



CHAPTER 8

The BIG Idea

Evidence from rocks helps us understand the history of life on Earth.

LESSON 1 4.b, 4.e, 4.g, 7.c

Geologic Time and Mass Extinctions

Main Idea Fossils provide evidence of how life and environmental conditions have changed over time. Geologists used fossils to create the geologic time scale.

LESSON 2 4.b, 4.e, 4.g, 7.d

Early Earth History

Main Idea Bacteria, the simplest organisms, were the first organisms to evolve on Earth. Increasingly complex organisms followed them.

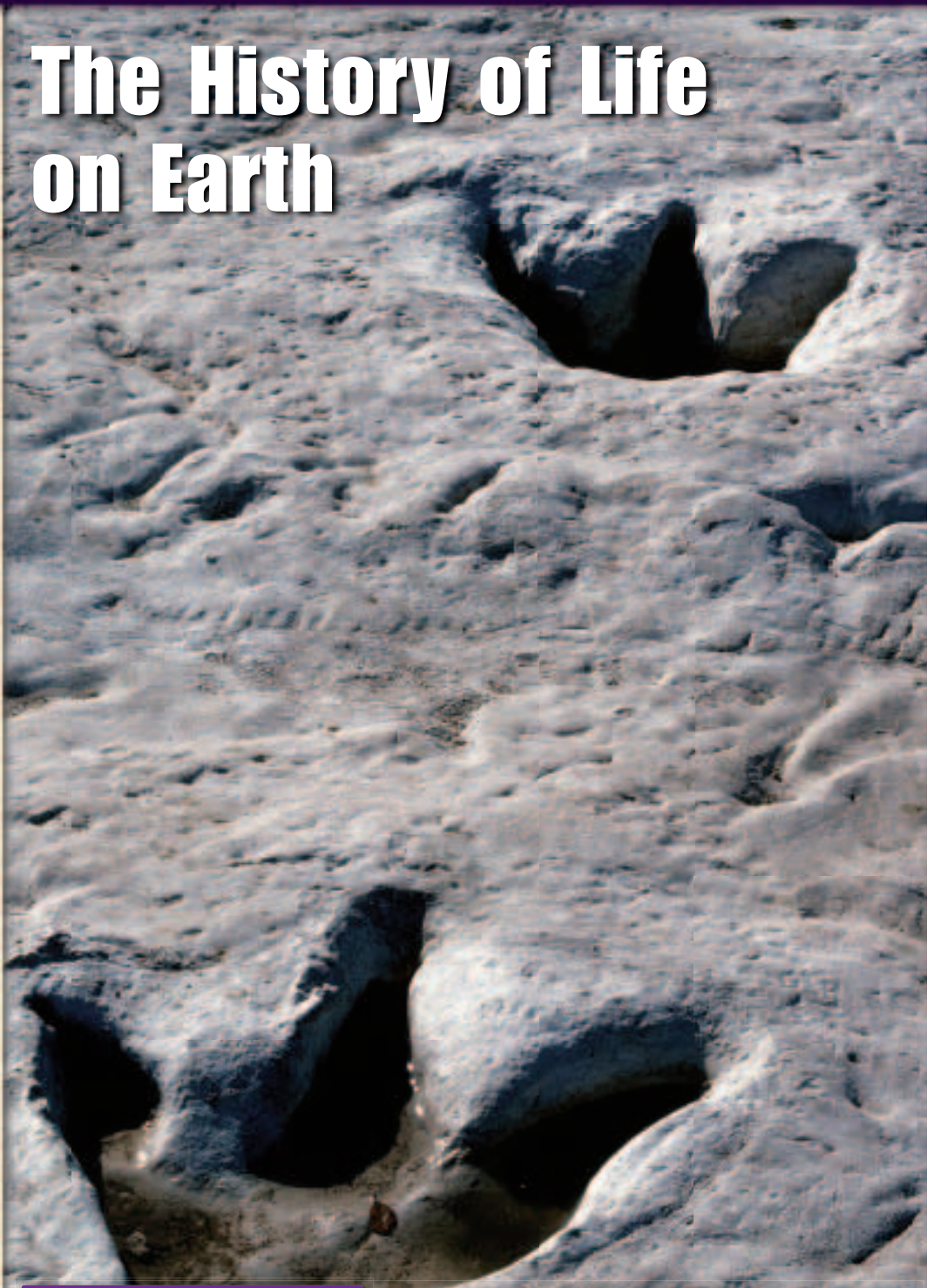
LESSON 3

4.b, 4.e, 4.g, 7.a, 7.c, 7.d

Middle and Recent Earth History

Main Idea Life continues to evolve into many of the forms we see on Earth today.

The History of Life on Earth



Footprints in Stone

Did you ever go barefoot on a muddy beach? Your feet sink down and mud oozes between your toes. The next day the mud may dry out and your footprints remain. If they get filled in by sand or gravel, a mold may form. Cover them over with layers of sediment, wait a few thousand years, and your tracks will be in stone just like these dinosaur tracks.

Science Journal Write a one-page description about the dinosaur that might have left these tracks. What did it look like? What was it doing? What happened to it?

Start-Up Activities

Launch Lab

00:20
minutes

How are events unscrambled?

The clues to Earth's past have appeared to humans out of sequence. How do scientists put events in order?

Procedure



1. Find a **cartoon strip** that is at least a half page long.
2. Cut apart each frame of the cartoon strip.
3. Mix up the order of the frames and trade with a partner.
4. Try to put each other's cartoons back in to order. Try mixing three or four strips.

Think about This

- **Analyze** How did you know which frame should go first and which should go last?
- **Explain** How did you put the other frames in order? What clues did you use?
- **Compare** How is putting the cartoon frames in order similar to the way scientists patch together the clues about the history of life on Earth?



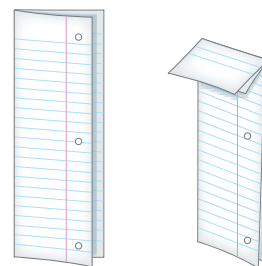
4.e, 4.g, 7.c



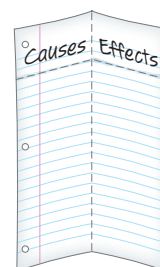
FOLDABLES™ Study Organizer

Mass Extinction Make the following Foldable to show the causes of mass extinctions and which organisms were affected.

- **STEP 1 Fold** a sheet of paper in half lengthwise. **Fold** the top down about 4 cm from the top.



- **STEP 2 Unfold** and draw lines along all folds. **Label** as shown.



Reading Skill



ELA7: R 2.3

Recognizing Cause and Effect

In the first column, explain the causes of mass extinctions throughout Earth's history. In the second column, explain why certain organisms became extinct as a result.

Scienceonline

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- explore Virtual Labs
- access content-related Web links
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Get Ready to Read

Identify Cause and Effect

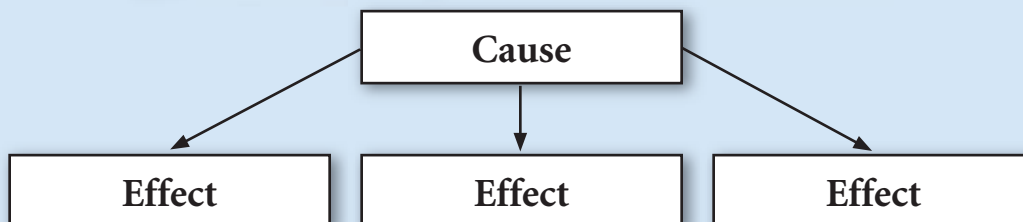


1 Learn It! A *cause* is the reason something happens. The result of what happens is called an *effect*. Learning to identify causes and effects helps you understand why things happen. By using graphic organizers, you can sort and analyze causes and effects as you read.

2 Practice It! Read the following paragraph. Then use the graphic organizer below to show what happened when oxygen entered the atmosphere.

Recall that Earth's early atmosphere had no oxygen. Because cyanobacteria are photosynthetic, they released oxygen into the atmosphere. Over the next hundreds of millions of years, oxygen levels rose slowly as cyanobacteria and other early life-forms released oxygen. The earliest organisms did not consume oxygen. In fact, oxygen could kill them. During this period, natural selection favored organisms that could tolerate or even use oxygen. The amount of ozone in the atmosphere also increased during this time, shielding life on Earth from ultraviolet rays. These gradual changes to the atmosphere resulted in major changes in life on Earth.

—from page 327



3 Apply It! As you read the chapter, be aware of causes and effects of environmental changes. Find five causes and their effects.

Reading Tip

Graphic organizers such as the Cause-Effect organizer help you organize what you are reading so you can remember it later.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 Before you read the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 After you read the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D	Statement	After You Read A or D
	1 Fossils are important to estimating the age of Earth.	
	2 Establishing a geologic time scale of Earth events was easy once fossils were found.	
	3 Catastrophic events have caused most extinctions of animals and plants.	
	4 Volcanic eruptions and tsunamis have been the main source of mass extinctions.	
	5 Over 90 percent of all species have gone extinct.	
	6 There are no fossils older than 65 million years.	
	7 At one time, there might have been little or no oxygen in the atmosphere.	
	8 Flying reptiles evolved into birds.	
	9 Mammals and dinosaurs were both alive on Earth at the same time.	
	10 Turtles, frogs, crocodiles, dinosaurs, and reptiles all evolved during the same era.	



Print a worksheet of this page at ca7.msscience.com.



LESSON 1



Science Content Standards

- 4.b** Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
- 4.e** Students know fossils provide evidence of how life and environmental conditions have changed.
- 4.g** Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.

Also covers: 7.c

Reading Guide

What You'll Learn

- **Describe** how fossils were used to organize the geologic time scale.
- **Describe** the mass extinction events on the geologic time scale.
- **Explain** how catastrophic events can lead to mass extinctions.

Why It's Important

The life and landscape around you are the result of change through geologic time.

Vocabulary

index fossil
mass extinction
catastrophic event

Review Vocabulary

volcano: land or underwater feature that forms when magma reaches Earth's surface (Grade 6)

Geologic Time and Mass Extinctions

Main Idea Fossils provide evidence of how life and environmental conditions have changed over time. Geologists used fossils to create the geologic time scale.

Real-World Reading Connection The storage media for home computers has changed over the last 25 years. During that time people have used 5.25-inch floppy disks, 3.5-inch disks, and now read-writable CDs and portable flash drives. In a similar way, life on Earth has changed throughout Earth's history.

Development of the Geologic Time Scale

The changes to life and Earth that have occurred throughout Earth's history are recorded on a time line called the geologic time scale. Because extinctions, growth rates, and environmental changes happen at different rates, the time scale's units are uneven. To organize geologic time into units, paleontologists (pay lee un TOL uh jihsts) study the types and ages of fossils in rock layers and decide where to mark the units.

Index Fossils

Units of time on the geologic time scale are described by the presence and the absence of certain types of fossils called index fossils. An **index fossil** is the remains of a species that existed over vast regions of Earth for a short period of time. **Table 1** explains how a species is selected to be an index fossil.

Table 1 Index Fossil Criteria

- | | |
|---|---|
| 1 | The remains of species must have hard parts, so they will preserve easily in the rock record. |
| 2 | The remains of species must be geographically widespread, so they are commonly found. |
| 3 | The species must have lived in many types of environments. This ensures that they will be preserved in many different types of sedimentary rocks. |
| 4 | The species must have lived for a short time before they became extinct. This allows rock layers to be divided into small units of geologic time. |



Divisions of the Geologic Time Scale

Figure 1 shows the geologic time scale used today. Notice that no two divisions of time have the same number of years. There are several major divisions of the geologic time scale. The largest divisions are called eons and are the longest units of time. Eons have been broken into smaller units called eras. Eras in turn are divided into periods and epochs.

Eras Paleontologists have defined three eras within the Phanerozoic (fan ayr oh ZOH ihk) eon. The Paleozoic (pay lee uh ZOH ihk) era, which means “ancient life,” was dominated by invertebrate marine organisms. Although they might have a shell, invertebrate marine animals are those without a backbone. During the Mesozoic (mez uh ZOH ihk) era, which means “middle life,” dinosaurs and mammals lived on land. The Cenozoic (sen uh ZOH ihk) era, which means “recent life,” continues today. Modern mammals and humans evolved during this recent time.



