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

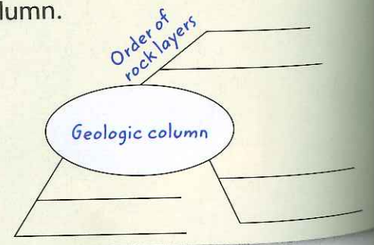
Graphic Organizers

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.

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.

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

THINK central
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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.)

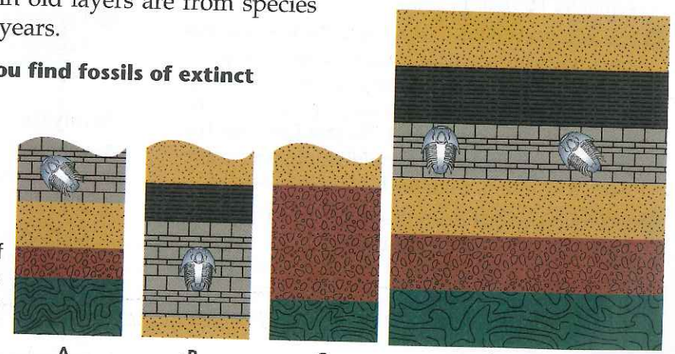

Figure 1 By combining observations of rock layers in areas A, B, and C, scientists can construct a geologic column. ***Why is relative position important for determining the ages of rock layers?***

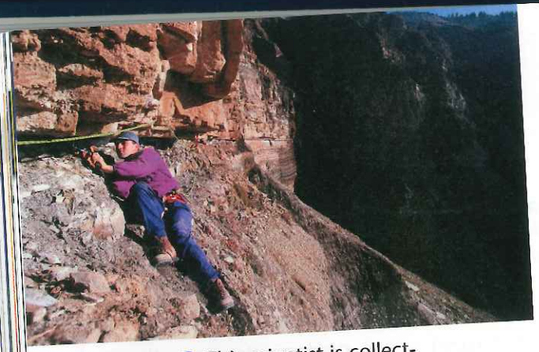

Figure 2 This scientist is collecting rock samples that contain fossilized fungal spores that date the rock to the Triassic Period.

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

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)	

DO NOT WRITE IN THIS BOOK

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.

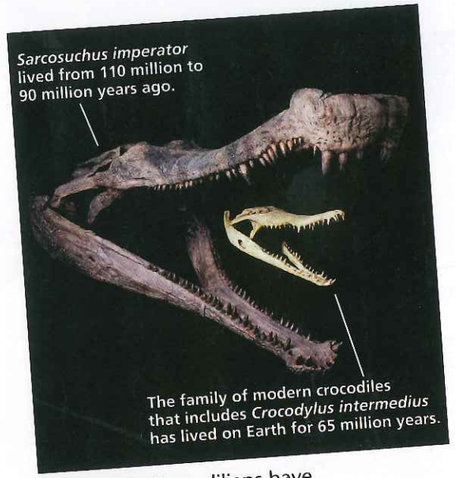

Figure 3 Crocodilians have lived on Earth for more than two geologic eras without major anatomical changes.

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.

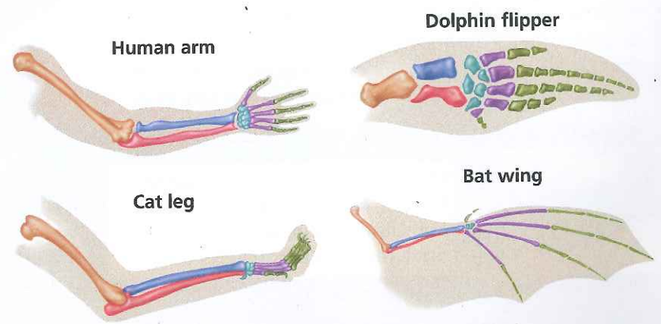

Figure 1 Bones in the front limbs of these animals are similar, even though the limbs are used in different ways. Similar structures indicate a common ancestor.