Section 2 Precambrian Time and the Paleozoic Era

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 a region indicates that the area was once covered by water.

OBJECTIVES

- **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.

KEY TERMS

evolution
Precambrian time
Paleozoic Era

Evolution

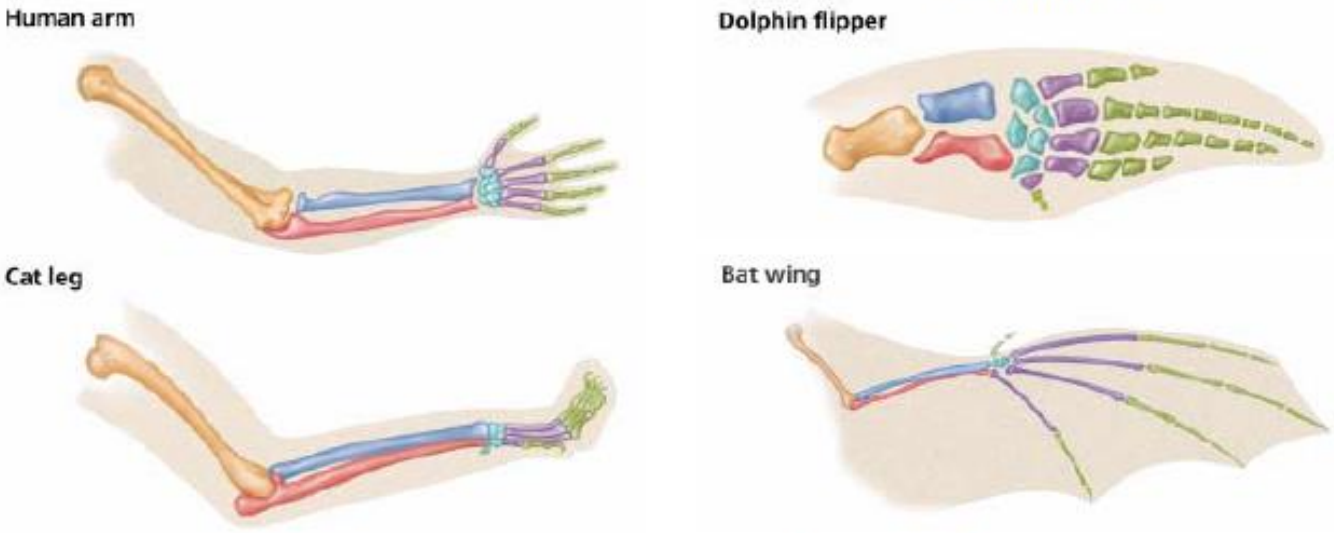
Fossils indicate the kinds of organisms that lived when rock formed. By examining rock layers and fossils, scientists have discovered evidence that species of living things have changed over time. Scientists call this process evolution. **Evolution** is the gradual development of new organisms from preexisting 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 a heritable change in the characteristics within a population from one generation to the next; the development of new types of organisms from preexisting types of organisms 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.



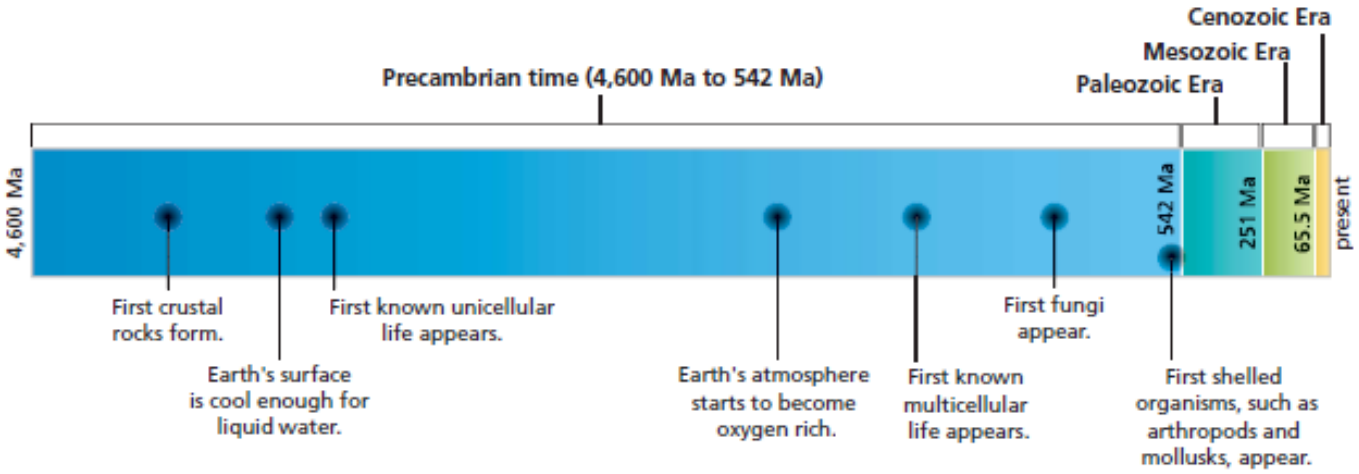


Figure 2 ▶ Precambrian Timeline
How many million years ago did the first unicellular life appear?