Figure 1 For how many years did the Paleozoic era last?

Periods and Epochs Divisions of eras are called periods. The Cenozoic era was once divided into two periods, the Tertiary (TER shee ayr ee) period and the Quaternary (KWAH tur nayr ee) period. As scientists learn more and do more research, they sometimes change the way they describe and name things. Today we no longer use the term *Tertiary* to describe the first division of the Cenozoic. Instead paleontologists divide the Tertiary into two parts called the Paleogene period and Neogene period. You can find these listed in the chart in **Figure 1**.

The Quaternary period began about 1.8 million years ago. The periods have been divided into epochs. The Pleistocene (PLYS tuh seen) epoch ended about 8,000 years ago. The Holocene (HOH luh seen) is the epoch we live in.

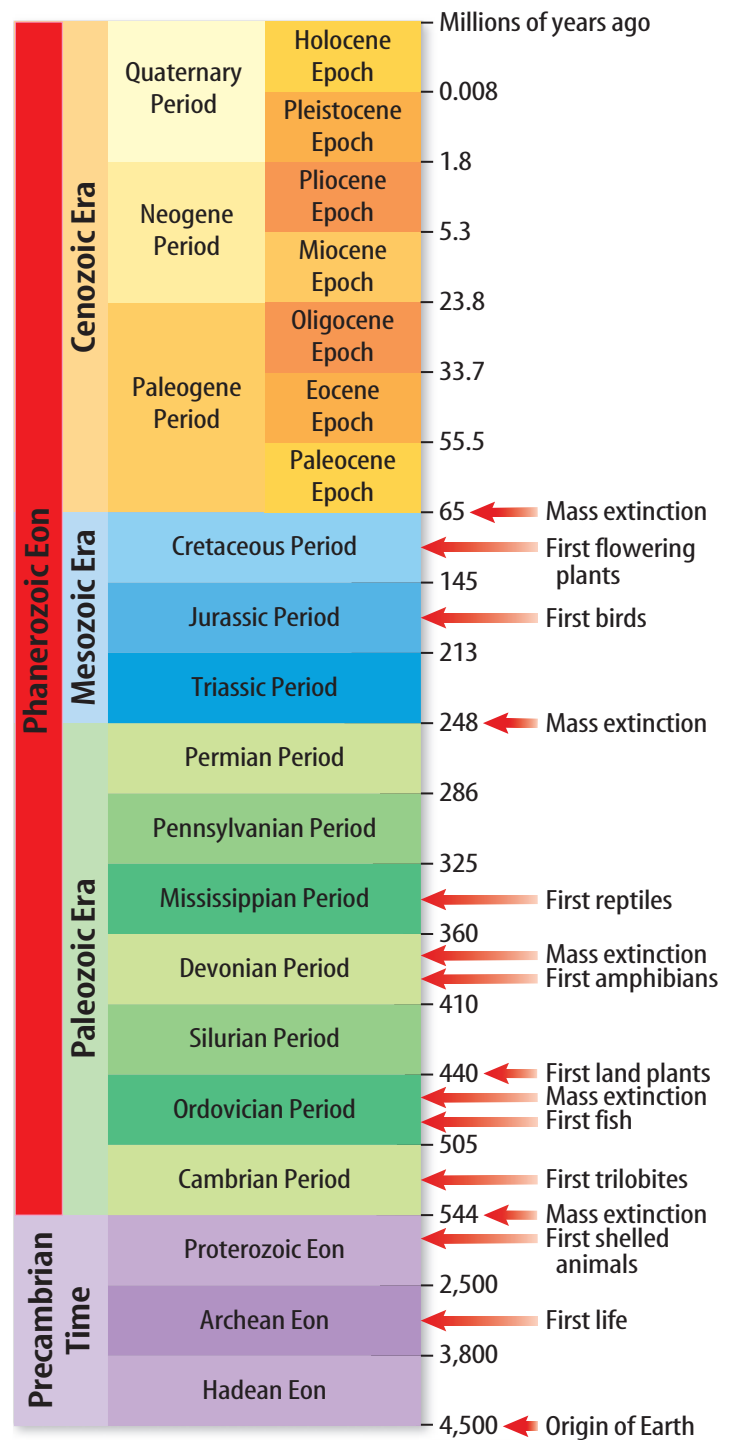


Figure 1 The geologic time scale was developed using relative and absolute dating methods.

Concepts in Motion

Interactive Table Organize information about the geologic time scale at ca7.msscience.com.

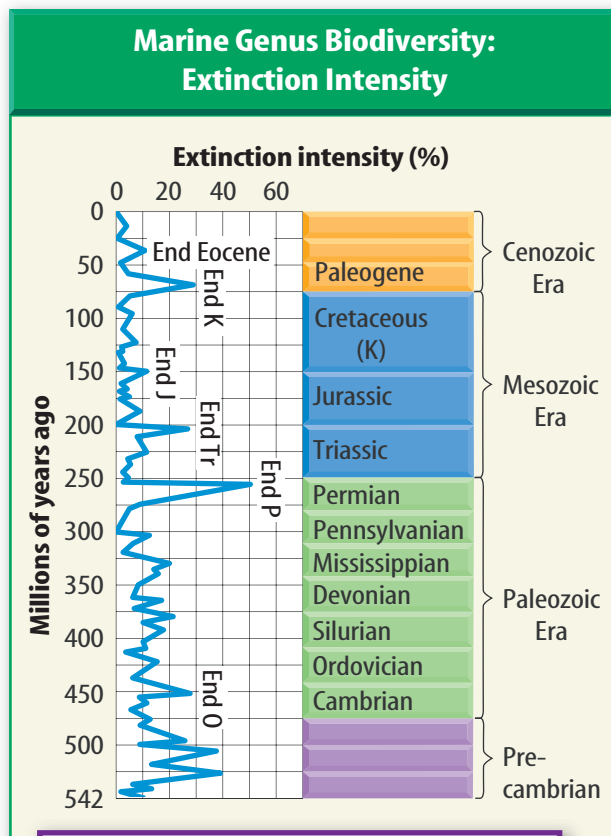


Figure 2 The graph shows how some extinction events were used to mark changes in the geologic time scale.

WORD ORIGIN

catastrophe

kata— prefix; from Greek; means *over*
-strephein from Greek; means *to turn*

What are mass extinctions?

How do paleontologists determine when one unit on the geologic time scale ends and another begins? Scientists look for layers of rock that include more diversity and greater numbers of fossils than rock layers above them. This indicates that many organisms might have died over a short period of time. Several units on the geologic time scale begin and end with mass extinction, as shown in **Figure 2**. **Mass extinction** is the dying off of many different species of organisms over a short period in geologic time.

The extinction of a single species of organisms is common. In fact, 99 percent of all species that have lived on Earth are now extinct. However, the extinction of several species over a short period of time is rare. It is important to note that mass extinctions do not occur instantaneously. They can happen over as great a span of time as a few million years.



What percent of extinctions marked the end of the Eocene era, the Triassic era, the Permian era, and Precambrian time?

Possible Causes of Mass Extinction

Once paleontologists recognized that mass extinctions occurred throughout geologic time, they began to search for catastrophic events that might cause them. A **catastrophic** (ca tuh STRAH fik) **event** is an event that causes a drastic change in the numbers of organisms of one or more species over a short period in geologic time. It may seem that all catastrophic events cause mass extinction, but that is not always true. Scientists still do not fully understand the specific catastrophic events that have caused each of the mass extinctions. They have identified several types of events, however, that have the ability to cause mass extinction. These events include changes in climate, volcanic eruptions, and asteroid impacts.



Climate Change

There is evidence that some mass extinctions were caused by relatively sudden changes in climate. **Figure 3** shows a diver collecting climatic evidence. Recall that climate is an average weather pattern over a long period of time. Species that are unable to survive a change in climate become extinct. Climate change can be caused by several events, including some volcanic eruptions and asteroid impacts. Global warming and global cooling are two types of climate change that might have caused some mass extinctions.

Global Warming Burning of fossil fuels, such as coal and oil, adds greenhouse gases, like carbon dioxide, to the atmosphere. Many scientists think greenhouse gases in the atmosphere contribute to global warming, a **global** increase in atmospheric temperature. If the overall temperature of the atmosphere increases, the temperature of the oceans also increases. Because warm water holds less oxygen than cold water, global warming could cause a decrease in oxygen levels in the water. If the oxygen levels drop in shallow waters, where most organisms live, mass extinctions could occur.

Global warming could also raise sea levels. Water from melting glaciers would flow into the oceans, causing sea levels to rise. Geologists have found evidence of warm temperatures, a rising sea level, and oxygen-poor waters flooding shallow-water areas during the Devonian mass extinction. Some scientists think global warming might have been the cause.



List possible effects of global warming.

ACADEMIC VOCABULARY

global (GLO buhl)

(*adj*) relating to the entire world

We live in a global economy.



Figure 3 Nearly microscopic corals build on top of the skeletons of their ancestors. The core sample that is being taken here will tell scientists what the environment was like thousands or millions of years ago.

Infer What climatic conditions would you expect to produce the most coral life-forms?



Figure 4 The iceberg breaks off the glacier edge as it enters the ocean. It looks much the same now as it did during the Ordovician era.

Global Cooling Mass extinctions could also be caused by global cooling, an overall decrease in atmospheric temperatures. Global cooling could lower sea levels as large amounts of water are frozen in glacial ice. Less water in the oceans would mean fewer warm, shallow-water environments. With fewer warm-water environments, there would be less space to support marine ecosystems. Global cooling appears to have initiated the Ordovician mass extinction event. **Figure 4** shows how at that time, large glaciers were active near the south pole.

Volcanoes

When you think of a volcanic eruption, you might think of a large explosion. However, volcanoes also produce nonexplosive eruptions. The dust, ash, lava, and gas emitted from volcanic eruptions can affect climate and organisms.

Explosive Eruptions Mt. Vesuvius, in Italy, erupted in A.D. 79. The ash and lava buried the cities of Pompeii and Herculaneum, killing thousands of people. The 1815 eruption of Tambora produced a flaming cloud of dust and gas that killed more than 30,000 people. The year after this eruption is referred to as the year without summer as the air was blanketed with ash, reducing the amount of sunlight that reached Earth. **Figure 5** shows part of the results of the violent, but relatively small, explosion of Mount St. Helens in Washington State. These eruptions are recent events in geologic time. Although catastrophic, these eruptions have not led to mass extinction. However, a volcanic eruption is one of several hypotheses proposed to explain the mass extinction event at the end of the Cretaceous period.



Figure 5 What force might have knocked over these trees?

Figure 5 Trees lie covered in ash in the blow-down zone after the eruption of Mount St. Helens in 1980.





Figure 6 The lava is red hot as it flows across the surface of the island of Hawaii. Gases from this eruption are also being added to the atmosphere.

Basalt Flows Along divergent plate boundaries and in isolated hot spots, such as under the Hawaiian Islands, lava flows smoothly onto Earth's surface. These nonexplosive floods of molten basalt emit the largest volume of matter of any eruptions. This matter comes from Earth's mantle. Geologic evidence shows that large basalt flows occurred in Siberia during the Permian mass extinction. The flows are called the Siberian Traps. During the Cretaceous mass extinction, another large basalt flow, called the Deccan Traps, was released in India. Although small by comparison, **Figure 6** shows a basalt flow around a volcano in Hawaii.

Volcanic Haze The gases produced by basalt flows cause a complex sequence of effects. First, sulfur dioxide gas is released into the atmosphere, resulting in the formation of acid clouds. These clouds block some of the sunlight from reaching Earth's surface. Over the course of months to tens of years, global cooling occurs. This is called the volcanic haze effect. Over periods of tens to hundreds of thousands of years, global temperatures may increase because heat becomes trapped in Earth's atmosphere by the sulfuric acid clouds. It is uncertain whether basaltic flows and the gases they emit were enough to cause the Permian and Cretaceous mass extinctions.



How could acid clouds affect temperatures?

