

# Time Marches On

**Key Concept** Life has changed through Earth's history as life-forms have developed, or evolved, and become extinct.

## What You Will Learn

- The geologic time scale organizes Earth's history into intervals of time.
- Life first appeared on Earth more than 3.6 billion years ago.
- Life-forms changed as environmental changes happened during the Paleozoic, Mesozoic, and Cenozoic Eras.

## Why It Matters

Understanding the history of life on Earth will help you understand how life-forms evolve.

## Vocabulary

- geologic time scale
- extinction

## READING STRATEGY

**Outlining** In your **Science Journal**, create an outline of the section. Use the headings from the section in your outline.

▶ Try to think of Earth's history in "fast forward." If you could watch Earth change in this way, you would see mountains rise up like wrinkles in fabric and quickly wear away. You would see life-forms appear, change, and disappear, or become extinct. In this section, you will learn that geologists must "fast forward" Earth's history when they write or talk about it. You will also learn about some incredible events in the history of life on Earth.

## The Geologic Time Scale

Fossils of dinosaurs that lived 150 million years ago are shown in **Figure 1**. You may think that 150 million years is a very long time. But 150 million years is less than 3% of the time Earth has existed. All together, geologists study 4.6 billion years of Earth's history! To help keep track of this history, geologists have developed the geologic time scale, shown in **Figure 2**. The **geologic time scale** divides Earth's 4.6 billion-year history into distinct intervals of time. Each interval is distinct because life and environments have changed throughout Earth's history.

**Standards Check** Define the term *geologic time scale*.  **7.4.g**

**Figure 1** Bones of dinosaurs that lived about 150 million years ago are exposed in this quarry at Dinosaur National Monument in Utah.



**7.4.d** Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.

**7.4.e** Students know fossils provide evidence of how life and environmental conditions have changed.

**7.4.g** Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.



Geologic Time Scale				
Eon	Era	Period	Epoch	Millions of years ago
PHANEROZOIC	Cenozoic	Quaternary	Holocene	0.01
			Pleistocene	1.8
		Tertiary	Pliocene	5.3
			Miocene	23.0
			Oligocene	33.9
			Eocene	55.8
			Paleocene	65.5
	Mesozoic	Cretaceous	146	
		Jurassic	200	
		Triassic	251	
	Paleozoic	Permian	299	
		Carboniferous	359	
		Devonian	416	
Silurian		444		
Ordovician		488		
Cambrian		542		
PROTEROZOIC	These three eons together are known as <i>Precambrian time</i> because they came before the Cambrian Period.			4,600
ARCHEAN				
HADEAN				

**Figure 2** The geologic time scale is divided into four major parts called eons. Dates given for intervals on the geologic time scale are approximate. **What percentage of Earth's history does the Cenozoic Era represent?**

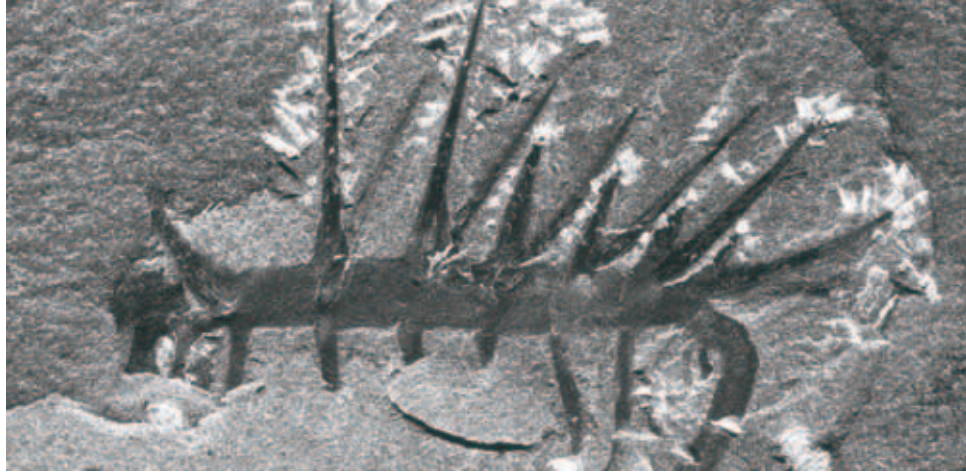
## Divisions of Time

Geologists have divided Earth's history into chunks of time, as shown on the geologic time scale in **Figure 2**. The largest divisions of geologic time are *eons* (EE AHNZ). Together, the first three eons of Earth's history are known as Precambrian time. The Phanerozoic Eon is divided into three *eras*, which are the second-largest divisions of geologic time. The three eras are further divided into *periods*. Periods are divided into *epochs* (EP uhks).

