Section 1

Fossils

Reading Preview

Key Concepts

- How do fossils form?
- What are the different kinds of fossils?
- What does the fossil record tell about organisms and environments of the past?

Key Terms

- fossil
- sedimentary rock
- mold
- cast
- petrified fossil
- carbon film
- trace fossil
- paleontologist
- scientific theory
- evolution
- extinct

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings and visuals to see what this section is about. Then write what you know about fossils in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Fossils come from ancient organisms. 2.

What You Learned
1. 2.

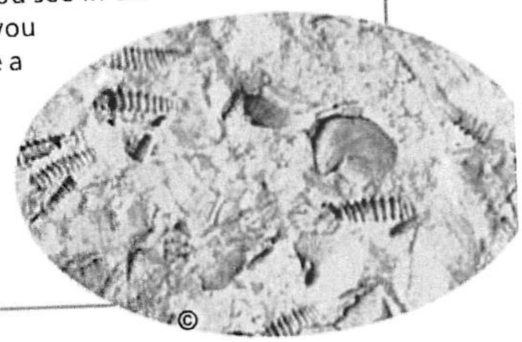
Lab zone Discover Activity

What's in a Rock?

1. Use a hand lens to carefully observe the rock sample provided by your teacher. You may also study the photograph of limestone below.
2. Make a drawing of any shapes you see in the rock. Include as many details as you can. Beneath your drawing, write a description of what you see.

Think It Over

Inferring What do you think the rock contains? How do you think the shapes you observed in the rock got there?

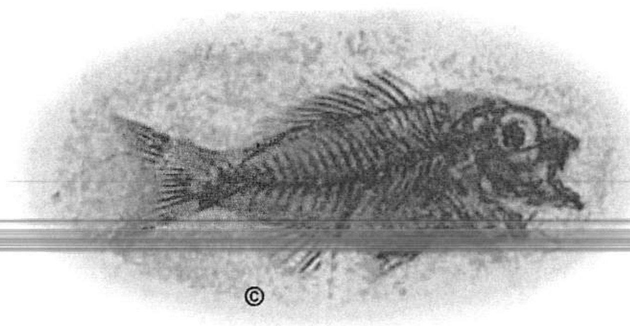


Millions of years ago, a fish died and sank to the bottom of a lake. Before the fish could decay completely, layers of sediment covered it. Minerals in the sediment seeped into the fish's bones. Slowly, pressure changed the sediment into solid rock. Inside the rock, the fish became a fossil.

Fossils are the preserved remains or traces of living things. Fossils like the ancient fish in Figure 1 provide evidence of how life has changed over time. Fossils can also help scientists infer how Earth's surface has changed. Fossils are clues to what past environments were like.

How a Fossil Forms

Most fossils form when living things die and are buried by sediments. The sediments slowly harden into rock and preserve the shapes of the organisms. Fossils are usually found in sedimentary rock. **Sedimentary rock** is the type of rock that is made of hardened sediment. Recall that sediment is the material removed by erosion. Sediment is made up of rock particles or the remains of living things. Sandstone, limestone, and coal are examples of sedimentary rocks. Most fossils form from animals or plants that once lived in or near quiet water such as swamps, lakes, or shallow seas where sediments build up. In Figure 1, you can see how a fossil might form.



