6

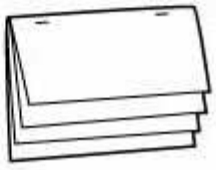
The History of Life on Earth

About the PHOTO

What is 23,000 years old and 9 ft tall? The partial remains of the woolly mammoth in this picture! The mammoth was found in the frozen ground in Siberia in 1999. Scientists think that several types of woolly mammoths roamed the northern hemisphere until about 4,000 years ago.

PRE-READING ACTIVITY

FOLDNOTES **Layered Book** Before you read the chapter, create the Foldnote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Precambrian time," "Paleozoic era," "Mesozoic era," and "Cenozoic era." As you read the chapter, write information you learn about each category under the appropriate tab.



START-UP ACTIVITY

Making a Fossil

In this activity, you will make a model of a fossil.

Procedure

1. Get a **paper plate,** some **modeling clay,** and a **leaf** or a **shell** from your teacher.
2. Flatten some of the modeling clay on the paper plate. Push the leaf or shell into the clay. Be sure that your leaf or shell has made a mark in the clay. Remove the leaf or shell carefully.
3. Ask your teacher to cover the clay with **plaster of Paris.** Allow the plaster to dry overnight.
4. Carefully remove the paper plate and the clay from the plaster the next day.

Analysis

1. Consider the following objects—a clam, a seed, a jellyfish, a crab, a leaf, and a mushroom. Which of the objects do you think would make good fossils? Explain your answers.
2. In nature, fossils form only under certain conditions. For example, fossils may form when a dead organism is covered by tiny bits of sand or dirt for a long period of time. The presence of oxygen can prevent fossils from forming. Considering these facts, what are some limitations of your model of how a fossil is formed?

SECTION 1

Evidence of the Past

In 1995, scientist Paul Sereno found a dinosaur skull that was 1.5 m long in the Sahara, a desert in Africa. The dinosaur may have been the largest land predator that has ever existed!

Scientists such as Paul Sereno look for clues to help them reconstruct what happened in the past. These scientists, called *paleontologists* (PAY lee uhn TAHL uh jists), use fossils to reconstruct the history of life before humans existed. Fossils show us that life on Earth has changed a great deal. They also provide us clues about how those changes happened.

READING WARM-UP

Objectives

- Explain how fossils can be formed and how their age can be estimated.
- Describe the geologic time scale and the way that scientists use it.
- Compare two ways that conditions for life on Earth have changed over time.

Terms to Learn

fossil
relative dating
absolute dating
geologic time scale
extinct
plate tectonics

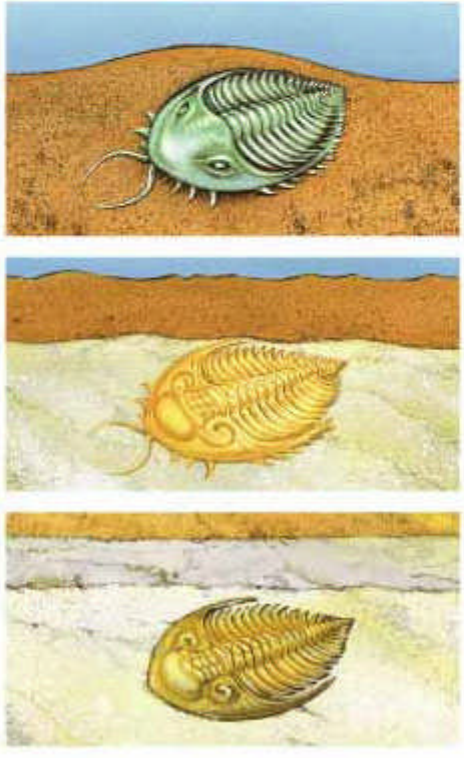
READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Fossils

Fossils are traces or imprints of living things—such as animals, plants, bacteria, and fungi—that are preserved in rock. Fossils sometimes form when a dead organism is covered by a layer of sediment. The sediment may later be pressed together to form sedimentary rock. **Figure 1** shows one way that fossils can form in sedimentary rock.

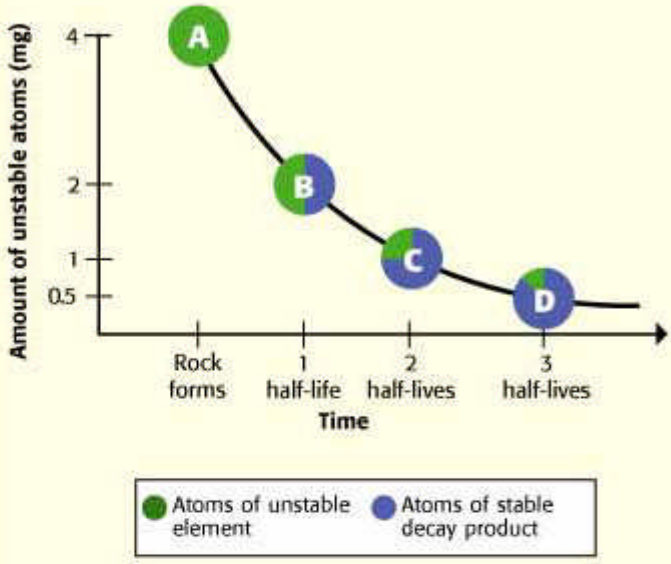
Figure 1 One Way Fossils Can Form



1. Fossils can form in several ways. The most common way is when an organism dies and becomes buried in sediment.
2. The organism gradually decomposes and leaves a hollow impression, or *mold*, in the sediment.
3. Over time, the mold fills with sediment, which forms a *cast* of the organism.

fossil the remains or physical evidence of an organism preserved by geological processes

Figure 2 **Using Half-Lives to Date Fossils**



A The unstable atoms in this sample of rock have a half-life of 1.3 billion years. The sample contained 4 mg of unstable atoms when it formed.

B After 1.3 billion years, (one half-life for this type of unstable atom), 2 mg of the unstable atoms have decayed to become stable atoms, and 2 mg of unstable atoms remain.

C After 2.6 billion years (two half-lives for this sample), the rock sample contains 3 mg of stable decay atoms and 1 mg of unstable atoms.

D After three half-lives, only 0.5 mg of unstable atoms remain in the rock sample. This is equal to one-eighth of the original amount.

The Age of Fossils

Sedimentary rock has many layers. The oldest layers are usually on the bottom. The newest layers are usually on the top. The layers can tell a scientist the relative age of fossils. Fossils found in the bottom layers are usually older than the fossils in the top layers. So, scientists can determine whether a fossil is older or younger than other fossils based on its position in sedimentary rock. Estimating the age of rocks and fossils in this way is called **relative dating.**

In addition, scientists can determine the age of a fossil more precisely. **Absolute dating** is a method that measures the age of fossils or rocks in years. In one type of absolute dating, scientists examine atoms. *Atoms* are the particles that make up all matter. Atoms, in turn, are made of smaller particles. Some atoms are unstable and will decay by releasing energy, particles, or both. When an atom decays it becomes a different, and more stable, kind of atom. Each kind of unstable atom decays at its own rate. As shown in **Figure 2,** the time it takes for half of the unstable atoms in a sample to decay is the *half-life* of that type of unstable atom. By measuring the ratio of unstable atoms to stable atoms, scientists can determine the approximate age of a sample of rock.