Figure 7 Scientific evidence of crater formation and meteorite deposits have identified this site as the impact site that might have killed off all the dinosaurs.

Discuss the reasons scientists might have had trouble locating this asteroid impact site.



Figure 8 Plants wouldn't be able to photosynthesize if the atmosphere were full of the dust an asteroid impact might kick up. Mass extinction might follow.



Asteroid Impacts

Figure 7 shows the location of a possible asteroid impact site on the Yucatan Peninsula in Mexico. Scientists believe this impact may have contributed to the Cretaceous mass extinction.

Effects of the Impact Some geologists propose that this impact sent enough dust and other material into the atmosphere to block sunlight. **Figure 8** shows how a cold and dark Earth killed plants and other primary producers. Without primary producers, there was no source of food. Mass extinctions followed. Global cooling, created by the initial impact, turned into global warming as carbon dioxide was released from burning plants ignited by the impact. These greenhouse conditions lasted thousands of years.

The Debate Most scientists accept the hypothesis that a large asteroid, or possibly several asteroids, hit Earth at the end of the Cretaceous period. Evidence supports the hypothesis that many species became extinct around the time of the impact. However, paleontologists propose that the impact did not cause all the extinctions. The fossil record shows that many species were decreasing in number and diversity long before the impact. In fact, many became extinct at least one million years before the impact. The fossil record also shows that the extinction rate increased tens of thousands of years before the impact. It appears that while the impact did cause some extinctions, it clearly did not cause all of them.

Is there an extinction pattern?

Although mass extinctions occur over a short geologic time span, they are not instantaneous. Fossil evidence indicates that mass extinctions can occur over a few million years or more. What caused the mass extinctions in geologic time? Investigations have revealed no clear patterns, although there are several types of catastrophic events that can cause mass extinction. It appears that each extinction event might have been caused by a unique series of events. Species that survive mass extinction inherit an environment with few competitors. In time, their descendants might repopulate Earth. In the next lesson, you will read about the organisms that populated Earth during major segments of geologic time.

LESSON 1 Review

Summarize

Create your own lesson summary as you write a script for a **television news report**.

1. **Review** the text after the **red** main headings and write one sentence about each. These are the headlines of your broadcast.
2. **Review** the text and write 2–3 sentences about each **blue** subheading. These sentences should tell *who*, *what*, *when*, *where*, and *why* information about each **red** heading.
3. **Include** descriptive details in your report, such as names of reporters and local places and events.
4. **Present** your news report to other classmates alone or with a team.



ELA7: LS 2.2



Standards Check

Using Vocabulary

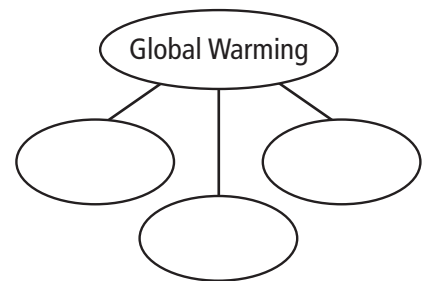
1. Use the term *index fossil* in a sentence. **4.e**

Understanding Main Ideas

2. **List** the types of remains that can be preserved as fossils. **4.e**
3. **Compare and contrast** global warming and global cooling. **4.g**
4. The Siberian Traps were an example of which of these?
A. greenhouse gases
B. asteroid impact
C. global warming
D. basalt flow **4.b**
5. **Organize** the divisions of the geologic time scale in order from longest length of time to shortest length of time. **4.g**

Applying Science

6. **Create** a worldwide technology time scale. Describe the criteria you used to create your time scale. **4.e**
7. **Predict** what criteria will be used to mark the end of the current era. **4.g**
8. **Describe** Fill in the features of global warming. **4.b**



Science  **online**

For more practice, visit **Standards Check** at ca7.msscience.com.

Which organisms return first following a catastrophic event?

Some catastrophic events cause mass extinctions. How do species survive after a catastrophic event?

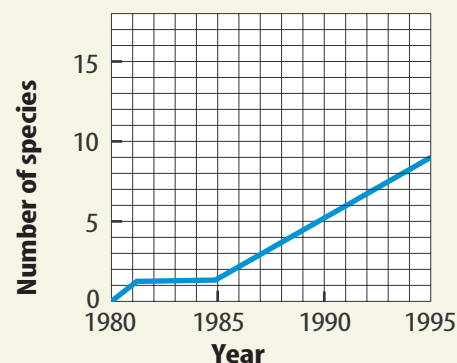
Data Collection

1. Study the graph of stream invertebrates.
2. How many species reappeared during the first ten years following the eruption of Mount St. Helens?
3. Study the graph of bird species.
4. How many species of birds reappeared during the first ten years following the eruption?
5. Compare the reappearance of bird species to that of stream invertebrates following the eruption.

Data Analysis

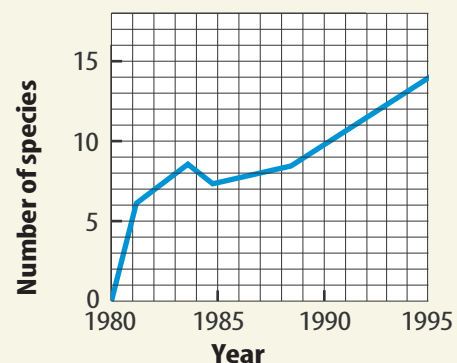
1. **Infer** Which animals would you have expected to return first, birds or stream invertebrates? Explain.
2. **Interpret Data** Which had the greater number of species in the blowdown zone 10 years after the eruption?
3. **Form Hypotheses** Plants, birds, and stream invertebrates now thrive in areas once covered by volcanic ash. Write a hypothesis about how this repopulation occurred for each group.

Amphibians



Source: USGS

Birds



Source: USGS



Science Content Standards

7.c Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.



MA7: MR 2.5



LESSON 2



Science Content Standards

- 4.b** Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
- 4.e** Students know fossils provide evidence of how life and environmental conditions have changed.
- 4.g** Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.
- 7.d** Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).

Reading Guide

What You'll Learn

- ▶ **Describe** the environment and first life from Precambrian time.
- ▶ **Trace** the changes in life-forms in the Paleozoic after the Cambrian explosion.
- ▶ **Infer** the changes that lead to mass extinctions.

Why It's Important

Learning about past events helps us predict the future.

Vocabulary

amniote
cyanobacteria
vertebrate

Review Vocabulary

extinct: no longer existing (species) (p. 224)

Early Earth History

Main Idea Bacteria, the simplest organisms, were the first organisms to evolve on Earth. Increasingly complex organisms followed them.

Real-World Reading Connection Imagine that you go into the kitchen and there on the table you find a paper plate with icing and candle wax on it. You might ask yourself what happened. Your hypothesis might be that in the recent past there was a birthday party in the room. Scientists have a similar task when they find the fossilized remains of ancient organisms. They ask themselves this question: What was life on Earth like in the past?

Life on Earth Changes

Fossils record the history of life on Earth. Paleontologists, who study fossils, discovered that the system used to classify modern organisms could also be used to classify fossils. They observed that fossils from rock layers that are touching are more similar to each other than fossils from widely separated layers. Geologists also recognized that the more recently a fossil was formed, the more it resembles a living organism. Perhaps you have been to the ocean and collected a sand dollar, or have seen a sand dollar skeleton. It likely looked most like the sand dollar in the first row of **Table 2**. In this lesson, you will read about these changes in life during the Precambrian (pre KAM bree un) time.

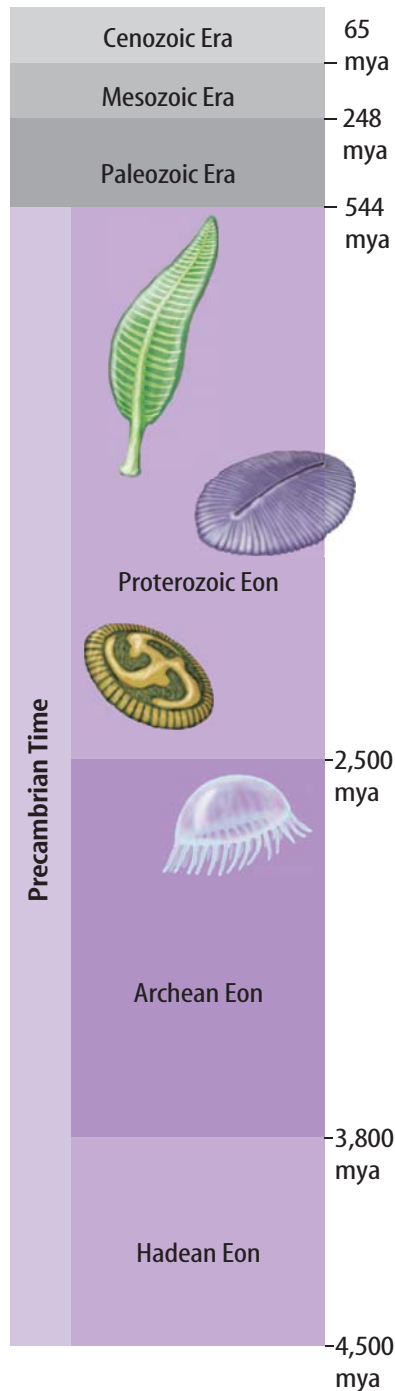


Table 2 How did the sand dollar change over time?

Table 2 Sand Dollar Changes			
Oldest → Youngest		Side View	Top View
	Middle Eocene		
	Early Eocene		
	Paleocene		



Figure 9 Precambrian time is divided into three eons.



Precambrian Time

Figure 9 shows the portion of the geologic time scale that represents Precambrian time. Precambrian time is divided into three eons—Hadean (HAY dee un), Archean (ar KEE un), and Proterozoic (proh ter oh ZOH ihk). The Precambrian age represents 88 percent of Earth's history. Precambrian rocks are difficult for scientists to study because most of the rock has been changed through metamorphism. Recall that it is difficult for scientists to determine the absolute age of metamorphosed rock using radiometric dating. Also, much of the Precambrian rock has been destroyed at subduction zones. As the plates move together, the more dense plate sinks into the mantle. There the rock in the plate may melt or become metamorphic. Any fossil remains will be destroyed.

Fossils are not as abundant in Precambrian-aged rocks as they are in younger rocks. But, the fossils that have been discovered provide a great deal of information about Earth's early atmosphere and environment during this time.

The Precambrian Atmosphere

Rocks of Archean age reveal that Earth's early atmosphere was very different from today's atmosphere. For example, Archean sediments contain large amounts of the minerals pyrite and uraninite. Today's atmosphere contains oxygen that quickly destroys these minerals through the chemical process of oxidation. We see oxidation today when water and oxygen react with iron to make rust. Pyrite contains lots of iron. It makes sense that the presence of pyrite and uraninite in very old rocks tells us that Earth's early atmosphere had very little oxygen.

Ozone Because we know oxygen is required to make ozone, the absence of oxygen also suggests that there was no ozone layer during Precambrian time. Scientists are concerned that the ozone layer today has been partially destroyed by chemicals made by humans. Without atmospheric ozone to protect life on Earth from harmful ultraviolet rays, exposure of life-forms to these rays could result in death or mutation. Recall how mutations occur in cells. Changes in one gene in an organism could result in new life-forms many, many generations later. Could this be the process leading up to the big changes in the Paleozoic era?



Why is ozone important to living organisms?



Figure 10 Cyanobacteria use sand and salt from the oceans to build stromatolite mounds similar in some ways to how corals build reefs.

The First Organisms

Stromatolites (stroh MAT uh lites) are mounds of alternating thin-layered sediments and photosynthetic cyanobacteria. They contain the fossils of one of the earliest known, ancient organisms.

Figure 10 shows how stromatolites form. **Cyanobacteria** are single-celled, blue-green algae thought to be one of the earliest organisms. Like other photosynthetic organisms, cyanobacteria take in carbon dioxide and release oxygen. Stromatolites were common during the Archaen eon until the late Proterozoic eon, when bacteria-eating animals evolved. Today, stromatolites exist only in water that is too salty and warm for other organisms to survive.