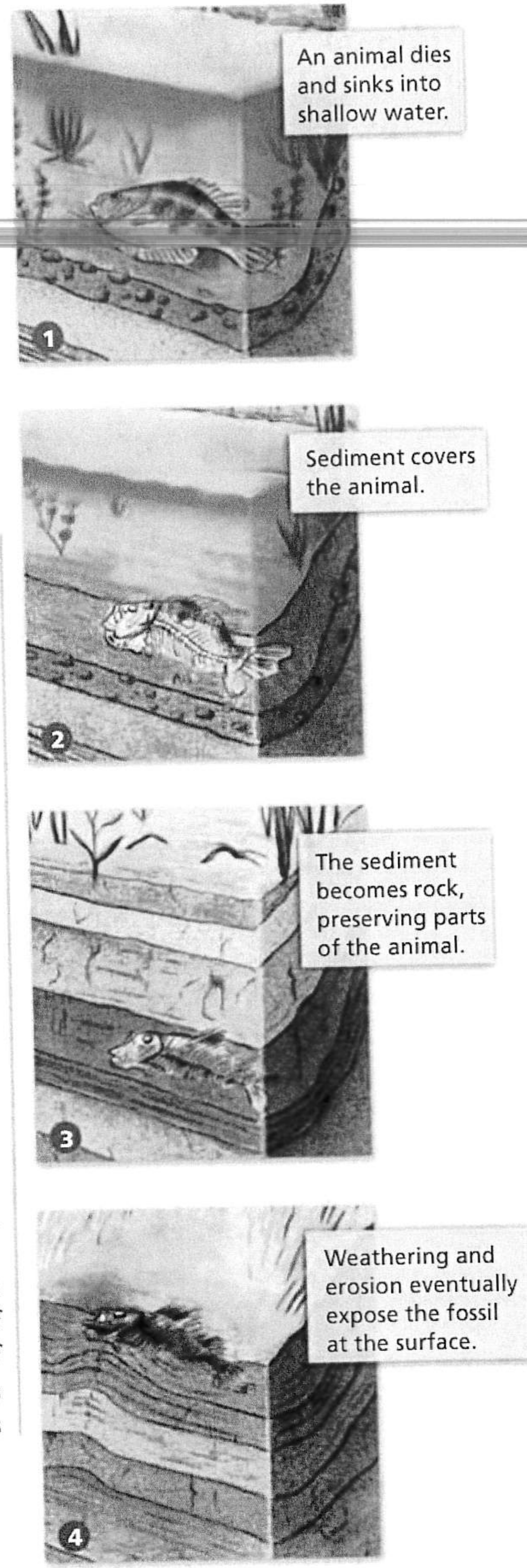


FIGURE 1
How a Fossil Forms
A fossil may form when sediment quickly covers an animal's body. Classifying *In what type of rock would this fossil be found?*

When an organism dies, its soft parts often decay quickly or are eaten by animals. That is why only hard parts of an organism generally leave fossils. These hard parts include bones, shells, teeth, seeds, and woody stems. It is rare for the soft parts of an organism to become a fossil.

For a fossil to form, the remains or traces of an organism must be protected from decay. Then several processes may cause a fossil to form. **Fossils found in rock include molds and casts, petrified fossils, carbon films, and trace fossils. Other fossils form when the remains of organisms are preserved in substances such as tar, amber, or ice.**

Molds and Casts The most common fossils are molds and casts. Both copy the shape of ancient organisms. A **mold** is a hollow area in sediment in the shape of an organism or part of an organism. A mold forms when the hard part of the organism, such as a shell, is buried in sediment.

Later, water carrying dissolved minerals and sediment may seep into the empty space of a mold. If the water deposits the minerals and sediment there, the result is a cast. A **cast** is a solid copy of the shape of an organism. A cast is the opposite of its mold. Both the mold and cast preserve details of the animal's structure. Figure 1 shows a process that could form a mold and cast fossil.

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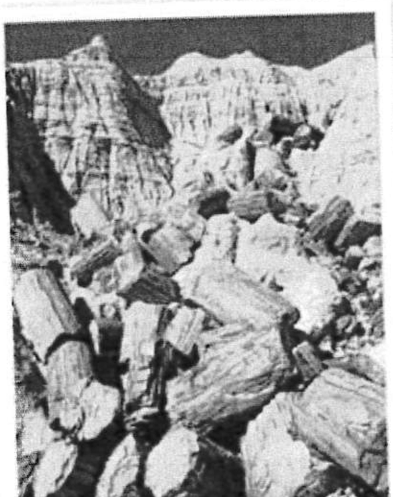
Petrified Fossils A fossil may form when the remains of an organism become petrified. The term *petrified* means "turned into stone." **Petrified fossils** are fossils in which minerals replace all or part of an organism. The fossil tree trunks shown in Figure 2 are examples of petrified wood. These fossils formed after sediment covered the wood. Then water rich in dissolved minerals seeped into spaces in the plant's cells. Over time, the minerals come out of solution and harden, filling in all of the spaces. Some of the original wood remains, but the minerals have hardened and preserved it.

Carbon Films Another type of fossil is a **carbon film,** an extremely thin coating of carbon on rock. How does a carbon film form? Remember that all living things contain carbon. When sediment buries an organism, some of the materials that make up the organism evaporate, or become gases. These gases escape from the sediment, leaving carbon behind. Eventually, only a thin film of carbon remains. This process can preserve the delicate parts of plant leaves and insects.

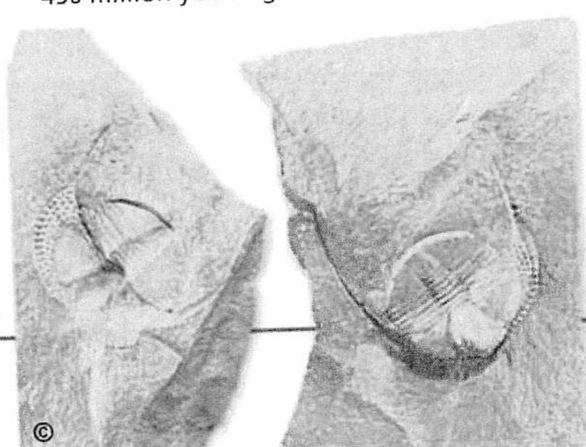
Trace Fossils Most types of fossils preserve the shapes of ancient animals and plants. In contrast, **trace fossils** provide evidence of the activities of ancient organisms. A fossilized footprint is one example of a trace fossil. A dinosaur made the fossil footprint shown in Figure 2. The mud or sand that the animal stepped in was buried by layers of sediment. Slowly the sediment became solid rock, preserving the footprint for millions of years.