Reading Check **Which type of fossil dating is more precise?**
(See the Appendix for answers to Reading Checks.)

relative dating any method of determining whether an event or object is older or younger than other events or objects

absolute dating any method of measuring the age of an object or event in years

MATH PRACTICE

Fractions of Fractions

Find the answer to each of the following problems. Be sure to show your work. You may want to draw pictures.

1. 1/2 × 1/2 × 1/2 × 1/2

2. 1/2 × 1/8

3. 1/4 × 1/4

The Geologic Time Scale

Think about important events that have happened during your lifetime. You usually recall each event in terms of the day, month, or year in which it happened. These divisions of time make it easier to recall when you were born, when you kicked the winning soccer goal, or when you started the fifth grade. Scientists also use a type of calendar to divide the Earth's long history. The span of time from the formation of the Earth to now is very long. Therefore, the calendar is divided into very long units of time.

The calendar scientists use to outline the history of life on Earth is called the **geologic time scale,** shown in **Table 1.** After a fossil is dated, a paleontologist can place the fossil in chronological order with other fossils. This ordering forms a picture of the past that shows how organisms have changed over time.

Table 1 Geologic Time Scale

Era	Period	Time*
Cenozoic era	Quaternary	2
	Tertiary	65
Mesozoic era	Cretaceous	144
	Jurassic	206
	Triassic	248
Paleozoic era	Permian	290
	Carboniferous	345
	Devonian	408
	Silurian	439
	Ordovician	495
	Cambrian	543
Precambrian time		4,600

**indicates how many millions of years ago the period began*

Divisions in the Geologic Time Scale

Paleontologists have divided the geologic time scale into large blocks of time. Each block may be divided into smaller blocks of time as scientists continue to find more fossil information.

The divisions known as *eras* are characterized by the type of organism that dominated the Earth at the time. For instance, the Mesozoic era—dominated by dinosaurs and other reptiles—is referred to as the *Age of Reptiles.* Eras began with a change in the type of organism that was most dominant.

Paleontologists sometimes adjust and add details to the geologic time scale. For example, the early history of the Earth has been poorly understood. There is little evidence that life existed billions of years ago. So, the earliest part of the geologic time scale is not named as an era. But more evidence of life before the Paleozoic era is being gathered. Scientists have proposed using this evidence to name new eras before the Paleozoic era.

CONNECTION TO Social Studies

A Place in Time Most of the periods of the Paleozoic era were named by geologists for places where rocks from that period are found. Research the name of each period of the Paleozoic era listed in **Table 1.** On a copy of a world map, label the locations related to each name.

ACTIVITY

Figure 3 *Scientists think that a meteorite hit Earth about 65 million years ago and caused major climate changes.*

Mass Extinctions

Some of the important divisions in the geologic time scale mark times when rapid changes happened on Earth. During these times, many species died out completely, or became **extinct**. When a species is extinct, it does not reappear. At certain points in the Earth's history, a large number of species disappeared from the fossil record. These periods when many species suddenly become extinct are called *mass extinctions*.

Scientists are not sure what caused each of the mass extinctions. Most scientists think that the extinction of the dinosaurs happened because of extreme changes in the climate on Earth. These changes could have resulted from a giant meteorite hitting the Earth, as shown in **Figure 3.** Or, forces within the Earth could have caused many volcanoes and earthquakes.

Reading Check **What are mass extinctions?**

geologic time scale the standard method used to divide the Earth's long natural history into manageable parts

extinct describes a species that has died out completely

QUICK LAB

Making a Geologic Timeline

1. Use a **metric ruler** to mark 10 cm sections on a **strip of paper** that is 46 cm long.
2. Label each 10 cm section in order from top to bottom as follows: 1 bya (billion years ago), 2 bya, etc. The timeline begins at 4.6 bya.
3. Divide each 10 cm section into 10 equal subsections. Divide the top 1 cm into 10 subsections. Calculate the number of years that are represented by 1 mm on this scale.
4. On your timeline, label the following events:
   a. Earth forms. (4.6 billion years ago)
   b. First animals appear. (600 million years ago)
   c. Dinosaurs appear. (251 million years ago)
   d. Dinosaurs are extinct. (65 million years ago)
   e. Humans appear. (160,000 years ago)
5. Label other events from the chapter.
6. Describe what most of the timeline looks like.
7. Compare the length of time dinosaurs existed with the length of time humans have existed.

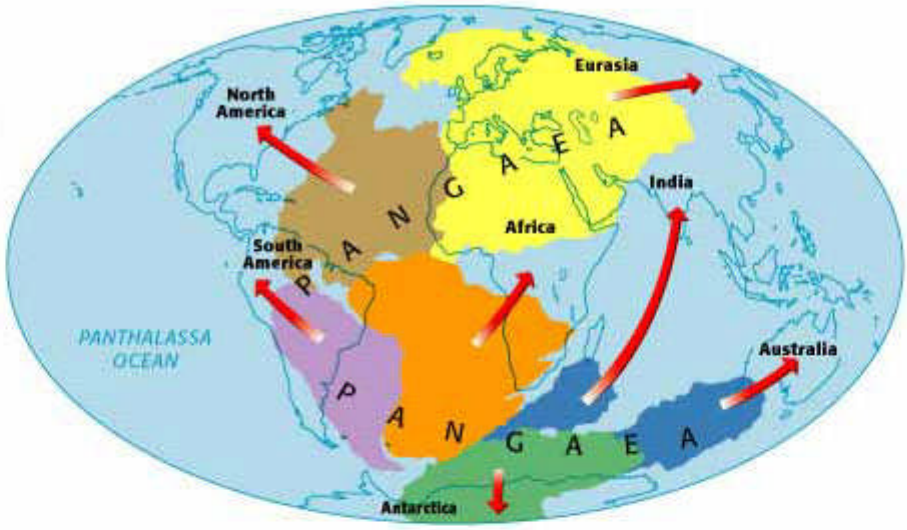


Figure 4 *The continents have been slowly moving throughout the history of Earth. The colored areas show the location of the continents 245 million years ago, and blue outlines show where the continents are today.*

The Changing Earth

Did you know that fossils of tropical plants have been found in Antarctica? Antarctica, now frozen, must have once had a warm climate to support these plants. The fossils provide evidence that Antarctica was once located near the equator!

plate tectonics the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates*, move and change shape

Pangaea

Have you ever noticed that the continents look like pieces of a puzzle? German scientist Alfred Wegener had a similar thought in the early 1900s. He proposed that long ago the continents formed one landmass surrounded by a gigantic ocean. Wegener called that single landmass *Pangaea* (pan JEE uh), which means "all Earth." **Figure 4** shows how the continents may have formed from Pangaea.

Reading Check **What idea did Alfred Wegener propose?**

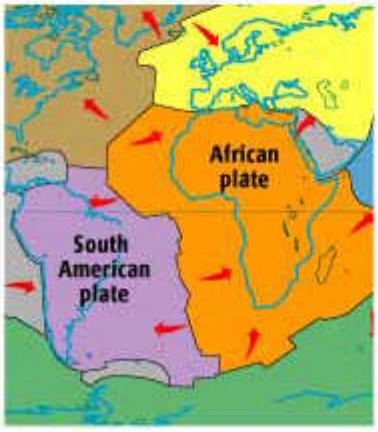


Figure 5 *The continents ride on tectonic plates, outlined here in black. The plates are still moving about 1 to 10 cm per year.*

Do the Continents Move?