How are cyanobacteria like other photosynthetic organisms?

A Changing Environment

Recall that Earth's early atmosphere had no oxygen. Because cyanobacteria are photosynthetic, they released oxygen into the atmosphere. Over the next hundreds of millions of years, oxygen levels rose slowly as cyanobacteria and other early life-forms released oxygen. The earliest organisms did not consume oxygen. In fact, oxygen could kill them. During this period, natural selection favored organisms that could tolerate or even use oxygen. The amount of ozone in the atmosphere also increased during this time, shielding life on Earth from ultraviolet rays. These gradual changes to the atmosphere resulted in major changes in life on Earth.

MiniLab

00:45
minutes

What makes the best fossils?

Paleontologists use fossils to determine what life was like in the past. Some life-forms formed better fossils than others. Determine what makes the best fossils.

Procedure



1. Complete a lab safety form.
2. Place a **rubber band**, a **paper clip**, a few **salt grains**, and a **bottle cap** on a flat surface.
3. Press some **clay** onto each of the objects.
4. Remove the objects from the clay and observe the fossil mold impression.

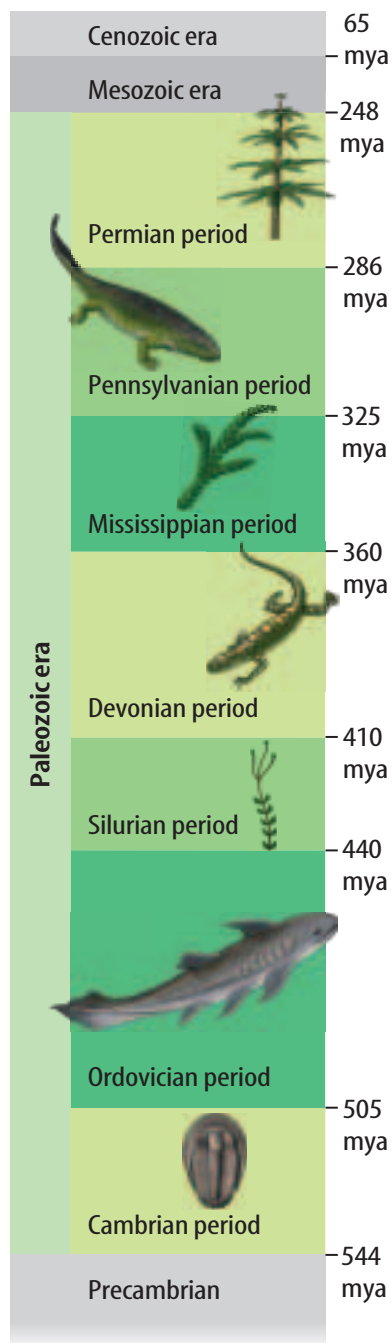
Analysis

1. **Determine** which made the best fossil.
2. **Explain** what is required for good fossils.
3. **Infer** why there are so few fossils from the Precambrian time.





Figure 11 The Paleozoic era ushered in a variety of new life-forms.



Soft-Bodied Organisms

Organisms increased in complexity in the Proterozoic eon. During this eon, the first invertebrate organisms appeared. Invertebrates are animals without backbones. Unusual fossils of soft-bodied organisms were discovered in the Ediacara Hills of Australia. These organisms, called the Ediacaran (eddy uh KER uhn) fauna, had shapes similar to present-day jellies, worms, and corals. Some paleontologists believe that some present-day organisms are descended from the Ediacaran fauna. Others think these organisms became extinct at the end of the Proterozoic eon.

The Paleozoic Era

The first appearance of fossils of organisms made from hard parts marks the end of the Proterozoic eon. Because organisms made from hard parts fossilize easier than those made of soft parts, fossils are easier to find in Paleozoic rocks than Precambrian rocks. **Figure 11** shows the portion of the geologic time scale that contains the Paleozoic era.

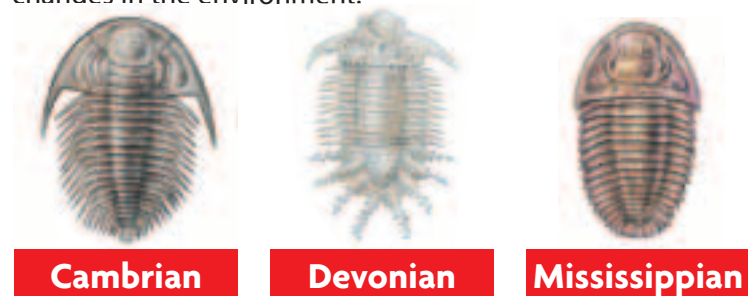


What marked the end of the Proterozoic eon?

The Cambrian Explosion

About five million years after the start of the Cambrian (KAM bree un) period, an event known as the Cambrian explosion occurred. The fossil record shows that during a relatively short period of time, the number of animals with shells greatly increased. Small-shelled organisms that looked like cones, plates, and tubes evolved along with larger-shelled organisms. Invertebrates, including sponges, jellies, and corals, also evolved during the Cambrian explosion. Trilobites, animals with hard outer skeletons, were the most commonly fossilized organisms of the Cambrian period. Some species of trilobites are shown in **Figure 12**.

Figure 12 Changes in trilobite body forms matched changes in the environment.



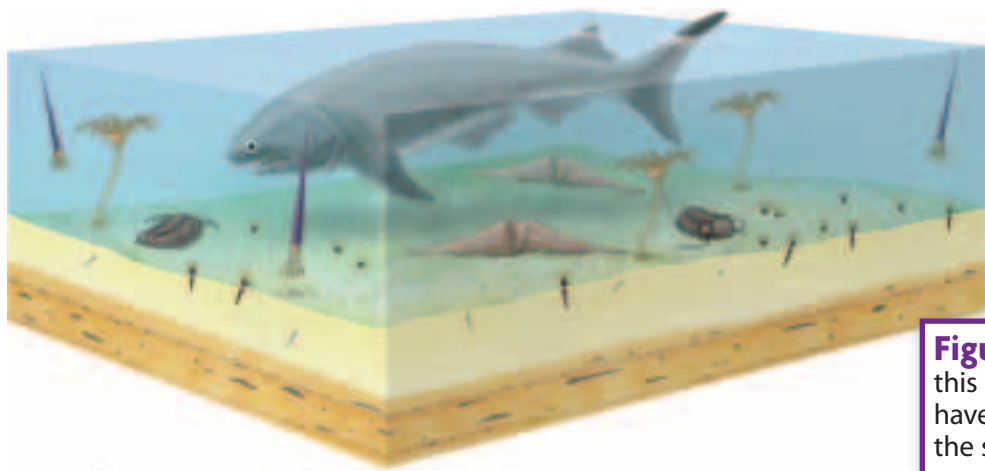


Figure 13 The teeth of this Paleozoic fish might have been used to crush the shells of its prey.

Invertebrates of the Paleozoic Era

Throughout the Paleozoic era, the oceans contained a wide **variety** of invertebrate organisms including corals, brachiopods (BRAY kee uh pahdz), crinoids (KRIH noydz), and bryozoans (bri UH zoh unz). **Figure 13** shows what the ocean floor may have looked like during the Ordovician (or duh VIH shun) period. Imagine a cockroach 10 cm long or a dragonfly with a wingspan of 74 cm. These insects would have lived during the Silurian (si LOOR ee un) period.

Vertebrates of the Paleozoic Era

Vertebrates, animals with backbones, evolved during the early Paleozoic Era. The first of these lived in the oceans.

Bony Fish Early vertebrates included two groups of bony fish. One group had thin, bony rays which supported their fins. Another group of bony fish had thick fins supported by large bones and muscles. Scientists believe that the first group evolved into modern-day fish, while the second group evolved into amphibians that can live both in water and on land. Amphibians later evolved into reptiles and mammals.

A New Egg In order to reproduce, amphibians had to return to the water to lay their eggs. The water carries food and wastes into and out of the eggs. Amphibian eggs are not watertight and they would dry out and die on land. During the Pennsylvanian period a significant development occurred in the process of egg-laying. Early in the Pennsylvanian period an organism evolved that could lay its eggs on land. The organism is called an **amniote** and it lays water-tight, amniotic eggs. This means the eggs do not dry out on land. Since plants had moved on land during the Ordovician and provided a food source, this allowed the amniotes to spend all their time on land. Mammals, dinosaurs, and reptiles all evolved from amniotes.

ACADEMIC VOCABULARY

variety

(**noun**) the quality of having different forms *The shirt comes in a variety of colors.*

SCIENCE USE V. COMMON USE

sponge

Science Use an invertebrate animal of the ocean. *A sponge reproduces by budding.*

Common Use a device used for cleaning. *She used a sponge to wash her car.*



Figure 14 Plants of the Mississippian and Pennsylvanian eras made up the biotic mass that produced the coal and oil we use as fuel today.

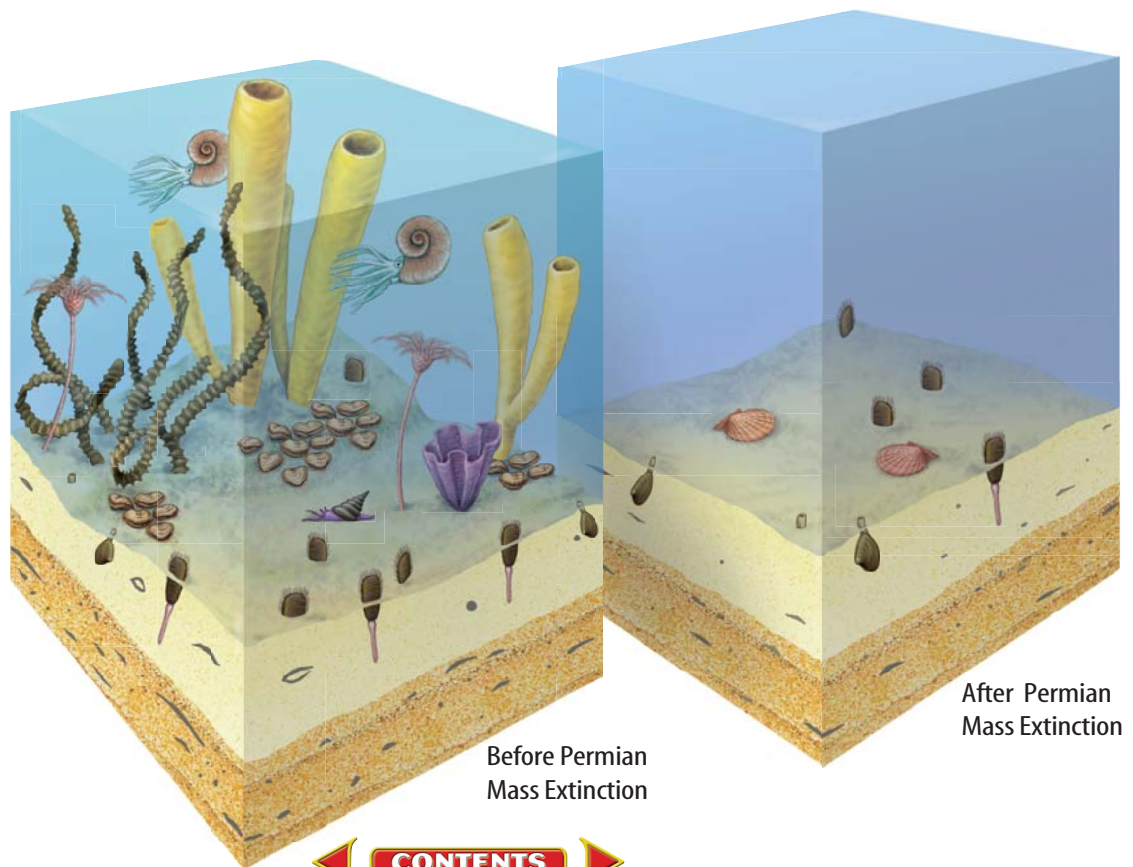
Plants of the Paleozoic Era

The first plants developed in the ocean from green algae. During the Ordovician period, plants spread onto land. Because these early plants could not move water and nutrients to all their parts, the plants remained small and lived in low, moist areas. Vascular plants then evolved with vascular systems that could move water and nutrients between their roots and leaves. Vascular club mosses were small, but by the Late Devonian they became the trees shown in **Figure 14**. Ferns and groups that include the present-day conifers appeared during the Mississippian period. Large swamps containing abundant trees and ferns developed during the Mississippian and Pennsylvanian periods. These plants decayed, and became large coal deposits.