FIGURE 2
Kinds of Fossils
In addition to petrified fossils, fossils may be molds and casts, carbon films, trace fossils, or preserved remains.
Classifying *You split apart a rock and find the imprint of a seashell on one half of the rock. What type of fossil have you found?*



▲ **Petrified Fossils**
These petrified tree trunks in Arizona were formed 200 million years ago, yet look as if they were just cut down.

Molds and Casts ▼
The fossil mold (left) clearly shows the shape of the animal called *Cryptolithus.* So does the fossil cast (right). *Cryptolithus* lived in the oceans about 450 million years ago.



▲ **Carbon Films**
This carbon film fossil of insects is between 5 million and 23 million years old.

From fossil footprints, scientists can find answers to questions about an animal's size and behavior. Did the animal walk on two or four legs? Did it live alone or as part of a group?

Other types of trace fossils also provide clues about ancient organisms. A trail or burrow can give clues about the size and shape of an organism, where it lived, and how it obtained food.

Preserved Remains Some processes preserve the remains of organisms with little or no change. For example, some remains are preserved when organisms become trapped in tar. Tar is sticky oil that seeps from Earth's surface. Many fossils preserved in tar have been found at the Rancho La Brea tar pits in Los Angeles, California. Thousands of years ago, animals came to drink the water that covered these pits. Somehow, they became stuck in the tar and then died. The tar soaked into their bones, preserving the bones from decay.

Ancient organisms also have been preserved in amber. Amber is the hardened resin, or sap, of evergreen trees. First, an insect is trapped on sticky resin. After the insect dies, more resin covers it, sealing it from air and protecting its body from decay.

Freezing can also preserve remains. The frozen remains of woolly mammoths, huge ancient relatives of elephants, have been found in very cold regions of Siberia and Alaska. Freezing has preserved even the mammoths' hair and skin.

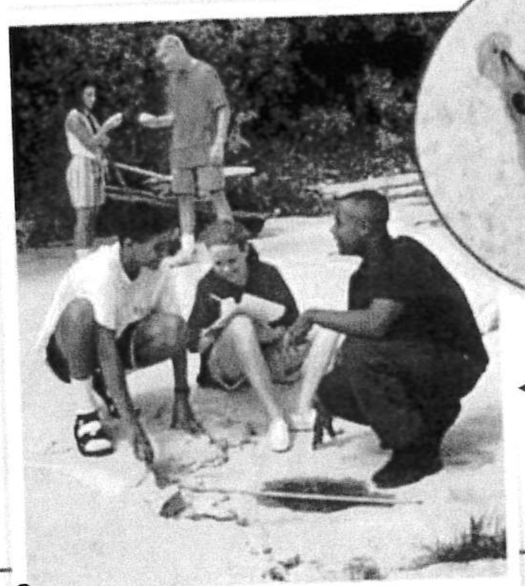
Reading Checkpoint **What are three ways in which the remains of an organism can be preserved with little change?**

Lab zone **Try This Activity**

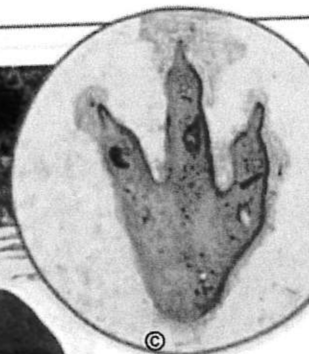
Sweet Fossils

1. Wrap a piece of clay around one sugar cube so that half of it is covered with clay.
2. Wrap clay entirely around a second sugar cube and seal it tightly.
3. Drop both cubes into a bowl of water, along with an uncovered sugar cube.
4. Stir until the uncovered sugar cube dissolves completely.
5. Remove the other cubes from the water and examine the remains.

Observing Describe the appearance of the two sugar cubes. Did the clay preserve the sugar cubes? How does this activity model the way fossils form?

