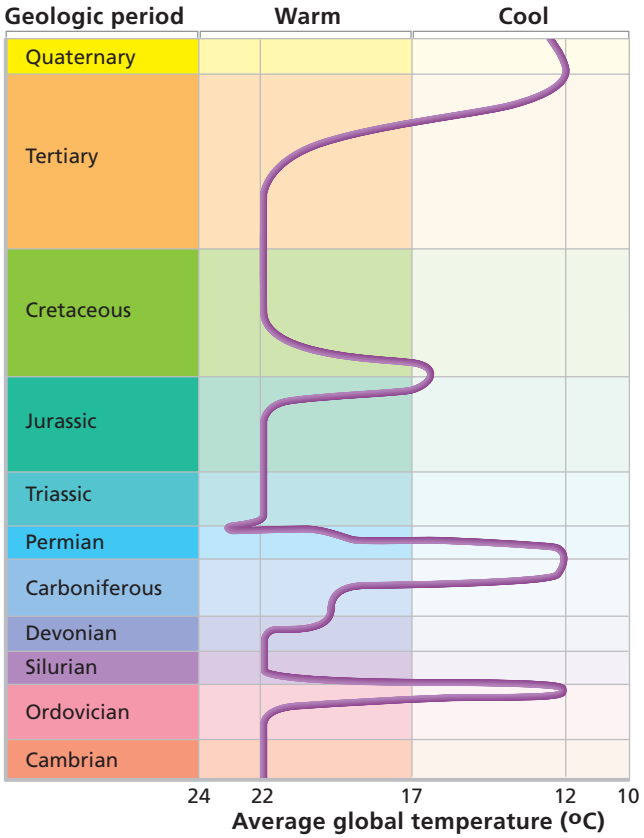
WRITING SKILLS

30. Creative Writing Write an essay about a trip back in time. Include descriptions of the organisms that lived during one of the geologic periods described in this chapter.

31. Writing from Research Research the discoveries made by British anthropologists Louis S.B. Leakey and Mary Leakey in Olduvai Gorge in Tanzania, Africa. Write a report about your findings.

INTERPRETING GRAPHICS

The graph below shows average global temperatures since Precambrian time. Use this graph to answer the questions that follow.



32. During which two periods was Earth's average global temperature the highest?

33. During which periods did Earth's average global temperature decrease?

34. Based on the graph, could long-term climate change have caused the Permian mass extinction? Is long-term climate change a likely cause of the mass extinction at the Cretaceous-Tertiary boundary? Explain your answer.

Chapter 9 Standardized Test Prep

Understanding Concepts

Directions (1–4): For each question, write on a separate sheet of paper the letter of the correct answer.

1. Dinosaurs first became the dominant life-forms during which geologic period?
- **A.** Quaternary Period
- **B.** Jurassic Period
- **C.** Triassic Period
- **D.** Cretaceous Period

2. Pangaea broke into separate continents during
- **F.** the Paleozoic Era.
- **G.** the Mesozoic Era.
- **H.** the Cenozoic Era.
- **I.** Precambrian time.

3. Why are fossils rarely found in Precambrian rock?
- **A.** Most Precambrian organisms did not have hard body parts that commonly form fossils.
- **B.** Precambrian rock is buried too deeply for geologists to study it.
- **C.** Most Precambrian organisms were too small to leave fossil remains.
- **D.** Precambrian rock is made of a material that prevented the formation of fossils.

4. Which of the following statements describes a principle of natural selection?
- **F.** The environment has more than enough resources to support all the individuals that are born in a given ecosystem.
- **G.** Only individuals well suited to the environment are likely to survive and reproduce.
- **H.** Individuals in a healthy population are identical and have the same traits.
- **I.** Most species produce plentiful offspring that will all live until maturity and reproduce.

Directions (5–7): For each question, write a short response.

5. What is the term for the largest unit of geologic time?

6. What is the term for the gradual development of organisms from other organisms by means of natural selection?

7. Why is the Cenozoic Era also known as the *Age of Mammals*?

Reading Skills

Directions (8–11): Read the passage below. Then, answer the questions.

