

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do geologists measure time?
- How has life changed during Earth's history?
- What can cause a mass extinction?

**National Science
Education Standards**
ES 2b

How Old Is the Earth?

The fossils in the figure below are dinosaur bones. The dinosaurs that became these fossils lived 150 million years ago. To most people, 150 million years seems like a very long time. However, to geologists, 150 million years is not very long at all. Geologists study the history of the Earth. The Earth is about 4.6 billion years old. Therefore, 150 million years is less than 3% of the age of the Earth!



How do geologists study such long periods of time? They use rocks and fossils to learn about how the Earth has changed with time. Remember that rocks form in layers, and that different rocks form in different environments. By studying very old rocks, geologists can guess what environments were like long ago. ✓

Fossils are also very important in helping geologists learn about the Earth's history. Remember that geologists can learn about an area's environment by studying the fossils that formed there. The fossils can give clues about how the Earth has changed with time.

Geologists have combined information from rocks and fossils to produce a timeline of the Earth's history. This timeline is called the **geologic time scale**.



Organize As you read, make a chart showing the eras of geologic time. Include major changes in life that happened during each era.

TAKE A LOOK

1. Identify What kinds of organisms formed the fossils in the picture?



2. Explain How can geologists figure out what the Earth's environment was like very long ago?

SECTION 5 Time Marches On *continued*

What Is the Geologic Time Scale?

The geologic time scale includes all of the Earth’s 4.6 billion years of history. Geologists have divided Earth’s history into many shorter sections of time. These sections are shown in the figure below.

Geologic Time Scale

	Era	Period	Epoch	Millions of ears ago	
PHANEROZOIC EON	Ceno oic	Quaternary	Holocene	0.01	
			Pleistocene		
		Tertiary	Pliocene		1.8
			Miocene		5.3
			Oligocene		23.8
			Eocene		33.7
			Paleocene		54.8
	Meso oic	Cretaceous		65	
		Jurassic		144	
		Triassic		206	
	Paleo oic	Permian		248	
		Pennsylvanian		290	
		Mississippian		323	
		Devonian		354	
Silurian			417		
Ordovician			443		
		Cambrian		490	
				543	
PROTEROZOIC EON	Protero oic Eon The first cells appeared during this eon.			2,500	
ARCHEAN EON	Archean Eon The oldest rocks on Earth formed during this eon.			3,800	
HADEAN EON	Hadean Eon The only known rocks from this eon are meteorites and rocks from the moon.			4,600	

Math Focus

3. Calculate About how long did the Triassic period last?

TAKE A LOOK

4. List Give the five epochs in the Tertiary period in order from oldest to most recent.

As you can see, the largest divisions of geologic time are the **eons**. Earth’s history is divided into four eons: the Hadean eon, the Archean eon, the Proterozoic eon, and the Phanerozoic eon. Most rocks and fossils on the Earth formed during the Phanerozoic eon. Scientists divide the Phanerozoic eon into three **eras**, which are the second-largest divisions of the time scale.

Scientists divide the eras into **periods**, which are the third-largest divisions of the time scale. For example, the Mesozoic era is divided into the Triassic, Jurassic, and Cretaceous periods. Periods are divided into **epochs**, which are the fourth-largest divisions of the time scale.

SECTION 5 Time Marches On *continued***THE APPEARANCE AND DISAPPEARANCE OF SPECIES**

Scientists use changes in life to define many of the boundaries between sections of geologic time. For example, some boundaries are defined by mass extinctions.

Extinction is the death of every member of a species. A *mass extinction* happens when many species go extinct at one time. ✓

Mass extinctions happen for different reasons. Gradual events, such as global climate change or changes in ocean currents, can cause mass extinctions. Sudden events, such as a large volcanic eruption or a meteorite impact, can also cause many species to go extinct. In many cases, mass extinctions happen because of a combination of sudden and gradual events.

Many geologic time boundaries are defined by the disappearance of species. Others are defined by the appearance of species. For example, the beginning of the Phanerozoic eon was marked by the appearance of many new species of ocean life. Some of these organisms looked similar to organisms that are alive today. However, others, such as the organism in the figure below, looked very different.



This organism, called *Hallucigenia*, lived in the early Cambrian period. Many ocean life forms, including *Hallucigenia*, first appeared at the beginning of the Phanerozoic eon.

 **READING CHECK**

5. Describe How do geologists define many of the boundaries between sections of geologic time?

TAKE A LOOK

6. Apply Concepts During which era did *Hallucigenia* live?

How Has Life Changed During the Phanerozoic Eon?

The Phanerozoic eon is the most recent eon in the Earth's history. It is the eon in which we live. Almost all of the fossils and rocks that are found on Earth today formed during the Phanerozoic eon.

SECTION 5 Time Marches On *continued*

THE PALEOZOIC ERA: BEGINNINGS OF MODERN LIFE

The Paleozoic era lasted from about 542 million to 251 million years ago. *Paleo* means “old,” and *zoic* means “life.” Therefore, the Paleozoic was the era of “old life.”

During the Paleozoic era, many species of organisms lived in the Earth’s oceans. However, there were not many species of organisms living on land until the middle of the Paleozoic era. By the end of the era, amphibians and reptiles lived on the land, and many species of insects existed. The figure below shows some of the types of organisms that evolved during the Paleozoic era. ✓

READING CHECK

7. Identify During which era did amphibians and reptiles evolve?

TAKE A LOOK

8. Apply Concepts Why are there no birds or mammals in this image?



Plants, fish, amphibians, and reptiles evolved during the Paleozoic era.