Paleozoic Era Extinctions

The fossil record indicates that mass extinction events occurred during the Ordovician period and the Devonian period. The Paleozoic era ended with the late Permian extinction—the extinction of more than 90 percent of all marine species and more than 70 percent of all land species. **Figure 15** shows how the ocean might have looked before and after an extinction event. Several hypotheses have been proposed to explain the Permian extinction. One proposes that the uplifting formation of Pangaea left little room for shallow-water life-forms as marine terraces became dry land. Another proposes that the Siberian Traps released ash and sulfur into the atmosphere, causing global cooling and the formation of glaciers on land.

Figure 15
The Permian extinction killed off 90 percent of all marine species.





Mass Extinction Ends the Paleozoic Era The early Cambrian period saw the expansion on Earth of many new species of life and the development of hard-shelled organisms that would leave fossil evidence of their existence. Before the Paleozoic era ended, there would be the evolution of the first fish, land plants, amphibians, and reptiles, all of which had hard parts that left fossil evidence. However, about 250 million years ago, the late Permian extinction resulted in the extinction of most marine and land species. Changes in species diversity usually follow an extinction event. Niches and habitats once inhabited by some organisms became empty and other species moved into these spaces. Extinction of predators allowed other organisms to increase in number and expand in distribution.

LESSON 2 Review

Summarize

Create your own lesson summary as you organize an **outline**.

1. **Scan** the lesson. Find and list the first **red** main heading.
2. **Review** the text after the heading and list 2–3 details about the heading.
3. **Find** and list each **blue** subheading that follows the **red** main heading.
4. **List** 2–3 details, key terms, and definitions under each **blue** subheading.
5. **Review** additional **red** main headings and their supporting **blue** subheadings. List 2–3 details about each.



Standards Check

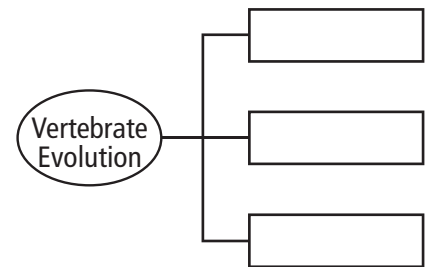
Using Vocabulary

1. Write the definition for *mass extinction* in your own words. **4.b**

Understanding Main Ideas

2. **Explain** how the introduction of oxygen to the atmosphere changed the life-forms on Earth. **4.e**
3. **Describe** the changes that mark the beginning of the Paleozoic era. **4.g**
4. **Infer** which changes during the Paleozoic era were most important to today's life-forms. **4.e**
5. Which is used as a record of Earth's history? **4.e**
 - A. bacteria
 - B. atmosphere
 - C. fossils
 - D. geologic time scale

6. **Trace** the evolution of vertebrates in the Paleozoic era. **4.e**



Applying Science

7. **Compare and contrast** the amniote egg with the amphibian egg. **4.b**
8. **Solve** How many generations of cyanobacteria would there be in a million years if each bacterium lives for 24 hours? How many generations for an organism that lives 100 years? **4.g**



For more practice, visit **Standards Check** at ca7.msscience.com.



LESSON 3



Science Content Standards

- 4.b** Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
- 4.e** Students know fossils provide evidence of how life and environmental conditions have changed.
- 4.g** Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.
- Also covers:** 7.a, 7.c, 7.d

Reading Guide

What You'll Learn

- **Identify** the evolution of organisms on Earth today.
- **Determine** the changes that pressure organisms to evolve.
- **Examine** the diversity of life over time.

Why It's Important

Many people are concerned with the rate of extinctions of life on Earth and the possibility that humans are the cause.

Vocabulary

pterosaur
ectotherm
endotherm
gymnosperm
primate

Review Vocabulary

angiosperm: a flowering seed plant (p. 138)

Middle and Recent Earth History

Main Idea Life continues to evolve into many of the forms we see on Earth today.

Real-World Reading Connection After it rains, you may see a puddle in the street or in your yard. In a day or two it is gone—it evaporated. You didn't see it happen, but it was evaporating the whole time. Imagine how long it would take for a lake to evaporate. Now imagine the ocean evaporating into nothing. How long would it take?

The Mesozoic Era

Figure 17 on the facing page shows the three periods of the geologic time scale that make up the Mesozoic era—the Triassic period, the Jurassic period, and the Cretaceous period. Most organisms that survived the Permian mass extinction event diversified widely during the next 50 million years.

A Changing Landscape

About 180 million years ago, the Pangaea land mass began to split into two land masses, Laurasia and Gondwanaland, as shown in **Figure 16**. The split started a new weather pattern that would create a warm, wet climate for a large area of these land masses.

Figure 16 The continent of Pangaea would split first into two continents and later into the present-day continents.





Invertebrates of the Mesozoic Era

After the extinction event at the end of the Paleozoic era, many of the predators of stromatolites had become extinct. This allowed stromatolites to increase in numbers. Algae and large clams, like the rudistids, were the new life forms to evolve in the Cretaceous period. By the Triassic, however, the rudistids had been replaced by reef-building corals. We can still find the descendents of crinoids and brachiopods that populated the Mesozoic oceans. They live in polar seas and in deep oceans. Although most groups of organisms became more widely diversified during the Mesozoic era, the insects that had become so abundant during the late Paleozoic era declined in number and diversity during the Mesozoic era.

Vertebrates of the Mesozoic Era

In addition to the fish that evolved during the Paleozoic era, the oceans of the Mesozoic era contained predatory reptiles such as plesiosaurs and mosasaurs. Amphibians, reptiles, and mammals that lived on land continued to evolve during the Mesozoic era. Frogs, turtles, crocodiles, pterosaurs, and dinosaurs evolved during this time.

Pterosaurs were flying reptiles. Many were the size of today's predatory birds. The pterosaur shown in **Figure 18** had a wingspan of 12 m and might have weighed 200 kg. Although pterosaurs shared many characteristics with dinosaurs, they were not dinosaurs. Pterosaurs differed from dinosaurs in that they had hollow bones, thin and translucent wings, extra bones in their hands or wings, and were probably covered with a hairlike material. Although they could fly like birds and bats, they are not a related species to either.

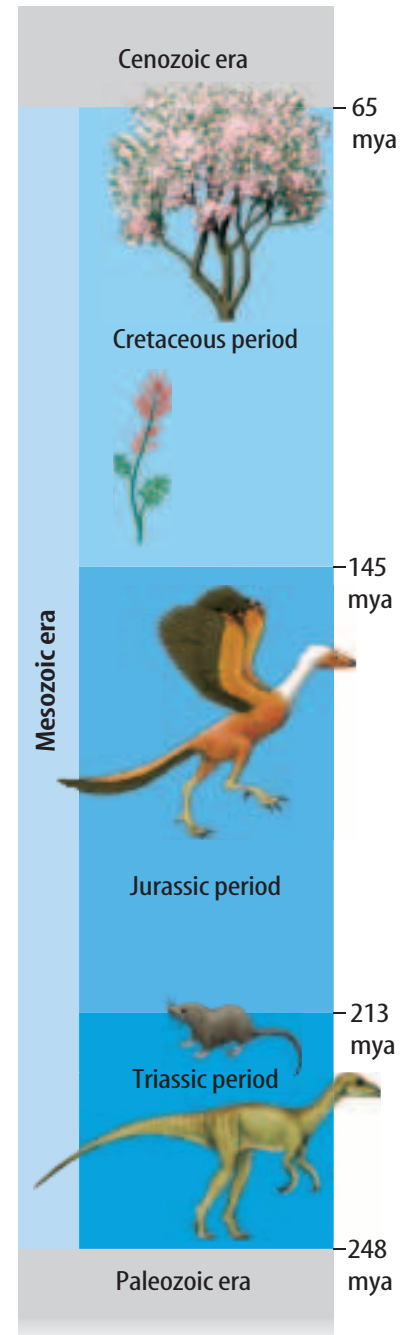


What Mesozoic animals still exist today?

Figure 18 Some pterosaurs skimmed the water with their beaks to catch fish.



Figure 17 The Mesozoic era included the Jurassic period, also known as the Age of Reptiles.



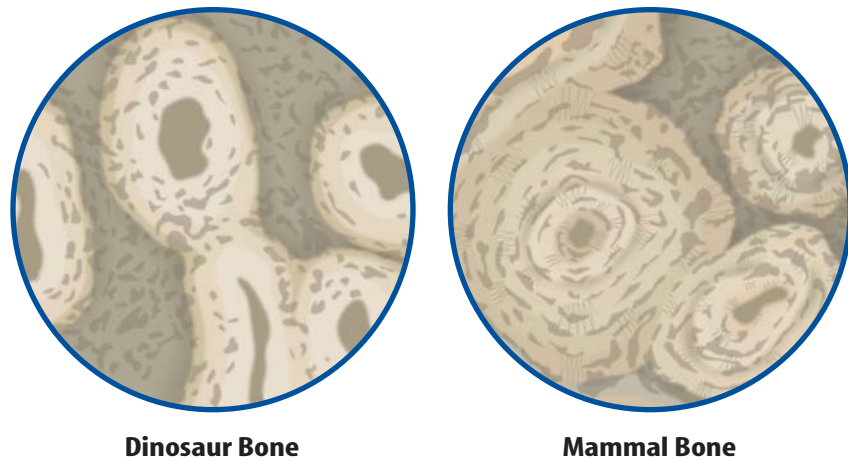
WORD ORIGIN

pterosaur

ptero- from Greek *pteron*; means *wing*
-saur from Greek; means *lizard*



Figure 19 Growth rings can be seen in this enlarged cross-section of dinosaur and mammal bones. The growth rate might be a clue to whether dinosaurs were endothermic.



Dinosaur Bone

Mammal Bone

WORD ORIGIN

ectotherm
endotherm

ecto— from Greek *ektos*; means *outside*

endo— from Greek *endon*; means *inside*

—therm from Greek *therme*; means *heat*

Dinosaurs Dinosaurs evolved during the Triassic period. The first dinosaurs were small, but as new species evolved, they grew bigger. *Apatosaurus* and *Diplodocus* were some of the largest animals to walk on Earth. The first scientists to study dinosaur fossils thought their skulls, feet, and tails suggested that they were just very large reptiles. Because they imagined them to be reptiles, they believed that they lived and behaved like modern reptiles do today. That would mean that dinosaurs were **ectotherms**, relying on their surroundings and behavior to help them regulate their body temperatures. As such they would have to find sunlight to warm up and move into the shade to cool off. Recent studies of dinosaur bones show that their structure is more similar to endothermic species. **Endotherms** generate internal body heat to maintain a constant body temperature. **Figure 19** shows a comparison of dinosaur and mammal bones. Rings in bones indicate the organism's growth rate much like tree rings tell the age and rate of growth of a tree. Similarities in growth rate have led scientists to think that dinosaurs were endothermic and may have lived more like today's mammals and birds than like reptiles. Other comparisons include speed of travel, carrying the tail and not dragging it, and having an upright stance.

Birds By the 1970s scientists had proposed that birds are the descendants of dinosaurs. Read about the extinct reptiles in **Figure 20** and think about the debate. It has been many millions of years since the time of dinosaurs. Birds have had many opportunities to evolve to fit into new and different environments. Did they become endothermic or have they always been endotherms?

Visualizing Extinct Reptiles

Figure 20

If you're like most people, the phrase "prehistoric reptiles" probably brings dinosaurs to mind. But not all ancient reptiles were dinosaurs. The first dinosaurs didn't appear until about 115 million years after the first reptiles. Paleontologists have unearthed the fossils of a variety of reptilian creatures that swam through the seas and waterways of ancient Earth. Several examples of these extinct aquatic reptiles are shown here.