The boundaries between geologic time intervals usually correspond to significant changes in Earth's history. Most boundaries are defined by the appearance or disappearance of a significant number of species. Some boundaries are defined by the appearance or disappearance of index fossils. Other boundaries are defined by major changes in Earth's surface or climate, such as the advance or retreat of glaciers.

**geologic time scale** (JEE uh LAHJ ik TIEM SKAYL) the standard method used to divide Earth's long natural history into manageable parts

**Figure 3** *Hallucigenia*, named for its “bizarre and dreamlike quality,” was one of numerous marine organisms to make its appearance during the early Cambrian Period.



## The Appearance and Disappearance of Organisms

At certain times in Earth’s history, the number of different kinds of organisms has increased or decreased dramatically. These increases can happen because of increases in competition or environmental changes. *Hallucigenia*, shown in **Figure 3**, appeared in the Cambrian Period, when the number of different kinds of marine organisms greatly increased.

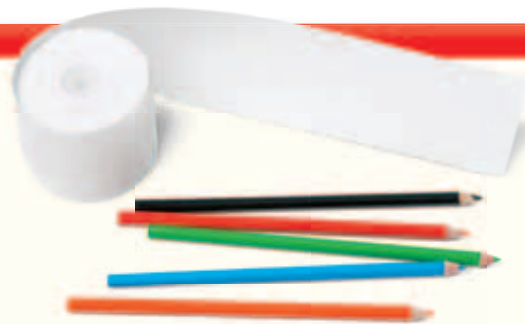
The diversity of organisms can decrease dramatically over a short period of time during a mass extinction. **Extinction** is the death of every member of a certain kind of organism. Gradual events, such as climate change and changes in ocean currents, can cause mass extinctions. Catastrophic events, such as the impact of an asteroid, can also cause mass extinctions.

**extinction** (ek STINGK shuhn) the death of every member of a species

## Quick Lab

### Timeline of Earth’s History

1. Lay a **5 m strip of adding machine paper** flat on a hard surface. With a **pencil**, put a mark at the top of the paper. Near this mark write “Present time.”
2. Using a **meterstick**, measure off 1 m sections from your first mark. At the first mark beyond “Present time,” write “1 bya” (1 billion years ago), and at the second, write “2 bya.” Continue marking 1 m sections until you have a mark labeled “4 bya.”
3. Make a mark 4.6 m from “Present time,” and label this mark “Earth forms, 4.6 bya.”
4. Use a **colored pencil** to mark off and label the Cenozoic Era from the present time to 0.065 bya (6.5 cm from “Present time”).
5. Use **another colored pencil** to mark off and label the Mesozoic Era from 0.065 bya to 0.25 bya (from the beginning of “Cenozoic Era” to 25 cm from the “Present time” mark).
6. Use **another colored pencil** to mark off and label the Paleozoic Era from 0.25 bya to 0.54 bya (from the beginning of “Mesozoic Era” to 54 cm from the “Present time” mark).
7. Use **another colored pencil** to mark off and label Precambrian time from 4.6 bya to 0.54 bya (from the beginning of “Paleozoic Era” to the “Earth forms, 4.6 bya” mark).
8. What percentage of the geologic time scale does Precambrian time represent?
9. Add to your timeline as you learn about events and life-forms in Precambrian time and in the Paleozoic, Mesozoic, and Cenozoic Eras.



7.4.d  
7.4.g

30 min



## Precambrian Time—Life Develops

Precambrian time is the time from the formation of Earth 4.6 billion years ago to about 542 million years ago. Early Earth was very different from today's Earth. The early atmosphere did not contain oxygen as it does today. Intense radiation from the sun bombarded Earth's surface. Life on Earth began during this time. The first organisms appeared in Earth's oceans more than 3.6 billion years ago. These organisms were *prokaryotes*, or single-celled organisms that lack a nucleus.