In the mid-1960s, J. Tuzo Wilson of Canada came up with the idea that the continents were not moving by themselves. Wilson thought that huge pieces of the Earth's crust were pushed around by forces within the planet. Each huge piece of crust is called a *tectonic plate*. Wilson's theory of how these huge pieces of crust move around the Earth is called **plate tectonics.**

According to Wilson, the outer crust of the Earth is broken into seven large, rigid plates and several smaller ones. The continents and oceans ride on top of these plates. The motion of the plates causes the continents to move. For example, the plates that carry South America and Africa are slowly moving apart, as shown in **Figure 5.**

Adaptation to Slow Changes

When conditions on the Earth change, organisms may become extinct. A rapid change, such as a meteorite impact, may cause a mass extinction. But slow changes, such as moving continents, allow time for adaptation.

Anywhere on Earth, you are able to see living things that are well adapted to the location where they live. Yet in the same location, you may find evidence of organisms that lived there in the past that were very different. For example, the animals currently living in Antarctica are able to survive very cold temperatures. But under the frozen surface of Antarctica are the remains of tropical forests. Conditions on Earth have changed many times in history, and life has changed, too.

CONNECTION TO Geology

Mid-Atlantic Ridge In 1947, scientists examined rock from a ridge that runs down the middle of the Atlantic Ocean, between Africa and the Americas. They found that this rock was much younger than the rock on the continents. Explain what this finding indicates about the tectonic plates.

SECTION Review

Summary

- Fossils are formed most often in sedimentary rock. The age of a fossil can be determined using relative dating and absolute dating.
- The geologic time scale is a timeline that is used by scientists to outline the history of Earth and life on Earth.
- Conditions for life on Earth have changed many times. Rapid changes, such as a meteorite impact, might have caused mass extinctions. But many groups of organisms have adapted to changes such as the movement of tectonic plates.

Using Key Terms

1. Use the following terms in the same sentence: *fossil* and *extinct*.
2. In your own words, write a definition for the term *plate tectonics*.

Understanding Key Ideas

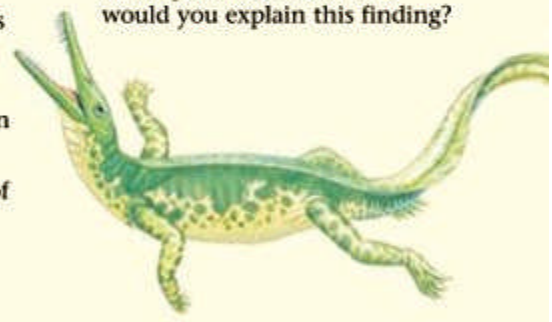
3. Explain how a fossil forms in sedimentary rock.
4. What kind of information does the geologic time scale show?
5. About how many years of Earth's history was Precambrian time?
6. What are two possible causes of mass extinctions?

Math Skills

7. The Earth formed 4.6 billion years ago. Modern humans have existed for about 160,000 years. Simple worms have existed for at least 500 million years. For what fraction of the history of Earth have humans existed? have worms existed?

Critical Thinking

8. **Identifying Relationships** Why are both absolute dating and relative dating used to determine the age of fossils?
9. **Making Inferences** Fossils of *Mesosaurus*, the small aquatic reptile shown below, have been found only in Africa and South America. Using what you know about plate tectonics, how would you explain this finding?



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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Evidence of the Past
SciLinks code: HSM0545

SECTION 2

Eras of the Geologic Time Scale

The walls of the Grand Canyon are layered with different kinds and colors of rocks. The deeper down into the canyon you go, the older the layers of rocks. Try to imagine a time when the bottom layer was the only layer that existed.

Each layer of rock tells a story about what was happening on Earth when that layer was on top. The rocks and fossils in each layer tell the story. Scientists have compared the stories told by fossils and rocks all over the Earth. From these stories, scientists have divided geologic history into four major parts. These divisions are Precambrian time, the Paleozoic era, the Mesozoic era, and the Cenozoic era.

READING WARM-UP

Objectives

- Outline the major developments that allowed life to exist on Earth.
- Describe the types of organisms that arose during the four major divisions of the geologic time scale.

Terms to Learn

Precambrian time
Paleozoic era
Mesozoic era
Cenozoic era

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the eras of geologic time.

Precambrian Time

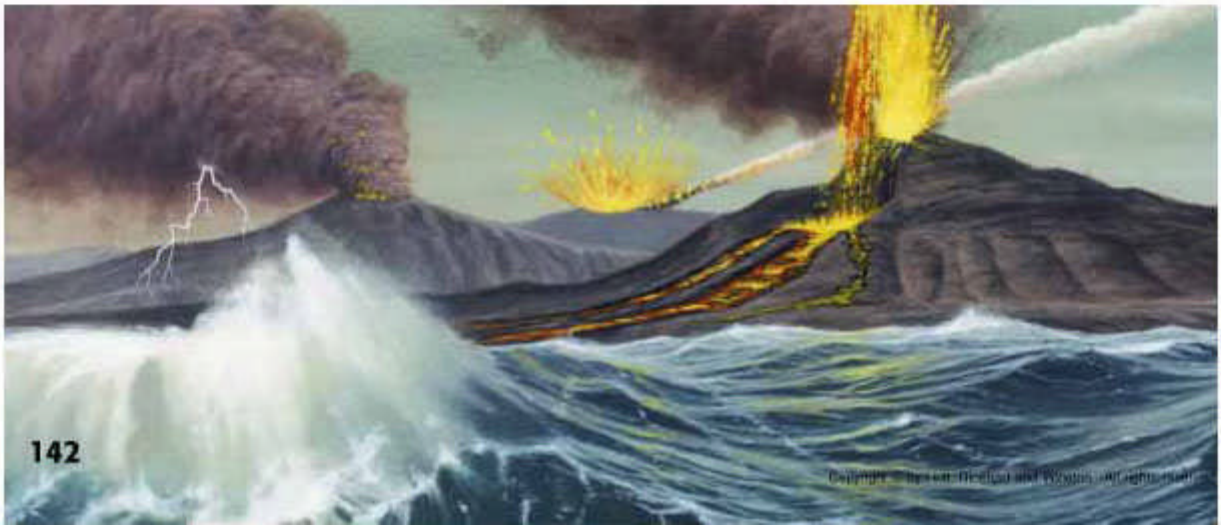
The layers at the bottom of the Grand Canyon are from the oldest part of the geologic time scale. **Precambrian time** (pree KAM bree UHN TIEM) is the time from the formation of Earth 4.6 billion years ago to about 543 million years ago. Life on Earth began during this time.

Scientists think that the early Earth was very different than it is today. The atmosphere was made of gases such as water vapor, carbon dioxide, and nitrogen. Also, the early Earth was a place of great turmoil, as illustrated in **Figure 1.** Volcanic eruptions, meteorite impacts, and violent storms were common. Intense radiation from the sun bombarded Earth's surface.

Precambrian time the period in the geologic time scale from the formation of the Earth to the beginning of the Paleozoic era, from about 4.6 billion to 543 million years ago

Reading Check **Describe the early Earth.** *(See the Appendix for answers to Reading Checks.)*

Figure 1 *This illustration shows the conditions under which the first life on Earth may have formed.*



How Did Life Begin?

Scientists think that life developed from simple chemicals in the oceans and in the atmosphere. Energy from radiation and storms could have caused these chemicals to react. Some of these reactions formed the complex molecules that made life possible. Eventually, these molecules may have joined to form structures such as cells.