▲ **ICHTHYOSAUR** (IHK thee uh sawr) Ichthyosaurs resembled a cross between a dolphin and a shark, with large eyes, four paddle-like limbs, and a fishlike tail that moved from side to side. These extinct reptiles were fearsome predators with long jaws armed with numerous sharp teeth.



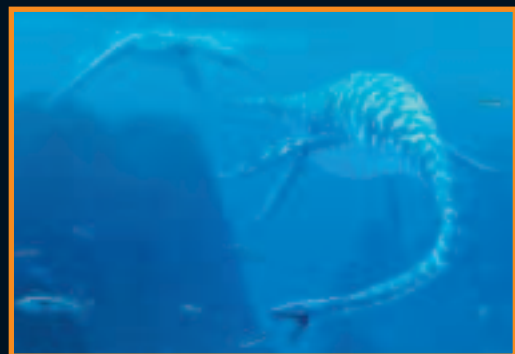
▲ **CHAMPOSAUR** (CHAMP uh sawr) This ancient reptile looked something like a modern crocodile, with a long snout studded with razor-sharp teeth. Champosaurs lived in the freshwater lakes and streams and preyed on fish and turtles. They were topped by a small head.



▲ **MOSASAUR** (MOH zuh sawr) Marine-dwelling mosasaurs had snake-like bodies, large skulls, and long snouts. They also had jointed jawbones, an adaptation for grasping and swallowing large prey.



◀ **ELASMOSAURUS** (uh laz muh SAWR us) Predatory Elasmosaurus had a long neck—with as many as 76 vertebrae—topped by a small head.



▲ **PLESIOSAUR** (PLEE see uh sawr) These marine reptiles had stout bodies, paddle-like limbs, and long necks. Plesiosaurs might have fed by swinging their heads from side to side through schools of fish.



Figure 21 Observe the fossil skeleton and decide if *Archaeopteryx* looked like this.

Decide what features of the *Archaeopteryx* fossil link it to birds and to dinosaurs.



Archaeopteryx Once scientists discovered a dinosaurlike skeleton with fossilized feathers in Jurassic-aged rocks, they knew they had the support they needed for their theory that birds evolved from dinosaurs. *Archaeopteryx* is the name that has been given to one ancestral bird species. The fossil and a reconstruction are shown in **Figure 21**.

Mammals evolved during the Triassic period, alongside the dinosaurs. Early mammals, shown in **Figure 22**, were small in size and not very numerous or diverse for most of the Mesozoic era. In the late Cretaceous period, they increased in both number and diversity. As dinosaur species became extinct, mammals were able to move into the niches that dinosaurs once occupied. You will read more about mammals later in this lesson.

Figure 22 The first mammals were small, rarely getting larger than an opossum.





Figure 23 Angiosperms evolved to fit many niches. Their water-tight seeds allowed them to move away from water and become the dominant plant form.

Plants of the Mesozoic Era

Plants called gymnosperms dominated the plant population of the Mesozoic era. **Gymnosperms** produce seeds but no flowers. Some gymnosperms, such as the pine and ginkgo trees, still exist today. Angiosperms evolved near the end of the Mesozoic era. Angiosperms are flowering plants that bear seeds with hard outer coverings. This gave them the ability to live in many different environments and to survive harsh climatic conditions. **Figure 23** shows what a plant landscape might have looked like during the Mesozoic era.



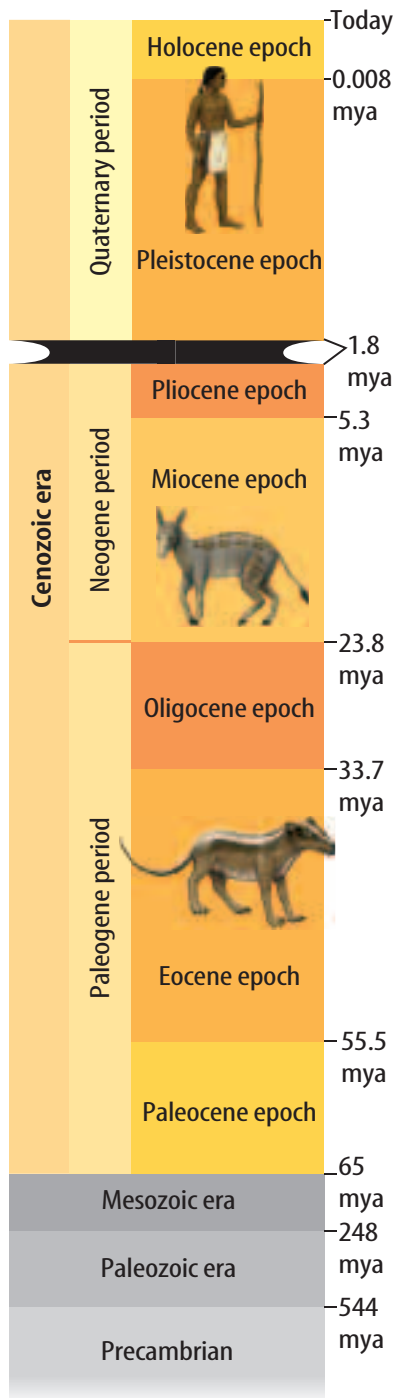
How are gymnosperms and angiosperms different?

Mesozoic Era Extinction Events

Scientists have observed evidence of extinction events in rocks of Mesozoic era age. The Triassic period ended with a mass extinction event that killed off approximately 20 percent of all marine families. Another mass extinction event occurred at the end of the Jurassic period. Several dinosaur groups including some of the largest dinosaurs, such as *Diplodocus*, became extinct during this event. One of the most well-known extinction events occurred at the end of the Cretaceous period. Almost 85 percent of all species in the oceans and all of the remaining dinosaurs became extinct, yet many mammal, bird, and reptile species survived. This event marked the end of the Mesozoic era.



Figure 24 The modern era, the Cenozoic, is when life as we know it evolved.



The Cenozoic Era

Figure 24 shows the portion of the geologic time scale that includes the Cenozoic era. The Cenozoic era is divided into seven epochs. During the Cenozoic era, marine life began to recover from the Cretaceous mass extinction event. The offspring of organisms that survived the Cretaceous extinction event make up the present marine ecosystems. A reconstruction of life in the early Cenozoic oceans is shown in **Figure 25**. How similar do these animals look to today's marine populations?

Animals on Land

By the beginning of the Cenozoic era, the modern mammals had evolved. Some mammals returned to the ocean. During the Eocene epoch, whales evolved from carnivorous, meat-eating, land mammals to the modern marine mammals they are today. **Primates**, animals with opposable thumbs and two eyes that look directly forward, evolved during the Eocene epoch. They diversified rapidly and lived in both the trees and on the ground. About 4.4 million years ago, during the Pliocene epoch, the hominids evolved. Hominids are descendants of these early primates. Hominids walk upright on two legs. The human species, *Homo sapiens*, belongs to the hominid group.

Plants of the Cenozoic Era

Recall that flowering plants evolved near the end of the Mesozoic era. They have continued to evolve ever since. Today, there are more than 250,000 species of flowering plants. Fruits, vegetables, and nuts are all produced by flowering plants. Grasses are flowering plants and during the Eocene epoch supported a large diversity of mammals, which enabled the mammals to multiply and diversify.



Figure 25 Fish, mammals, and many invertebrates and plants have become common life forms in today's oceans.

Cenozoic-Era Extinctions

Cenozoic mass extinction events have not occurred on the scale of those previously discussed in this chapter. Some extinctions are the result of natural selection while others have been **induced** by humans. Can you think of animals that have become extinct during the Cenozoic era?

Complexity Increases over Time

Fossil sequences from the Archean eon to the Cenozoic era show that complexity increases over time. Life began as simple bacteria. Then more complex organisms with shells evolved. Organisms became more diversified and continued to evolve from marine invertebrates to marine and land vertebrates and plants. The fossil record reveals this change.

ACADEMIC VOCABULARY

induce (en DOOS)

(verb) to move by persuasion or influence

The candidate's editorial induced me to vote for her.

LESSON 3 Review

Summarize

Create your own lesson summary as you write a **newsletter**.

1. **Write** this lesson title, number, and page numbers at the top of a sheet of paper.
2. **Review** the text after the **red** main headings and write one sentence about each. These will be the headlines of your newsletter.
3. **Review** the text and write 2–3 sentences about each **blue** subheading. These sentences should tell *who*, *what*, *when*, *where*, and *why* information about each headline.
4. **Illustrate** your newsletter with diagrams of important structures and processes next to each headline.



Standards Check

Using Vocabulary

1. Use the term *angiosperm* in a sentence. **4.g**

Select the correct term to complete the sentences.

ectotherm endotherm primate

2. An animal that warms itself in the Sun is a(n) _____. **4.g**
3. An animal with opposable thumbs is a(n) _____. **4.g**

Understanding Main Ideas

4. Which of the following began the Mesozoic era? **4.e**
 - A. the breakup of Pangaea
 - B. the formation of continental ice sheets
 - C. the melting of European glaciers
 - D. the extinction of the dinosaurs

5. **Compare and contrast** the organisms in the Mesozoic and Cenozoic eras. **4.g**

Mesozoic	Cenozoic

Applying Science

6. **Think Critically** In the last several decades birds have been identified as descendants of dinosaurs. What discoveries allowed this change to occur? **4.g**
7. **Explain** why Earth's life-forms became so diverse after an extinction event. **4.b**



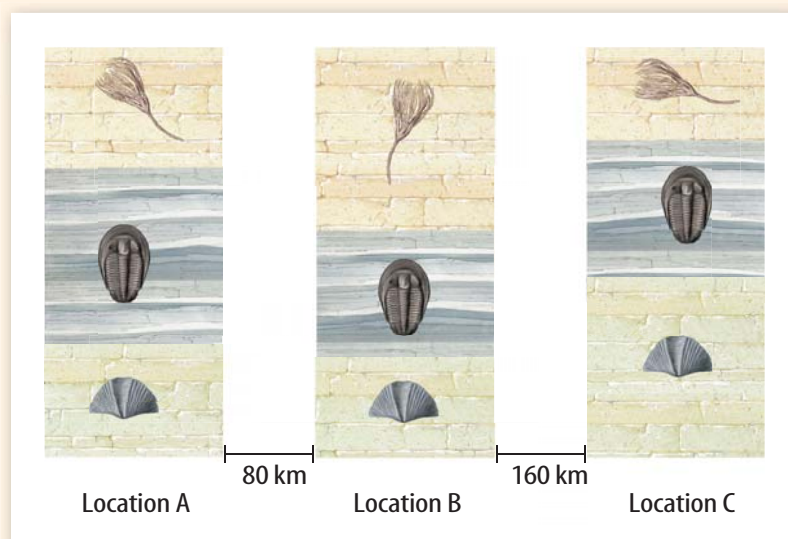
For more practice, visit **Standards Check** at ca7.mssscience.com.

What happened here?

Geologists can determine what an area was like in the past by studying evidence in the rock record. The rock record refers to the information that is stored by the way rocks are formed. The diagram below shows rock layers from three separate locations.

Procedure

1. Study the diagram below.
2. Compare the locations of different fossils in the layers.
3. Decide what each layer tells you about the relative age of the fossils.



Analysis

1. **Analyze** Which rocks in the diagram are oldest? Which are the youngest? What principle explains how you know this?
2. **Analyze** What can you infer about the relative ages of the fossils in each of the three locations? Explain.
3. **Infer** What might have occurred at the boundaries between each layer? What might scientists look for to verify this?



Science Content Standards

7.c Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

Applying Math

Scientific Notation and Age of Meteorites



MA7: NS 1.1

The Gao Meteorite fell on March 5, 1960, at Gao, Sissili, Burkina. The composition of the silicate spheres of the meteorite formed from solar dust and gas about 4.6 billion years ago.

Example

Write 4.6 billion in standard notation and in scientific notation.

What you know: 4.6 billion years

What you need to find: Standard notation
Scientific notation

Write the number in standard notation: Write the number form for billion, 1,000,000,000.
4.6 billion is $4.6 \times 1,000,000,000$ or 4,600,000,000.