The Discovery of a Dinosaur

In 1995, paleontologist Paul Sereno was working in a previously unexplored region of Morocco when his team made an astounding discovery—an enormous dinosaur skull. The skull was nearly 1.6 m long. Given the size of the skull, Sereno concluded that the skeleton of the animal it came from must have been about 14 m long—about as long as a full-sized school bus. The dinosaur was even larger than the *Tyrannosaurus rex*. The newly discovered dinosaur was thought to be 90 million years old. It most likely chased other dinosaurs by running on large, powerful hind legs, and its bladelike teeth must have meant certain death for its prey.

8. Which of the following is evidence that the dinosaur described in the passage above was most likely a predator?
- **A.** It had sharp, bladelike teeth.
- **B.** It had a large skeleton and powerful hind legs used for running.
- **C.** It was found next to the bones of a smaller animal.
- **D.** It was more than 90 million years old.

9. What types of information do you think fossilized teeth provide about an organism?
- **F.** the color of its skin
- **G.** the types of food it ate
- **H.** the speed at which it ran
- **I.** the mating habits it had

10. According to the passage, which of the following statements is true?
- **A.** This dinosaur was most likely a predator.
- **B.** This skull belonged to a large *Tyrannosaurus rex*.
- **C.** This dinosaur had powerful arms.
- **D.** This dinosaur ate mainly plants and berries.

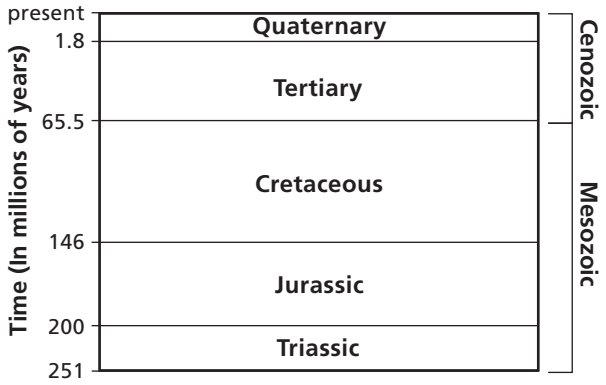
11. What are some methods that scientists might have used to determine that the dinosaur skull was 90 million years old?

Interpreting Graphics

Directions (12–15): For each question below, record the correct answer on a separate sheet of paper.

The timeline below shows the time divisions of the Mesozoic and Cenozoic Eras. Use this timeline to answer questions 12 through 14.

The Mesozoic and Cenozoic Eras



12. Human civilization developed during which of the following periods of time?

F. Triassic Period
G. Jurassic Period
H. Tertiary Period
I. Quaternary Period

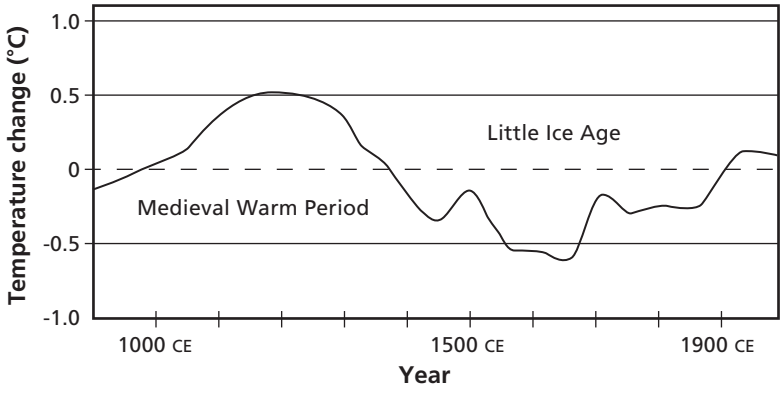
13. If Earth formed about 4.6 billion years ago, what percentage of Earth's total history has the Cenozoic Era filled?

A. about 1.5%
B. about 10.5%
C. about 15%
D. about 50%

14. Which event coincides with the start of the Cenozoic Era?

The graph below shows data on global temperature changes during the last millennium. Use this graph to answer question 15.

The Medieval Warm Period and the Little Ice Age



15. How do you think the temperature changes during the Little Ice Age of the Middle Ages affected the freezing and thawing of global waters? Explain your answer.

Test Tip

Simply keeping a positive attitude during any test will help you focus on the test and likely improve your score.