The early atmosphere of the Earth did not contain oxygen gas. The first organisms did not need oxygen to survive. These organisms were *prokaryotes* (proh KAR ee OHTS), or single-celled organisms that lack a nucleus.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5HISW.**

Photosynthesis and Oxygen

There is evidence that *cyanobacteria,* a new kind of prokaryotic organism, appeared more than 3 billion years ago. Some cyanobacteria are shown in **Figure 2.** Cyanobacteria use sunlight to produce their own food. Along with doing other things, this process releases oxygen. The first cyanobacteria began to release oxygen gas into the oceans and air.

Eventually, some of the oxygen formed a new layer of gas in the upper atmosphere. This gas, called *ozone,* absorbs harmful radiation from the sun, as shown in **Figure 3.** Before ozone formed, life existed only in the oceans and underground. The new ozone layer reduced the radiation on Earth's surface.

Figure 2 *Cyanobacteria are the simplest living organisms that use the sun's energy to produce their own food.*

Multicellular Organisms

After about 1 billion years, organisms that were larger and more complex than prokaryotes appeared in the fossil record. These organisms, known as *eukaryotes* (yoo KAR ee OHTS), contain a nucleus and other complex structures in their cells. Eventually, eukaryotic cells may have evolved into organisms that are composed of many cells.

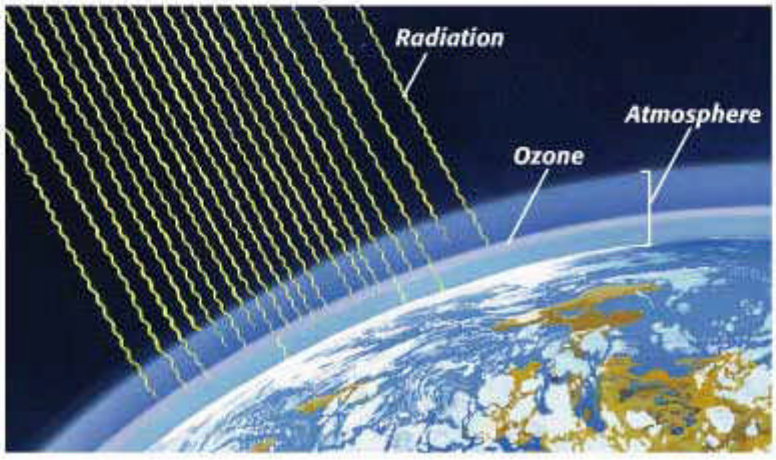


Figure 3 *Oxygen in the atmosphere formed a layer of ozone, which helps to absorb harmful radiation from the sun.*

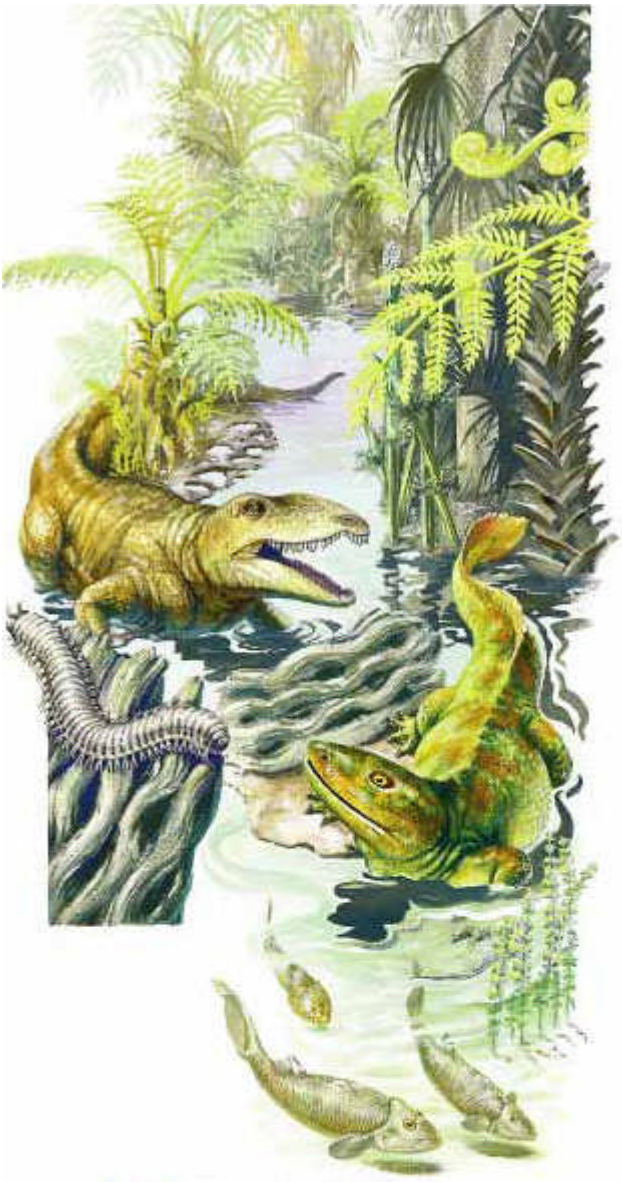


Figure 4 *Organisms that first appeared in the Paleozoic era include reptiles, amphibians, fishes, worms, and ferns.*

The Paleozoic Era

The **Paleozoic era** (PAY lee OH ZOH ik ER uh) began about 543 million years ago and ended about 248 million years ago. Considering the length of Precambrian time, you can see that the Paleozoic era was relatively recent. Rocks from the Paleozoic era are rich in fossils of animals such as sponges, corals, snails, clams, squids, and trilobites. Fishes, the earliest animals with backbones, appeared during this era, and sharks became abundant. **Figure 4** shows an artist's depiction of life in the Paleozoic era.

The word *Paleozoic* comes from Greek words that mean "ancient life." When scientists first named this era, they thought it held the earliest forms of life. Scientists now think that earlier forms of life existed, but less is known about those life-forms. Before the Paleozoic era, most organisms lived in the oceans and left few fossils.

Life on Land

During the 300 million years of the Paleozoic era, plants, fungi, and air-breathing animals slowly colonized land. By the end of the era, forests of giant ferns, club mosses, horsetails, and conifers covered much of the Earth. All major plant groups except for flowering plants appeared during this era. These plants provided food and shelter for animals.

Fossils indicate that crawling insects were some of the first animals to live on land. They were followed by large salamander-like animals. Near the end of the Paleozoic era, reptiles and winged insects appeared.

The largest mass extinction known took place at the end of the Paleozoic era. By 248 million years ago, as many as 90% of all Paleozoic species had become extinct. The mass extinction wiped out entire groups of marine organisms, such as trilobites. The oceans were completely changed.

Paleozoic era the geologic era that followed Precambrian time and that lasted from 543 million to 248 million years ago

CONNECTION TO Oceanography

Prehistoric Marine Organisms Find a variety of pictures and descriptions of marine organisms from the Cambrian period of the Paleozoic era. Choose three organisms that you find interesting. Draw or write a description of each organism. Find out whether scientists think the organism is related to any living group of organisms, and add this information to your description.

The Mesozoic Era

The **Mesozoic era** (MES oh ZOH ik ER uh) began about 248 million years ago and lasted about 183 million years. *Mesozoic* comes from Greek words that mean "middle life." Scientists think that the surviving reptiles evolved into many different species after the Paleozoic era. Therefore, the Mesozoic era is commonly called the *Age of Reptiles*.