The end of the Paleozoic era is marked by a huge mass extinction. Ninety percent of all ocean species died out during this extinction. Scientists are not sure what caused this extinction, but it may have been caused by changing ocean currents.

THE MESOZOIC ERA: THE AGE OF REPTILES

The Mesozoic era began about 251 million years ago and ended about 65 million years ago. *Meso* means “middle,” so the Mesozoic was the era of “middle life.”

Reptiles were the dominant organisms that lived during the Mesozoic. Probably the most famous of these reptiles are the dinosaurs. However, small mammals and birds also evolved during the later parts of the Mesozoic. Many scientists think that birds evolved from a type of dinosaur.

The end of the Mesozoic era is also marked by a mass extinction. About 15% to 20% of all species on Earth, including all of the dinosaurs, went extinct at the end of the Mesozoic era. Most scientists think that global cooling because of a meteorite impact caused this extinction.

Say It

Infer and Discuss How could changes in ocean currents cause mass extinction? Write down some ideas of your own about how this could happen. Then, talk about your ideas with other students.

SECTION 5 Time Marches On *continued*



Dinosaurs were the dominant land organisms during the Mesozoic era. Small mammals and birds also evolved during the Mesozoic.

TAKE A LOOK

9. Explain Why is the Mesozoic era sometimes called the “Age of Reptiles?”

THE CENOZOIC ERA: THE AGE OF MAMMALS

The Cenozoic era began about 65 million years ago and continues to the present. *Ceno* means “recent,” so the Cenozoic is the era of “recent life.”

After the dinosaurs went extinct, mammals no longer had to compete with them for resources. As a result, mammals have become more dominant during the Cenozoic. Many features of mammals may have helped them survive the climate changes that caused the extinction of the dinosaurs. These features include being able to control body temperature and bearing young that grow inside the mother.

The Cenozoic era continues today, but many organisms that lived at the beginning of the era are now extinct. The figure below shows some of these organisms.



Thousands of species of mammals evolved during the Cenozoic. Many of the mammals in this figure are now extinct.

Critical Thinking

10. Infer How could controlling body temperature and bearing live young have helped mammals survive the events that caused the extinction of the dinosaurs?

Section 5 Review

SECTION VOCABULARY

<p>eon the largest division of geologic time</p> <p>epoch a subdivision of geologic time that is longer than an age but shorter than a period</p> <p>era a unit of geologic time that includes two or more periods</p>	<p>extinction the death of every member of a species</p> <p>geologic time scale the standard method used to divide the Earth's long natural history into manageable parts</p> <p>period a unit of geologic time that is longer than an epoch but shorter than an era</p>
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1. **List** What are four divisions of geological time?

2. **Identify** How old is the Earth?

3. **Explain** How can geologists use rocks and fossils to learn how the Earth's environments have changed?

4. **List** Write the seven periods of the Paleozoic era in order from oldest to most recent.

5. **Describe** How do geologists define the ends of the Paleozoic and Mesozoic eras?

6. **Identify** Give two things that can cause mass extinctions.

SECTION 5 TIME MARCHES ON

1. dinosaurs
2. by studying rocks and fossils
3. about 50 million years
4. Paleocene, Eocene, Oligocene, Miocene, Pliocene
5. by changes in life on Earth
6. Paleozoic
7. Paleozoic
8. Birds and mammals did not evolve until after the Paleozoic era.
9. Reptiles were the dominant land animals during the era.
10. Being warm-blooded and having young develop inside the mothers' bodies could allow mammals to survive in a wider temperature range than dinosaurs. If the extinction was caused by climate change, mammals would have been more likely to survive.

Review

1. eon, era, period, and epoch
2. about 4.6 billion years
3. Different kinds of rocks form in different environments. Different kinds of organisms live in different environments. By studying the rocks and fossils that formed long ago, geologists can infer which environments existed then.
4. Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian
5. by mass extinctions
6. Possible answers: sudden events and gradual events; examples of sudden/gradual events

Chapter 7 Plate Tectonics

SECTION 1 INSIDE THE EARTH

1. The continental crust is thicker and contains less iron than oceanic crust.
2. about 1/20
3. The rock in the mantle contains more magnesium and less aluminum than the crust.
4. by studying rock that erupts from the mantle
5. crust, mantle, core
6. the upper, rigid layer of Earth made of the crust and some of the mantle
7. Possible answer: Different scientists are interested in different properties of the Earth.

8. lithosphere, asthenosphere, mesosphere, inner core, outer core
9. Oceanic: Pacific
Continental: African
10. continental crust
11. vibrations created by earthquakes
12. Some kinds of seismic waves cannot travel through it.

Review

	Crust	Mantle	Core
Thickness or radius	5 km to 100 km	2,900 km	3,430 km
Location	outer layer of the Earth	middle layer of the Earth	inner layer of the Earth
Percent of Earth's mass	less than 1%	67%	33%

2. The inner core is solid, but the outer core is liquid. Both are made of iron and nickel.
3. The lithosphere contains the crust and some of the mantle.
Both the crust and the lithosphere are the outermost layers of Earth.
4. by studying mantle rocks that push to the surface, by studying rocks on the sea floor, using seismic waves

SECTION 2 RESTLESS CONTINENTS

1. They were once part of a single continent.
2. Europe; they share similar-aged mountain rocks.
3. The same kinds of fossils are found on widely separated continents.
4. about 200 million years ago
5. North America and Europe were connected; India and Asia were separated.
6. an underwater mountain chain
7. when Earth's magnetic poles change places
8. They are mirror images of each other.

Review

1. The shapes of continental coastlines seem to match. Similar fossils are found on widely separated continents. Mountain chains of similar ages and compositions are found on widely separated continents.