Now write 4,600,000,000 in scientific notation:

- 1 Move the decimal 9 places to the left.
4,600,000,000.
- 2 Drop the zeros to the right of the decimal.
4.6
- 3 Add $\times 10^9$ after 4.6. The exponent equals the number of places the decimal was moved. If it was moved left, the exponent is positive. If it was moved right, the exponent is negative.

Answer: 4.6 billion is 4.6×10^9 in scientific notation.

Practice Problems

In 1996 a meteorite from Mars was found in Alan Hills, Antarctica. The meteorite provided evidence of possible life on Mars dating to about 3.6 billion years ago.

1. Write this number in standard notation.
2. Write this number in scientific notation.

Science online
For more math practice,
visit Math Practice at
ca7.msscience.com.

Use the Internet: How has California changed over geologic time?

Materials
computer with
internet access



Science Content Standards

7.a Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.

7.d Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).

Problem

Imagine what California was like millions of years ago. What animals might have been roaming around the spot where you now sit? Fossils can help uncover clues about how plants and animals evolved over time. By using Internet resources and sharing data with your peers, you can learn more about how life in California has changed over time.

Form a Hypothesis

Predict how the plants and animals have changed over time.

Collect Data and Make Observations

1. Make a data table like the one below with your region name in the title. Leave a larger space for the sixth row.

Species that Lived in (Your Region) California				
Species name				
Location fossils are found				
Period or epoch species lived				
Plant or animal	plant	plant	animal	animal
Type of plant or animal				
Sketch of the species				
Descendants (if any)				

2. Use library resources and ca7.msscience.com to gather information about two plants and two animals found in your region during one of these geologic time intervals—Precambrian time, the Paleozoic era, the Mesozoic era, or the Cenozoic era.
3. List the species' names, and the locations and geologic time interval in which they lived on the data table.
4. Determine the group each species belongs to. Is it a vertebrate or invertebrate animal? Is it a bird, fish, amphibian, reptile, insect, or mammal? Is it a gymnosperm or an angiosperm? List this in the data table.
5. Draw a sketch of the species in the data table.
6. Determine if any present-day species might have descended from the selected species.
7. Post your data at ca7.msscience.com.

Analyze and Conclude

1. **Analyze** your data, those of your classmates, and those posted at ca7.msscience.com. What similarities exist among species that lived during the same time period?
2. **Infer** What clues do the plant and animal fossils provide about the environment in which these species lived? How do these environments compare to the present-day environment in your area?
3. **Form a Hypothesis** Which time periods showed the greatest diversity of fossils? For time periods that had fewer types of fossils, provide two hypotheses as to why this might be true.
4. **Predict** when the species you studied died out and form a hypothesis to explain why they are no longer living. Explain how paleontologists would determine this information.

Communicate

WRITING in Science



Write a two-page story about your four organisms. Give a general description of the organism, its habitat, and the niche it belonged to. If any two of the organisms are from the same era, write about how they interacted. If they are from different eras, explain how things might have been different if they had existed at the same time.

Real World Science

Science & Career



You can study ancient life!

Would you like to learn more about ancient plants, sea creatures, dinosaurs, and early mammals? Paleontology is a multidisciplinary science incorporating biology, geology, chemistry, physics, and mathematics. It is the study of all types of ancient life—their structure, evolution, and environment—as shown through their fossils. The paleontologist in this picture is shown with a dinosaur fossil collected from El Chocon, Argentina. To become a paleontologist you should study math, science, and computer courses in high school.

Go to **Careers** at ca7.msscience.com to learn more about what you can do as a paleontologist. Write a paragraph on how paleontology aids in the understanding of ancient Earth. Your paragraph should show proper sentence structure, punctuation, grammar, and spelling.



How old is it?

Radiometric dating continues to be the most common way scientists date geologic timescales. It's based on the half-lives of radioactive isotopes. Dating can be conducted on objects as small as 0.0000000001 g using a mass spectrometer. The ages are not taken from fossils but from the rocks surrounding them. This technician at the U.S. Geological Survey is using a mass spectrometer to determine the proportions of carbon isotopes contained in a sample of organic remains.

Visit **Technology** at ca7.msscience.com to find out more about radiometric dating. Divide into groups and pick one dating isotope to research. Create a table listing information about the isotope.

Science & Technology



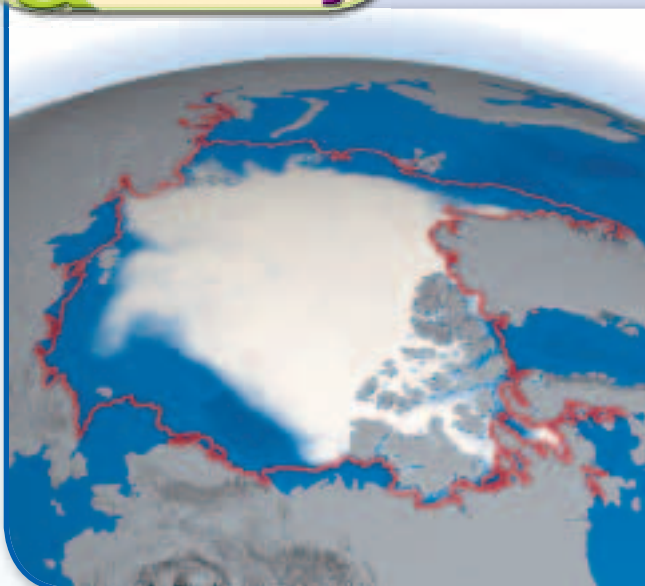
The “Age of the Fishes”

Picture warm, tropical seas filled with brachiopods, swimming trilobites, “sea flowers” (crinoids), sea scorpions, ammonites, and corals. That would be the Devonian period. Many new kinds of fish appeared during this time. Placoderms, armored fish with bony plates in their mouths instead of teeth, reached their greatest diversity. The photo shows the head and trunk plate of a placoderm fossil. Early sharks and rays became abundant during this period. The first ray-finned and lobe-finned fishes also appeared.

Visit **History** at ca7.msscience.com to find out more about the Devonian time period. Create a bar graph showing the length of the time period on one axis and the appearance and duration of the different fishes from this time including, but not limited to, placoderms, sharks, rays, and early finned fishes. What does this tell us about the evolution of these organisms? Draw or paste pictures of these organisms onto the graph.



Changing Climate and Our World



Paleoecology is the study of the ecology and climate of the past, as revealed both by fossils and by other methods. Since 1979, the size of the summer polar ice cap has shrunk more than 20 percent, which could indicate global warming. But how do we know if it is warming or cooling?

Visit **Society** at ca7.msscience.com to learn more about paleoecology and global warming. If Earth warmed up by 10°C, what would the ramifications be? Assign each student to a group to research the effects of this rise for one of the continents. Explore the organisms, environments, countries, and societies.



The BIG Idea

Evidence from rocks helps us understand the history of life on Earth.

Lesson 1 Geologic Time and Mass Extinctions



4.b, 4.e, 4.g, 7.c

Main Idea Fossils provide evidence of how life and environmental conditions have changed over time. Geologists used fossils to create the geologic time scale.

- Fossils were used to organize the geologic time scale.
- The geologic time scale is divided into eras, periods, and epochs.
- Scientists use extinctions and developments to mark the time scale divisions.
- Mass extinctions may be caused by global warming, global cooling, volcanoes, asteroid impacts, or combinations of all of these.

- catastrophic event (p. 318)
- index fossil (p. 316)
- mass extinction (p. 318)

Lesson 2 Early Earth History



4.b, 4.e, 4.g, 7.d

Main Idea Bacteria, the simplest organisms, were the first organisms to evolve on Earth. Increasingly complex organisms followed them.

- The first life-forms were bacteria. They began to evolve into more complex life forms.
- Newer life-forms evolved to tolerate or use oxygen.
- The Paleozoic era evolved organisms with hard shells during the Cambrian explosion.
- Some of the life-forms, including fish, evolved a spinal column.
- The amniotes developed an egg with a shell so they could survive on land.
- Plants moved onto land first, followed by animals that used them for food.
- The Permian extinction killed off most of the species on Earth and ended the Paleozoic era.

- amniote (p. 329)
- cyanobacteria (p. 327)
- vertebrate (p. 329)

Lesson 3 Middle and Recent Earth History



4.b, 4.e, 4.g, 7.a, 7.c, 7.d

Main Idea Life continues to evolve into many of the forms we see on Earth today.

- Pangaea begins to break up and creates changes in the environment and climate.
- The dominant creatures of the Mesozoic era are reptiles and dinosaurs.
- The extinction of the dinosaurs marks the beginning of the Cenozoic era.
- In the Cenozoic era, organisms that we see today evolved.
- Cooling climates gave an advantage to plants that could produce seeds and animals with body coverings and temperature regulation.

- ectotherm (p. 334)
- endotherm (p. 334)
- gymnosperm (p. 337)
- primate (p. 338)
- pterosaur (p. 333)

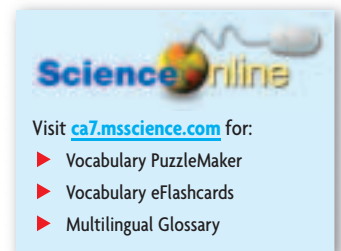
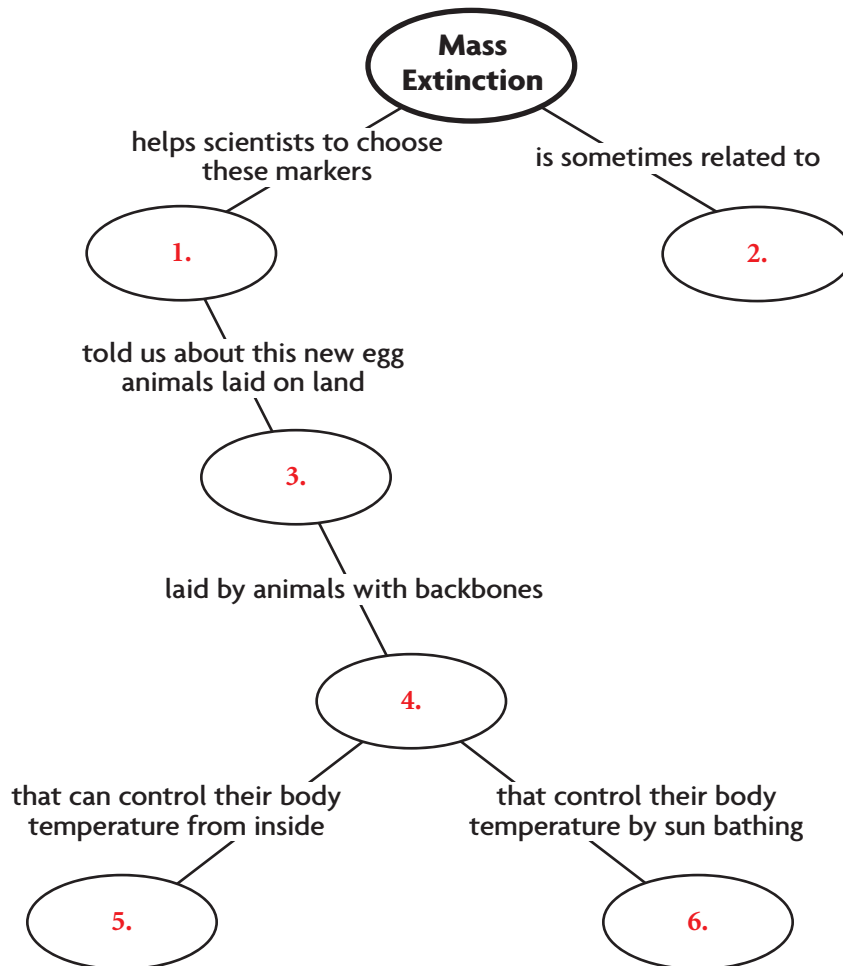


Download quizzes, key terms, and flash cards from ca7.msscience.com.



Linking Vocabulary and Main Ideas

Use vocabulary terms from page 346 to complete this concept map.



Using Vocabulary

Fill in the blanks with the correct vocabulary word from this chapter.