Life in the Mesozoic Era

Dinosaurs are the most well known reptiles that evolved during the Mesozoic era. Dinosaurs dominated the Earth for about 150 million years. A great variety of dinosaurs lived on Earth. Some had unique adaptations, such as ducklike bills for feeding or large spines on their bodies for defense. In addition to dinosaurs roaming the land, giant marine lizards swam in the ocean. The first birds also appeared during the Mesozoic era. In fact, scientists think that some of the dinosaurs became the ancestors of birds.

The most important plants during the early part of the Mesozoic era were conifers, which formed large forests. Flowering plants appeared later in the Mesozoic era. Some of the organisms of the Mesozoic era are illustrated in **Figure 5.**

The Extinction of Dinosaurs

At the end of the Mesozoic era, 65 million years ago, dinosaurs and many other animal and plant species became extinct. What happened to the dinosaurs? According to one hypothesis, a large meteorite hit the Earth and generated giant dust clouds and enough heat to cause worldwide fires. The dust and smoke from these fires blocked out much of the sunlight and caused many plants to die out. Without enough plants to eat, the plant-eating dinosaurs died out. And the meat-eating dinosaurs that fed on the plant-eating dinosaurs died. Global temperatures may have dropped for many years. However, some mammals and birds survived.

Reading Check **What kind of event happened at the end of both the Paleozoic and Mesozoic eras?**

Figure 5 *The Mesozoic era was dominated by dinosaurs. The era ended with the mass extinction of many species.*

Mesozoic era the geologic era that lasted from 248 million to 65 million years ago; also called the *Age of Reptiles*

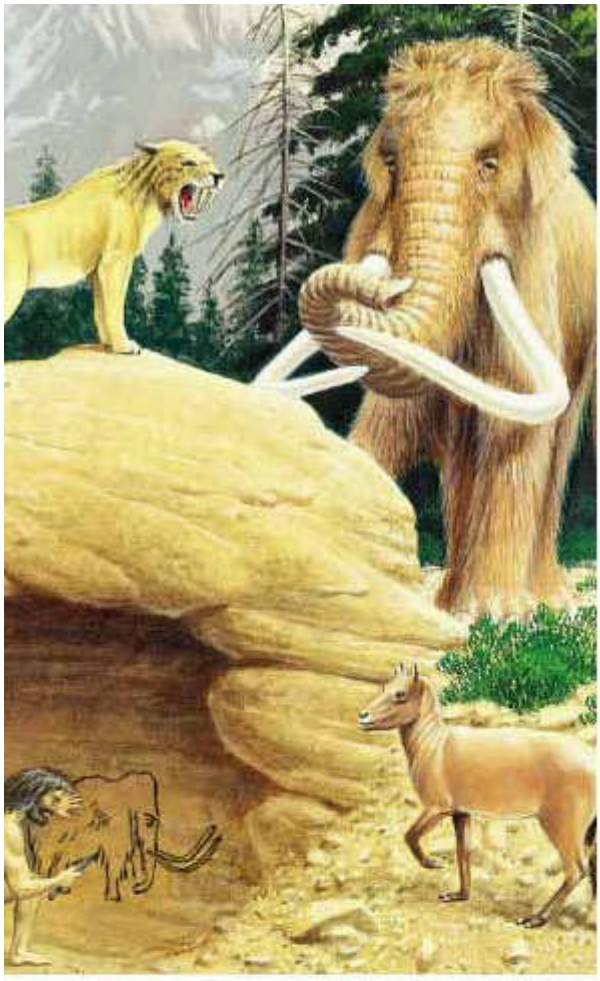


Figure 6 *Many types of mammals evolved during the Cenozoic era.*

The Cenozoic Era

The **Cenozoic era** (SEN uh ZOH ik ER uh) began about 65 million years ago and continues today. *Cenozoic* comes from Greek words that mean "recent life." Scientists have more information about the Cenozoic era than about any of the previous eras. Fossils from the Cenozoic era formed recently in geologic time, so they are found in rock layers closer to the Earth's surface. The closer the fossils are to the surface, the easier they are to find.

During the Cenozoic era, many kinds of mammals, birds, insects, and flowering plants appeared. Some organisms that appeared in the Cenozoic era are shown in **Figure 6.**

Reading Check What does *Cenozoic* mean?

The Age of Mammals

The Cenozoic era is sometimes called the *Age of Mammals*. Mammals have dominated the Cenozoic era the way reptiles dominated the Mesozoic era. Early Cenozoic mammals were small, forest dwellers. Larger mammals appeared later in the era. Some of these larger mammals had long legs for running, teeth that were specialized for eating different kinds of food, and large brains. Cenozoic mammals have included mastodons, saber-toothed cats, camels, giant ground sloths, and small horses.

MATH FOCUS

Relative Scale It's hard to imagine 4.6 billion years. One way is to use a *relative scale*. For example, we can represent all of Earth's history by using the 12 h shown on a clock. The scale would begin at noon, representing 4.6 billion years ago, and end at midnight, representing the present. Because 12 h represent 4.6 billion years, 1 h represents about 383 million years. (Hint: 4.6 billion ÷ 12 = 383 million) So, what time on the clock represents the beginning of the Paleozoic era, 543 million years ago?

Step 1: Write the ratio.

$$\frac{x}{543{,}000{,}000 \text{ years}} = \frac{1 \text{ h}}{383{,}000{,}000 \text{ years}}$$

Step 2: Solve for x.

$$x = \frac{543{,}000{,}000 \text{ years} \times 1 \text{ h}}{383{,}000{,}000 \text{ years}} = 1.42 \text{ h}$$

Step 3: Convert the answer to the clock scale.

$$1.42 \text{ h} = 1 \text{ h} + (0.42 \times 60 \text{ min/h})$$

$$1.42 \text{ h} = 1 \text{ h } 25 \text{ min}$$

So, the Paleozoic era began 1 h 25 min before midnight, at about 10:35.

Now It's Your Turn

1. Use this method to calculate the relative times at which the Mesozoic and Cenozoic eras began.

The Cenozoic Era Today

We are currently living in the Cenozoic era. Modern humans appeared during this era. The environment and landscapes that we see around us today are part of this era.

However, the climate has changed many times during the Cenozoic era. Earth's history includes some periods called *ice ages*, during which the climate was very cold. During the ice ages, ice sheets and glaciers extended from the Earth's poles. To survive, many organisms migrated toward the equator. Other organisms adapted to the cold or became extinct.

When will the Cenozoic era end? No one knows. In the future, geologists might draw the line at a time when life on Earth again undergoes major changes.

Cenozoic era the most recent geologic era, beginning 65 million years ago; also called the *Age of Mammals*

SECTION Review

Summary

- The Earth is about 4.6 billion years old. Life formed from nonliving matter long ago.
- Precambrian time includes the formation of the Earth and the appearance of simple organisms.
- The first cells did not need oxygen. Later, photosynthetic cells evolved and released oxygen into the atmosphere.
- During the Paleozoic era, animals appeared in the oceans and on land, and plants grew on land.
- Dinosaurs dominated the Earth during the Mesozoic era.
- Mammals have dominated the Cenozoic era. This era continues today.

Using Key Terms

1. Use each of the following terms in a separate sentence: *Precambrian time*, *Paleozoic era*, *Mesozoic era*, and *Cenozoic era*.