**Standards Check** When did life first appear on Earth?  7.4.d, 7.4.g

### Life and Oxygen

*Cyanobacteria*, a kind of prokaryotic organism, were some of the first organisms on Earth. Some cyanobacteria are shown in **Figure 4**. Cyanobacteria use sunlight to produce their own food through a process called *photosynthesis*. During this process, the cyanobacteria make oxygen. Cyanobacteria began to release oxygen gas into the oceans and the air.

Oxygen began to accumulate in the atmosphere. 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 5**. Before ozone formed, life existed only in the oceans and underground. The new ozone layer reduced the amount of radiation that reached Earth's surface. The decrease in radiation allowed life to survive on land.

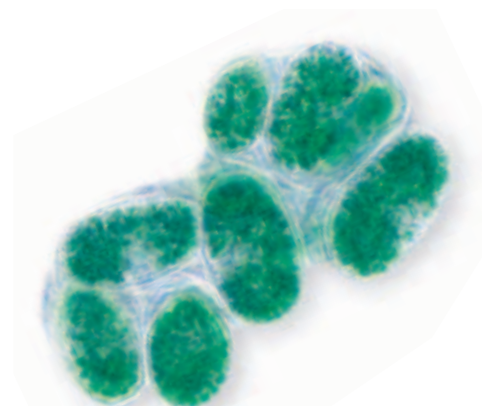
### Organisms That Are More Complex

After about 1 billion years, organisms that were larger and more complex than prokaryotes appeared in the fossil record. These organisms, known as *eukaryotes*, contain a nucleus and other structures in their cells. Eukaryotes may have evolved into more complex multicellular organisms.

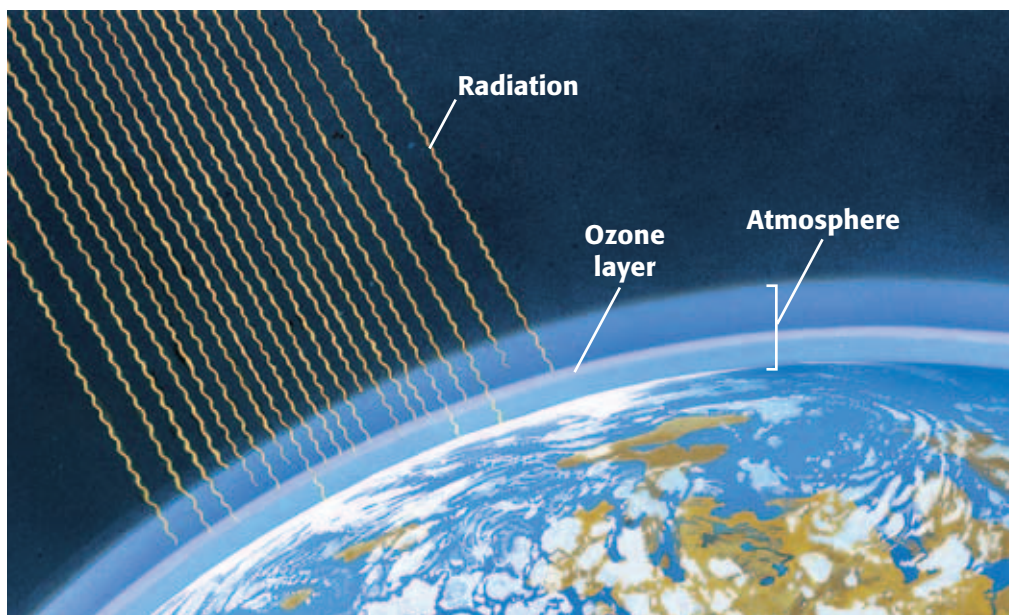
## INTERNET ACTIVITY

### A Fossil's Life

Can you discover how an organism lived by studying its fossil? Describe a day in the life of an extinct organism. Go to **go.hrw.com**, and type in the keyword HY7FOSW.



**Figure 4** Cyanobacteria are the simplest living organisms that use the sun's energy to produce their own food. They are still common on Earth and are very similar to the cyanobacteria that existed on Earth billions of years ago.



**Figure 5** Oxygen in the atmosphere formed a layer of ozone, which absorbs harmful radiation from the sun.



**Figure 6** *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 542 million years ago and ended about 251 million years ago. 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 know 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.