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? (See the Appendix for answers to Reading Checks.)**

Connection to BIOLOGY

Natural Selection

In part, evolution occurs through a process called *natural selection.* Natural selection has four basic principles. First, every species produces more offspring than will survive to maturity. Second, individuals in a population are slightly different, and each individual has a unique combination of traits. Third, the environment does not have enough resources to support all of the individuals that are born. Fourth, only individuals that are well suited to the environment are likely to survive and reproduce.

Natural selection ensures that individuals who have better traits for surviving in their environment are more likely to pass those traits to their offspring. One of the assumptions of evolution is that only organisms that can adapt to the environmental changes will survive. Organisms that cannot survive—in other words, those that are unfit to live and reproduce in the changing environment—become extinct.

Because their fur hides them from predators, rabbits that are adapted to survive in the arctic are white. Brown rabbits are adapted to survive in other environments.

Precambrian Rocks

Large areas of exposed Precambrian rocks, called *shields,* exist on every continent. 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.

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 *stromatolites,* or reeflike deposits formed by blue-green algae. Stromatolites form today in warm, shallow waters, as shown in **Figure 3.** The presence of stromatolite fossils in Precambrian rocks indicates that shallow seas covered much of Earth during periods of Precambrian time. Imprints of marine worms, jellyfish, and single-celled organisms have also been discovered in rocks from late Precambrian Time.

QuickLAB 10 min

Chocolate Candy Survival

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.
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 you change the color of candies you picked up?
3. How could camouflage help an organism survive?

Figure 3 ▶ Stromatolites, which are mats of blue-green algae, are the most common Precambrian fossils.

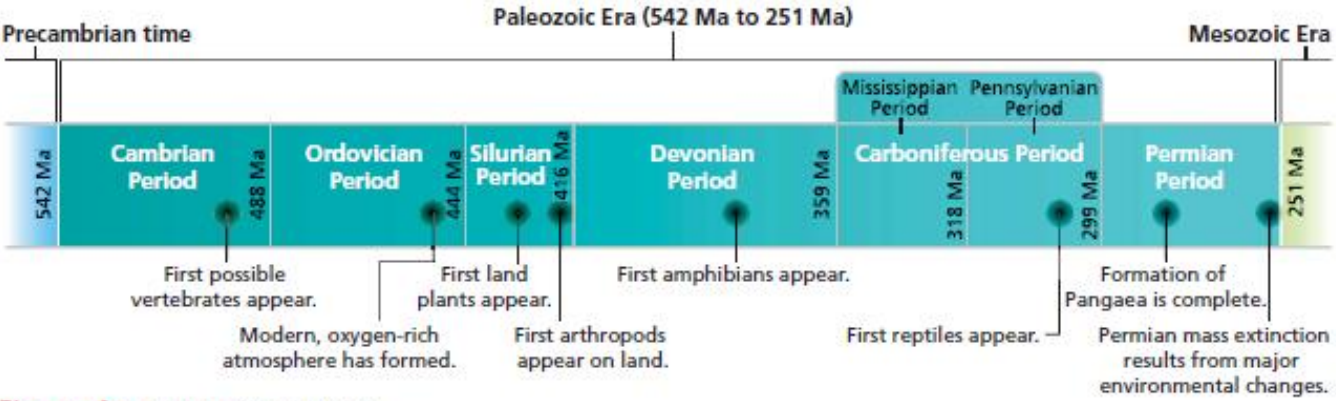


Figure 4 ▶ Paleozoic Timeline

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 abundant fossil record. 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 seven 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 from the genus *Moducia,* flourished in the warm, shallow seas.

The second most common animals of the Cambrian Period were the *brachiopods*, a group of 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 common Cambrian invertebrates include worms, jellyfish, snails, and sponges. However, no evidence of land-dwelling plants or animals has been discovered in Cambrian rocks.

Reading Check **Name three common invertebrates from the Cambrian Period. (See the Appendix for answers to Reading Checks.)**

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 populations of trilobites began to shrink. Clamlike brachiopods and cephalopod mollusks became the dominant invertebrate life-forms. 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 and Precambrian times, there was no 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 nearly 3 m long have been discovered in western New York. Near the end of this period, the earliest 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. The first amphibians, from the genus *Ichthyostega* (IK thee oh STEG uh), probably evolved from rhipidistians. *Ichthyostega,* which 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.

Graphic Organizer **Spider Map**

Create the Graphic Organizer entitled "Spider Map" described in the Skills Handbook section of the Appendix. Label the circle "Periods of the Paleozoic Era." Create a leg for each period in the Paleozoic Era. Then, fill in the map with details about each time period.

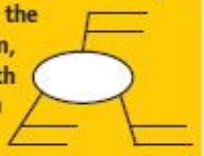


Figure 7 ▶ During the Carboniferous Period, crinoids, such as the one shown here, were common in the oceans. Crinoids are thought to be ancestors of modern sea lillies.

The Carboniferous Period

During the Carboniferous Period, the climate was generally warm, and the humidity was extremely 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 Pennsylvanian 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

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.*