Understanding Key Ideas

2. Unlike the atmosphere today, the atmosphere 3.5 billion years ago did not contain
   a. carbon dioxide.
   b. nitrogen.
   c. gases.
   d. ozone.
3. How do prokaryotic cells and eukaryotic cells differ?
4. Explain why cyanobacteria were important to the development of life on Earth.
5. Place in chronological order the following events on Earth:
   a. The first cells appeared that could make their own food from sunlight.
   b. The ozone layer formed.
   c. Simple chemicals reacted to form the molecules of life.
   d. Animals appeared.
   e. The first organisms appeared.
   f. Humans appeared.
   g. The Earth formed.

Math Skills

6. Calculate the total number of years that each of the geologic eras lasted, rounding to the nearest 100 million. Then, calculate each of these values as a percentage of the total 4.6 billion years of Earth's history. Round your answer to the units place.

Critical Thinking

7. **Making Inferences** Which chemicals probably made up the first cells on Earth?
8. **Forming Hypotheses** Think of your own hypothesis to explain the disappearance of the dinosaurs. Explain your hypothesis.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Geologic Time Scale
SciLinks code: HSM0669

SECTION 3

Humans and Other Primates

Have you ever heard someone say that humans descended from monkeys or apes? Well, scientists would not exactly say that. The scientific theory is that humans, apes, and monkeys share a common ancestor. This common ancestor probably lived more than 45 million years ago.

Most scientists agree that there is enough evidence to support this theory. Many fossils of organisms have been found that show traits of both humans and apes. Also, comparisons of modern humans and apes support this theory.

READING WARM-UP

Objectives

- Describe two characteristics that all primates share.
- Describe three major groups of hominids.

Terms to Learn

primate
hominid
Homo sapiens

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

primate a type of mammal characterized by opposable thumbs and binocular vision

Primates

What characteristics make us human? Humans are classified as primates. **Primates** are a group of mammals that includes humans, apes, monkeys, and lemurs. Primates have the characteristics illustrated in **Figure 1.**

The First Primates

The ancestors of primates may have co-existed with the dinosaurs. These ancestors were probably mouselike mammals that were active at night, lived in trees, and ate insects. The first primates did not exist until after the dinosaurs died out. About 45 million years ago, primates that had larger brains appeared. These were the first primates that had traits similar to monkeys, apes, and humans.

Figure 1 Characteristics of Primates

Both eyes are located at the front of the head, and they provide binocular, or three-dimensional, vision.

Almost all primates, such as these orangutans, have five flexible fingers—four fingers and an opposable thumb. This thumb enables primates to grip objects. Most primates besides humans also have opposable big toes.

Apes and Chimpanzees

Scientists think that the chimpanzee, a type of ape, is the closest living relative of humans. This theory does not mean humans descended from chimpanzees. It means that humans and chimpanzees share a common ancestor. Sometime between 5 million and 30 million years ago, the ancestors of humans, chimpanzees, and other apes began to evolve along different lines.

Hominids

Humans are in a family separate from other primates. This family, called **hominids,** includes only humans and their human-like ancestors. The main characteristic that separates hominids from other primates is bipedalism. *Bipedalism* means "walking primarily upright on two feet." Evidence of bipedalism can be seen in a primate's skeletal structure. **Figure 2** shows a comparison of the skeletal features of apes and hominids.

hominid a type of primate characterized by bipedalism, relatively long lower limbs, and lack of a tail

Reading Check **In which family are humans classified?**
(See the Appendix for answers to Reading Checks.)

Figure 2 **Comparison of Primate Skeletons**

The bones of gorillas (a type of ape) and humans (a type of hominid) have a very similar form, but the human skeleton is adapted for walking upright.

▲ The gorilla pelvis tilts the ape's large rib cage and heavy neck and head forward. The gorilla spine is curved in a C shape. The arms are long to provide balance on the ground.

The human pelvis is vertical and helps hold the entire skeleton upright. The human spine is curved in an S shape. The arms are shorter than the legs. ▶

Hominids Through Time

Figure 3 *This skull was found in the Sahel desert in Chad, Africa. The skull is estimated to be 6 million to 7 million years old.*

Scientists are constantly filling in pieces of the hominid family picture. They have found many different fossils of ancient hominids and have named at least 18 types of hominids. However, scientists do not agree on the classification of every fossil. Fossils are classified as hominids when they share some of the characteristics of modern humans. But each type of hominid was unique in terms of size, the way it walked, the shape of its skull, and other characteristics.

The Earliest Hominids

The earliest hominids had traits that were more humanlike than apelike. These traits include the ability to walk upright as well as smaller teeth, flatter faces, and larger brains than earlier primates. The oldest hominid fossils have been found in Africa. So, scientists think hominid evolution began in Africa. **Figure 3** shows a fossil that may be from one of the earliest hominids. It is 6 million to 7 million years old.

Reading Check **Where are the earliest hominid fossils found?**

Australopithecines

Many early hominids are classified as *australopithecines* (AW struh LOH PITH uh SEENS). Members of this group were similar to apes but were different from apes in several ways. For example, their brains were slightly larger than the brains of apes. Some of them may have used stone tools. They climbed trees but also walked on two legs.

Fossil evidence of australopithecines has been found in several places in Africa. The fossilized footprints in **Figure 4** were probably made by a member of this group over 3 million years ago. Some skeletons of australopithecines have been found near what appear to be simple tools.

Figure 4 *Anthropologist Mary Leakey discovered these 3.6 million year old footprints in Tanzania, Africa.*

A Variety of Early Hominids

Many australopithecines and other types of hominids lived at the same time. Some australopithecines had slender bodies. They had humanlike jaws and teeth but had small, apelike skulls. They probably lived in forests and grasslands and ate a vegetarian diet. Scientists think that some of these types of hominids may have been the ancestors of modern humans.

Some early hominids had large bodies and massive teeth and jaws. They had a unique skull structure and relatively small brains. Most of these types of hominids lived in tropical forests and probably ate tough plant material, such as roots. Scientists do not think that these large-bodied hominids are the ancestors of modern humans.

Global Hominids

About 2.3 million years ago, a new group of hominids appeared. These hominids were similar to the slender australopithecines but were more humanlike. These new hominids had larger and more complex brains, rounder skulls, and flatter faces than early hominids. They showed advanced tool-making abilities and walked upright.

These new hominids were members of the group *Homo*, which includes modern humans. Fossil evidence indicates that several members of the *Homo* group existed at the same time and on several continents. Members of this group were probably scavengers that ate a variety of foods. Some of these hominids may have adapted to climate change by migrating and changing the way they lived.

An early member of this new group was *Homo habilis* (HOH moh HAB uh luhs), which lived about 2 million years ago. In another million years, a hominid called *Homo erectus* (HOH moh i REK tuhs) appeared. This type of hominid could grow as tall as modern humans do. A museum creation of a member of *Homo erectus* is shown in **Figure 5.** No one knows what early hominids looked like. Scientists construct models based on skulls and other evidence.