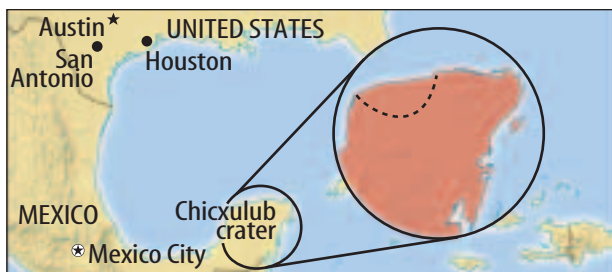
_____ 7. _____ are used by scientists to identify the start or the end of a geologic time period. These are usually in the fossil record because of some _____ 8. _____ that may have been caused by a(n) _____ 9. _____.

The fossil record tells us that _____ 10. _____ were probably the first organisms on Earth and they still live in extreme conditions today. Most of the major life forms on Earth today are _____ 11. _____ that descended when animals moved on to land. This was made possible by the evolution of a new egg form, the _____ 12. _____ egg.



Understanding Main Ideas

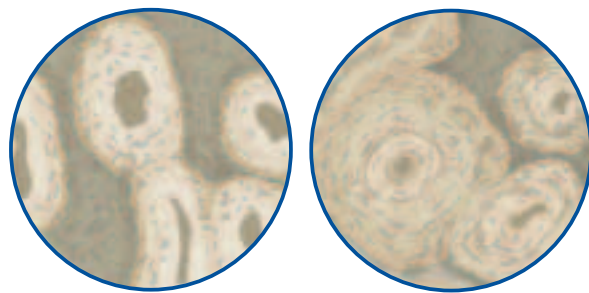
- Which type of fossil is used to mark geologic time?
 A. mold fossil
 B. cast fossil
 C. dinosaur fossil
 D. index fossil **4.e**
- Which is the largest segment of time on the geologic time scale?
 A. epoch
 B. period
 C. eon
 D. era **4.g**
- Which might cause a mass extinction?
 A. magnetic reversal
 B. asteroid impact
 C. earthquake
 D. tsunami **4.b**
- The map below shows the location of an asteroid impact.



Why was the asteroid impact site so difficult to find?

- It was in Mexico.
 - It had a different shape from other impact sites.
 - It was so old.
 - It was mostly underwater. **4.b**
- Global warming is generally the result of which?
 A. global cooling
 B. fire
 C. greenhouse gases
 D. basaltic flow **4.g**

- Precambrian fossils are hard to find because they are which?
 A. soft-bodied organisms
 B. shelled organisms
 C. in rock buried very deep
 D. microscopic **4.b**
- The Cambrian explosion produced lots of which organisms?
 A. vertebrates
 B. shelled animals
 C. algae
 D. plankton **4.g**
- The figures below show bone cells of dinosaur and mammal bone.



What were scientists trying to determine by comparing dinosaur and mammal bone cells?

- that dinosaurs had feathers
 - that dinosaurs were endotherms
 - that dinosaurs could walk upright
 - that dinosaurs could run fast **4.e**
- Which could be said about the Archaeopteryx fossil?
 A. It is the first bird fossil.
 B. It is the first fossil found with feathers.
 C. It is the missing link.
 D. It is a hoax. **4.e**
 - Differences between angiosperms and gymnosperms are most obvious in which part?
 A. seeds
 B. roots
 C. leaves
 D. pollen **4.e**



Applying Science

11. **Analyze** Your class is examining a road cut and finds several trilobite fossils. One is found at the bottom of the road cut and the other is found at the top. They look identical. Which one is older? **4.e**
12. **Infer** A middle Eocene sand dollar is thinner than an early Eocene sand dollar. What might have caused the evolution in thickness? **4.g**
13. **Explain** how a catastrophic event may not cause a mass extinction. **4.b**
14. **Hypothesize** why Precambrian organisms had no shells, but after the Cambrian explosion, there were many species with shells. **4.g**

The image below shows an iceberg breaking off from a glacier.



15. **Explain** how glaciers might be affected during both global warming and global cooling. **4.b**

WRITING in Science

16. **Select** an epoch from the Cenozoic Era and write three paragraphs about life during that time. **ELA7: W 1.1**

Cumulative Review

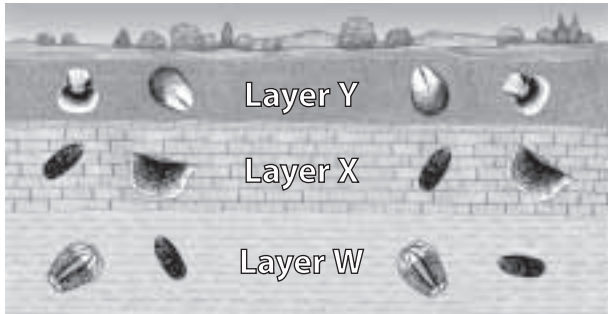
17. **Explain** how the principle of superposition helps us understand that dinosaurs and humans didn't live at the same time. **4.c**
18. **Explain** how radioactive decay tells us the age of a dinosaur fossil. **4.d**
19. **Describe** how Steno's principle of original horizontality is related to the geologic time scale. **4.g**
20. **Explain** the relationship between the principle of original lateral continuity, index fossils, and the geologic time scale. **4.g**

Applying Math

21. Radiometric dating of chondrites has placed them at the age of 4.55 billion years, which is the approximate age of the solar system. Write this number in standard notation and in scientific notation. **MA7: NS 1.1**
22. A basalt meteorite found on the ice in Antarctica was likely formed in a volcanic eruption about 180 million years ago. Write this number in standard notation and in scientific notation. **MA7: NS 1.1**
23. The Barringer Meteor Crater in Arizona is about 49,000 years old. Write this number in scientific notation. **MA7: NS 1.1**
24. The Paleozoic era started 5.44×10^8 years ago. Write this as standard notation. **MA7: NS 1.1**



Use this diagram to answer questions 1–3.



1 During which geologic time period did layer W form?

- A Cambrian
- B Ordovician
- C Devonian
- D Silurian

4.e

2 During which geologic time period did layer X form?

- A Devonian
- B Silurian
- C Ordovician
- D Cambrian

4.e

3 During which geologic time period did layer Y form?

- A Cambrian
- B Silurian
- C Mississippian
- D Ordovician

4.e

4 When did dinosaurs roam Earth?

- A Precambrian time
- B Paleozoic era
- C Mesozoic era
- D Cenozoic era

4.e

5 The diagram below shows the breakup of supercontinent that formed at the end of the Paleozoic Era.



What is the name of this continent?

- A Gondwanaland
- B Eurasia
- C Laurasia
- D Pangaea

4.g

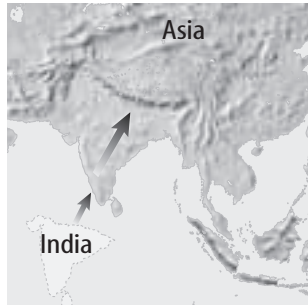
6 During which geologic period did modern humans evolve?

- A Quaternary
- B Triassic
- C Ordovician
- D Tertiary

4.e



- 7 The figure below shows the collision of India and the Asian continent.



Which mountain range formed because India collided with Asia?

- A Alps
- B Andes
- C Ural
- D Himalayas

4.g

- 8 What is the oldest epoch in the Cenozoic era?

- A Pleistocene
- B Paleocene
- C Miocene
- D Holocene

4.g

- 9 What is the youngest epoch in the Cenozoic era?

- A Miocene
- B Holocene
- C Paleocene
- D Eocene

4.g

- 10 Which epoch is part of the Quaternary period?

- A Oligocene
- B Eocene
- C Pleistocene
- D Pliocene

4.g

- 11 The figure below shows a strand from a stromatolite.



What is the oldest life-form on Earth?

- A dinosaurs
- B pterosaurs
- C cyanobacteria
- D algae

4.e

- 12 Environmental changes brought on by catastrophic events caused which to happen?

- A mass extinction
- B volcano formation
- C asteroid impacts
- D cracks in Earth's plates

4.b

- 13 Which is the best definition of mass extinction?

- A the end of an era
- B the dying off of one species
- C the dying off of just dinosaurs
- D the dying off of many species of plants and animals

4.b

- 14 After a mass extinction, life-forms evolved because of which reason?

- A New niches were created.
- B Old niches were left empty.
- C Temperature changes always cause mutations.
- D Global temperatures increased.

4.b

Reading on Your Own...



From the Recommended Literature for Science and Math

Are you interested in learning more about how Earth and life on Earth have changed? If so, check out these great books.



Poetry

Sierra, by Diane Siebert, is a poem in which one of the Sierra Mountains speaks of the beauty and timelessness of herself and her sister peaks. The poem includes references to the geologic processes that created the mountains. *The content of this book is related to Science Standard 7.4.*

Narrative Nonfiction

Asteroid Impact, by Douglas Henderson, tells the story of an enormous asteroid that struck Earth 65 million years ago. This impact may have been responsible for the extinction of dinosaurs at the end of the Cretaceous Period. *The content of this book is related to Science Standard 7.4.*



Nonfiction

Giant Shark: Megalodon, Prehistoric Super Predator, by Caroline Arnold, describes the life cycle and habits of the "largest ocean predator." Extinct for over two million years, this enormous shark comes to life in double-spread watercolor illustrations. *The content of this book is related to Science Standard 7.4.*

Nonfiction

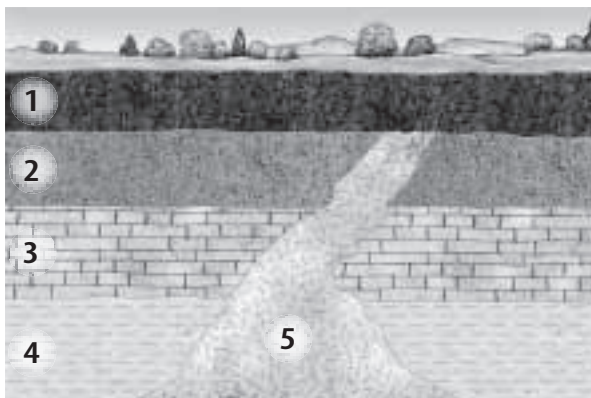
Plate Tectonics, by Alvin Silverstein, is a thorough discussion of plate tectonics. The book provides details about how continental drift has affected the evolution of life on the planet, how volcanoes act as Earth's safety valves, and the causes of earthquakes. *The content of this book is related to Science Standard 7.4.*





Choose the word or phrase that best answers the question.

1. The figure shows a series of rock layers.



Which lists the layers in order from oldest to youngest?

- A. 5-4-3-2-1
 B. 1-2-3-4-5
 C. 2-3-4-5-1
 D. 4-3-2-5-1
2. A fault can be used to determine which of the following for a group of rocks?
 A. absolute age
 B. index age
 C. radiometric age
 D. relative age
3. "The present is the key to the past" summarizes which principle?
 A. superposition
 B. succession
 C. radioactivity
 D. uniformitarianism
4. Which are the remains of species that existed on Earth for short periods of time and were abundant geographically wide-spread?
 A. trace fossils
 B. index fossils
 C. carbon films
 D. body fossils

Write your responses on a sheet of paper.

5. **Explain** how scientists hypothesize that Earth is about 4.5 billion years old.
6. **Predict** Suppose you are trying to determine the ages of rock layers in the western United States. You find a layer of volcanic ash deposits. How might this layer help you determine the ages of the rock layers?
7. **Analyze** Suppose you discover layers of rocks. How can you tell if the layers have not been disturbed?
8. **Design** In a canyon, erosion by water and wind has cut through the sedimentary rock, exposing layers of rock. Infer the relative age of rocks in the lowest layers compared to the top layer. Design a sequence chart similar to the one shown below to compare plant and animal fossils you might find in the different layers.

Relative Age of Rock	Examples of Plant and Animal Fossils
	Trilobites

9. **Explain** why relative dating can only estimate the age of a fossil.
10. **Hypothesize** how a fossil of an organism that lived in ocean water millions of years ago might be found in the middle of North America.
11. **Summarize** how early photosynthetic organisms changed the conditions on Earth to allow more advanced organisms to flourish.