### The Cambrian Explosion

The Cambrian Period was the first period in the Paleozoic Era. Many marine life-forms appeared during this period in what scientists call the “Cambrian explosion.” This event was not an actual explosion. It was the appearance of many new and more-complex life-forms. For the first time, some had preservable hard parts such as shells and exoskeletons.

### Life on Land

Rocks from the Paleozoic Era are rich in fossils of animals such as sponges, corals, snails, squids, and trilobites. Fishes, the earliest animals with backbones, also appeared during this era. During the middle of this era, plants, fungi, and animals colonized land.

By the end of the era, forests of giant ferns, horse-tails, and conifers covered much of Earth. All major plant groups except for flowering plants appeared during this era. The plants provided food and shelter for animals. Fossils indicate that arthropods such as scorpions were the first land animals. Large salamander-like animals also evolved. Near the end of the era, reptiles and insects appeared. **Figure 6** is an artist’s depiction of life in the Paleozoic Era.

### The Permian Extinction

The largest known mass extinction was the Permian extinction. It took place about 251 million years ago, at the end of the Permian Period of the Paleozoic Era. Earth’s continents had joined to form Pangaea, and shallow inland seas had disappeared. As many as 90% of marine species and 78% of land species had become extinct. The fossil record shows that groups such as reptiles and amphibians survived the Permian extinction.



## The Mesozoic Era

The *Mesozoic Era* (MES oh ZOH ik ER uh) began about 251 million years ago. *Mesozoic* comes from Greek words meaning “middle life.” Scientists think that the reptiles that survived the Permian extinction evolved into many reptile species in the Mesozoic 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 lived during the Mesozoic Era. Dinosaurs dominated Earth for about 150 million years. Some had unique adaptations, such as ducklike bills for feeding or large spines on their bodies for defense. In addition to dinosaurs on land, giant marine reptiles swam in the oceans. The first birds also appeared during the Mesozoic Era. Scientists think that some dinosaurs were the ancestors of birds. The first mammals also appeared during the Mesozoic Era.

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 7**.

### The Cretaceous-Tertiary Extinction

The Mesozoic Era ended about 65 million years ago. Around this time, all of the dinosaurs and about half of the animal and plant species became extinct. This event is called the *Cretaceous-Tertiary* (or *K-T*) *extinction* because it defines the boundary between the Cretaceous and Tertiary Periods. Scientists find evidence for this mass extinction in the disappearance of many types of fossils from the fossil record during this time.

What happened? According to one hypothesis, an object from our solar system hit Earth. The impact formed giant dust clouds and enough heat to cause worldwide fires. The dust and smoke blocked out some sunlight and caused many plants to die out. Without enough plants to eat, the plant-eating dinosaurs died out. As a result, the meat-eating dinosaurs that fed on the plant-eating dinosaurs died.

**Standards Check** What fossil evidence is there for the Cretaceous-Tertiary extinction?  **7.4.e, 7.4.g**



**Figure 7** The Mesozoic Era ended with the mass extinction of many of the large animals, such as the ankylosaur and the aquatic plesiosaur shown above.



**Figure 8** Many types of mammals, including humans, appeared during the Cenozoic Era.

### **Wordwise** Cenozoic

The root *-cene* means “new” or “recent.” The suffix *-zoic* means “pertaining to animals.”

## 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 meaning “recent life.” Scientists have more information about the Cenozoic Era than about any of the previous eras. Because Cenozoic rocks formed on top of rocks from previous eras, many Cenozoic fossils are closer to Earth’s surface. The closer the fossils are to the surface, the more likely they are to be found.

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 8**.

### 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 horses. Humans appeared very late in the Cenozoic Era.

**Standards Check** What significant organisms appeared during the Cenozoic Era?  7.4.g

### The Cenozoic Era Today

The environment and landscapes that we see around us today developed during the Cenozoic Era. For example, the Alps and the Himalayas formed during this era. The climate has also changed many times during the Cenozoic Era. Earth’s history includes some lengths of time called *ice ages*, during which the climate was very cold. During the ice ages, ice sheets and glaciers extended from Earth’s poles. To survive, many organisms migrated toward the equator. Other organisms adapted to the cold or became extinct.

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