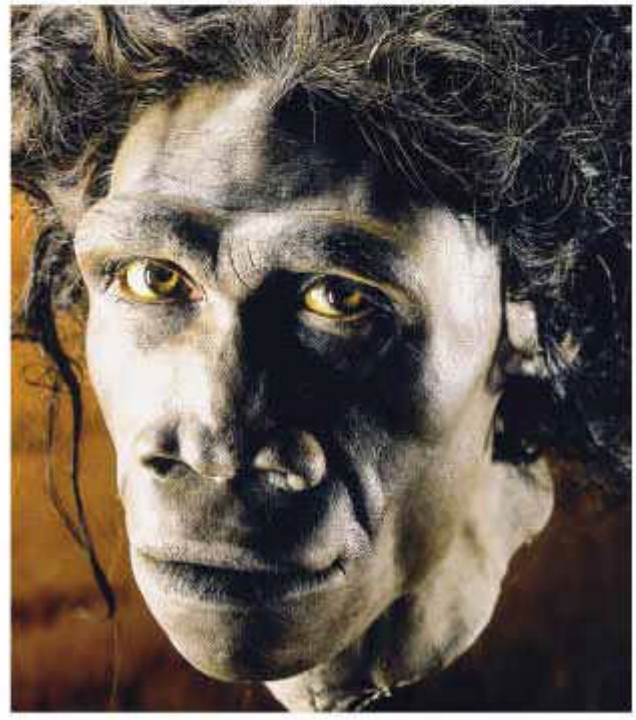


Figure 5 *Fossils of a hominid known as* Homo erectus *have been found in Africa, Europe, and Asia.*

SCHOOL to HOME

Thumb Through This

1. Keep your thumbs from moving by attaching them to the sides of your hands with **tape.**
2. Attempt each of the following tasks: using a **pencil sharpener,** using **scissors,** tying your **shoelaces,** buttoning **buttons.**
3. After each attempt, answer the following questions:
   - **a.** Is the task more difficult with an opposable thumb or without one?
   - **b.** Do you think you would carry out this task on a regular basis if you did not have an opposable thumb?

ACTIVITY

Recent Hominids

As recently as 30,000 years ago, two types of hominids may have lived in the same areas at the same time. Both had the largest brains of any hominids and made advanced tools, clothing, and art. Scientists think that modern humans may have descended from one of these two types of hominids.

Neanderthals

One recent hominid is known as *Neanderthal* (nee AN duhr TAWL). Neanderthals lived in Europe and western Asia. They may have lived as early as 400,000 years ago. They hunted large animals, made fires, and wore clothing. They also may have cared for the sick and elderly and buried their dead with cultural rituals. About 30,000 years ago, Neanderthals disappeared. No one knows what caused their extinction.

Homo sapiens the species of hominids that includes modern humans and their closest ancestors and that first appeared about 100,000 to 160,000 years ago

Early and Modern Humans

Modern humans are classified as the species ***Homo sapiens*** (HOH moh SAY pee UHNZ). The earliest *Homo sapiens* existed in Africa 100,000 to 160,000 years ago. The group migrated out of Africa sometime between 40,000 and 100,000 years ago. Compared with Neanderthals, *Homo sapiens* has a smaller and flatter face, and has a skull that is more rounded. Of all known hominids, only *Homo sapiens* still exists.

Homo sapiens seems to be the first to create art. Early humans produced sculptures, carvings, paintings, and clothing such as that shown in **Figure 6.** The preserved villages and burial grounds of early humans show that they had an organized and complex society.

Figure 6 *These photos show museum recreations of early* Homo sapiens.

Drawing the Hominid Family Tree

Scientists review their hypotheses when they learn something new about a group of organisms and their related fossils. As more hominid fossils are discovered, there are more features to compare. Sometimes, scientists add details to the relationships they see between each group. Sometimes, new groups of hominids are recognized. Human evolution was once thought to be a line of descent from ancient primates to modern humans. But scientists now speak of a "tree" or even a "bush" to describe the evolution of various hominids in the fossil record.

Reading Check **What is likely to happen when a new hominid fossil is discovered?**

SECTION Review

Summary

- Humans, apes, and monkeys are primates. Almost all primates have opposable thumbs and binocular vision.
- Hominids, a subgroup of primates, include humans and their humanlike ancestors. The oldest known hominid fossils may be 7 million years old.
- Early hominids included australopithecines and the *Homo* group.
- Early *Homo sapiens* did not differ very much from present-day humans. *Homo sapiens* is the only type of hominid living today.

Using Key Terms

1. Use each of the following words in the same sentence: *primate*, *hominid*, and *Homo sapiens*.

Understanding Key Ideas

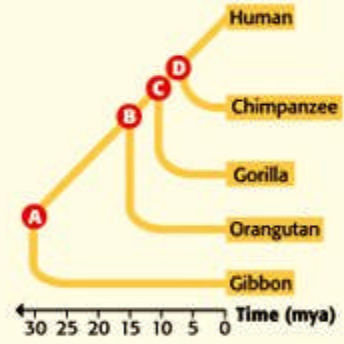
2. The unique characteristics of primates are
   a. bipedalism and thumbs.
   b. opposable thumbs.
   c. opposable thumbs and binocular vision.
   d. opposable toes and thumbs.
3. Describe the major evolutionary developments from early hominids to modern humans.
4. Compare members of the *Homo* group with australopithecines.

Critical Thinking

5. **Forming Hypotheses** Suggest some reasons why Neanderthals might have become extinct.
6. **Making Inferences** Imagine you are a scientist excavating an ancient campsite. What might you infer about the people who used the site if you found the charred bones of large animals and various stone blades among human fossils?

Interpreting Graphics

The figure below shows a possible ancestral relationships between humans and some modern apes. Use this figure to answer the questions that follow.



7. Which letter represents the ancestor of all the apes?
8. To which living ape are gorillas most closely related?

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Topic: Human Evolution
SciLinks code: HSM0769

Using Scientific Methods

Inquiry Lab

Mystery Footprints

Sometimes, scientists find clues preserved in rocks that are evidence of the activities of organisms that lived thousands of years ago. Evidence such as preserved footprints can provide important information about an organism. Imagine that your class has been asked by a group of scientists to help study some human footprints. These footprints were found embedded in rocks in an area just outside of town.

OBJECTIVES

Form a hypothesis to explain observations of traces left by other organisms.

Design and **conduct** an experiment to test one of these hypotheses.

Analyze and **communicate** the results in a scientific way.

MATERIALS

- ruler, metric or meterstick
- sand, slightly damp
- large box, at least 1 m^2 or large enough to contain 3 or 4 footprints

SAFETY

Ask a Question

1. Your teacher will give you some mystery footprints in sand. Examine the mystery footprints. Brainstorm what you might learn about the people who walked on this patch of sand.

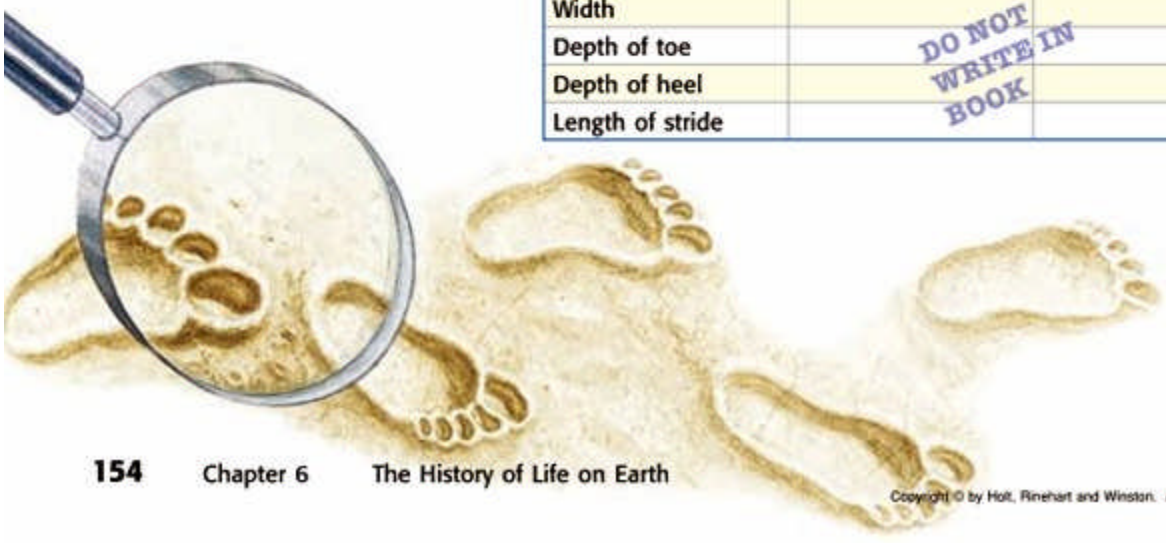
Form a Hypothesis

2. As a class, formulate several testable hypotheses about the people who left the footprints. Form groups of three people, and choose one hypothesis for your group to investigate.

Test the Hypothesis

3. Draw a table for recording your data. For example, if you have two sets of mystery footprints, your table might look similar to the one below.

Mystery Footprints		
	Footprint set 1	**Footprint set 2**
Length		
Width		
Depth of toe		
Depth of heel		
Length of stride		



4. With the help of your group, you may first want to analyze your own footprints to help you draw conclusions about the mystery footprints. For example, use a meterstick to measure your stride when you are running. Is your stride different when you are walking? What part of your foot touches the ground first when you are running? When you are running, which part of your footprint is deeper?

5. Make a list of the kind of footprint each different activity produces. For example, you might write, "When I am running, my footprints are deep near the toe area and 110 cm apart."

Analyze the Results

1. **Classifying** Compare the data from your footprints with the data from the mystery footprints. How are the footprints alike? How are they different?

2. **Identifying Patterns** How many people do you think made the mystery footprints? Explain your interpretation.

3. **Analyzing Data** Can you tell if the mystery footprints were made by men, women, children, or a combination? Can you tell if they were standing still, walking, or running? Explain your interpretation.

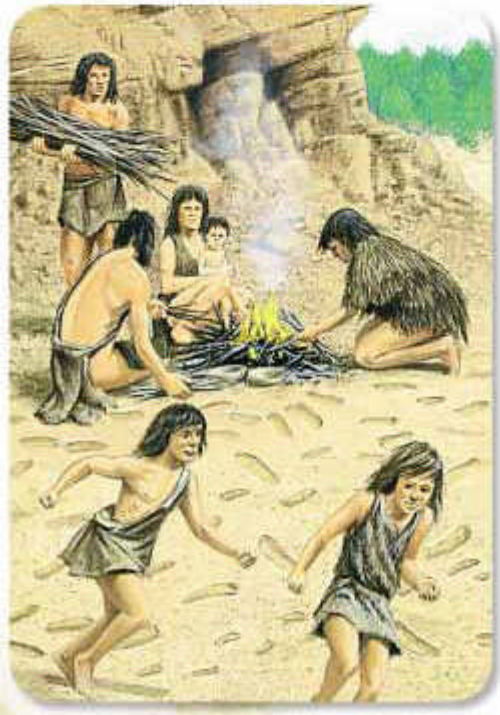
Draw Conclusions

4. **Drawing Conclusions** Do your data support your hypothesis? Explain.

5. **Evaluating Methods** How could you improve your experiment?

Communicating Your Data

WRITING SKILL Summarize your group's conclusions in a report for the scientists who asked for your help. Begin by stating your hypothesis. Then, summarize the methods you used to study the footprints. Include the comparisons you made between your footprints and the mystery footprints. Add pictures if you wish. State your conclusions. Finally, offer some suggestions about how you could improve your investigation.



Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

Precambrian time	Paleozoic era
Mesozoic era	Cenozoic era

1. During ___, life is thought to have originated from nonliving matter.
2. The Age of Mammals refers to the ___.
3. The Age of Reptiles refers to the ___.
4. Plants colonized land during the ___.

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

5. *relative dating* and *absolute dating*
6. *primates* and *hominids*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. If the half-life of an unstable element is 5,000 years, what percentage of the parent material will be left after 10,000 years?
   - a. 100%
   - b. 75%
   - c. 50%
   - d. 25%

8. The first cells on Earth appeared in
   - a. Precambrian time.
   - b. the Paleozoic era.
   - c. the Mesozoic era.
   - d. the Cenozoic era.

9. In which era are we currently living?
   - a. Precambrian time
   - b. Paleozoic era
   - c. Mesozoic era
   - d. Cenozoic era

10. Scientists think that the closest living relatives of humans are
    - a. lemurs.
    - b. monkeys.
    - c. gorillas.
    - d. chimpanzees.

Short Answer

11. Describe how plant and animal remains can become fossils.
12. What information do fossils provide about the history of life?
13. List three important steps in the early development of life on Earth.
14. List two important groups of organisms that appeared during each of the three most recent geologic eras.
15. Describe the event that scientists think caused the mass extinction at the end of the Mesozoic era.

16 From which geologic era are fossils most commonly found?

17 Describe two characteristics that are shared by all primates.

18 Which hominid species is alive today?

CRITICAL THINKING

19 **Concept Mapping** Use the following terms to create a concept map: *Earth's history, humans, Paleozoic era, dinosaurs, Precambrian time, land plants, Mesozoic era, cyanobacteria,* and *Cenozoic era.*

20 **Applying Concepts** Can footprints be fossils? Explain your answer.

21 **Making Inferences** If you find rock layers containing fish fossils in a desert, what can you infer about the history of the desert?

22 **Applying Concepts** Explain how an environmental change can threaten the survival of a species. Give two examples.

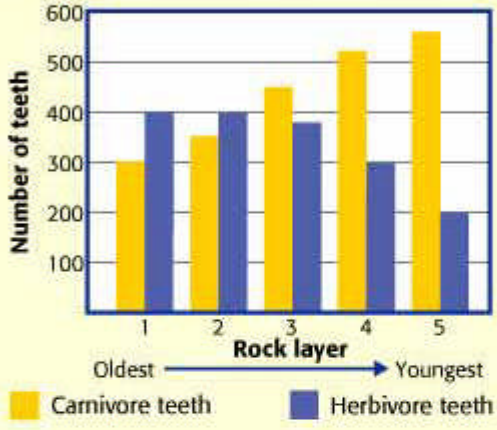
23 **Analyzing Ideas** Why do scientists think the first cells did not need oxygen to survive?

24 **Identifying Relationships** How does the extinction that occurred at the end of the Mesozoic era relate to the Age of Mammals?

25 **Making Comparisons** Make a table listing the similarities and differences between australopithecines, early members of the group *Homo*, and modern members of the species *Homo sapiens.*

INTERPRETING GRAPHICS

The graph below shows data about fossilized teeth that were found within a series of rock layers. Use this graph to answer the questions that follow.



26 Which of the following statements best describes the information presented in the graph?

a. Over time, the number of carnivores decreased and the number of herbivores increased.

b. Over time, the number of carnivores increased and the number of herbivores increased.

c. Over time, the number of carnivores and herbivores remained the same.

d. Over time, the number of carnivores increased and the number of herbivores decreased.

27 At what point did carnivore teeth begin to outnumber herbivore teeth?

a. between layer 1 and layer 2

b. between layer 2 and layer 3

c. between layer 3 and layer 4

d. between layer 4 and layer 5