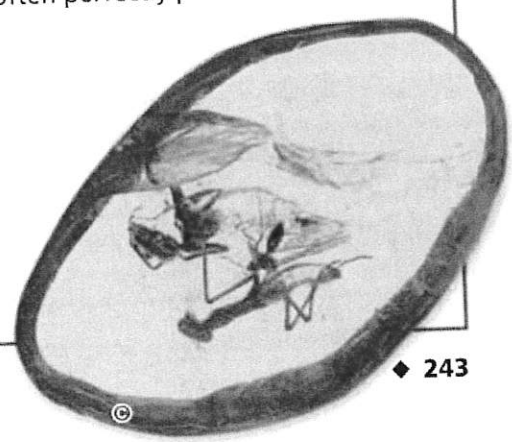


◄ **Trace Fossils**
These students are measuring a dinosaur footprint in Zilker Park in Austin, Texas.



▲ **Dinosaur Footprint**

Amber
A fossil preserved in amber provides a window into the history of past life on Earth. Body parts, including the hairlike bristles on an insect's legs, its antennae, and its delicate wings, are often perfectly preserved. ▼

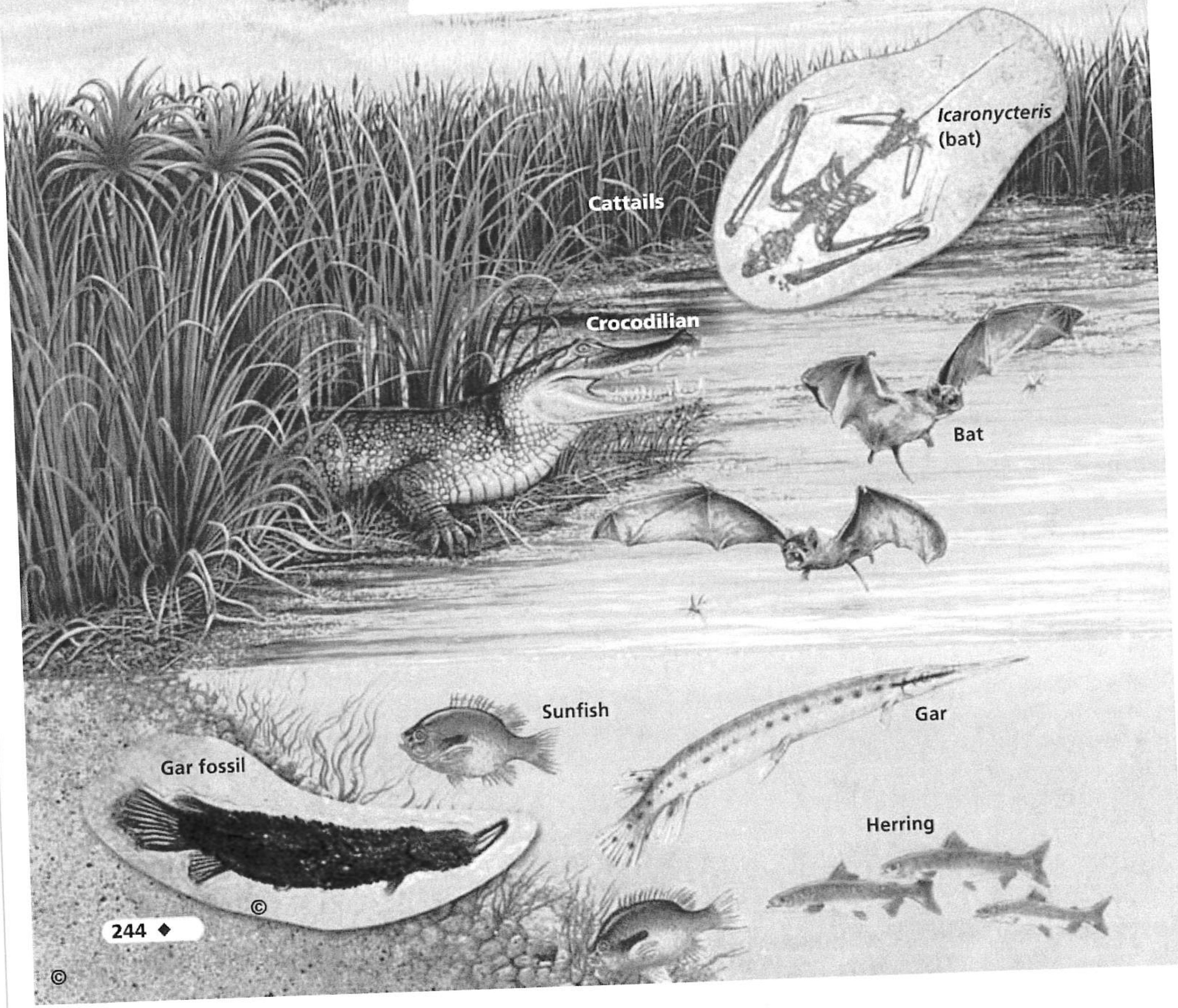


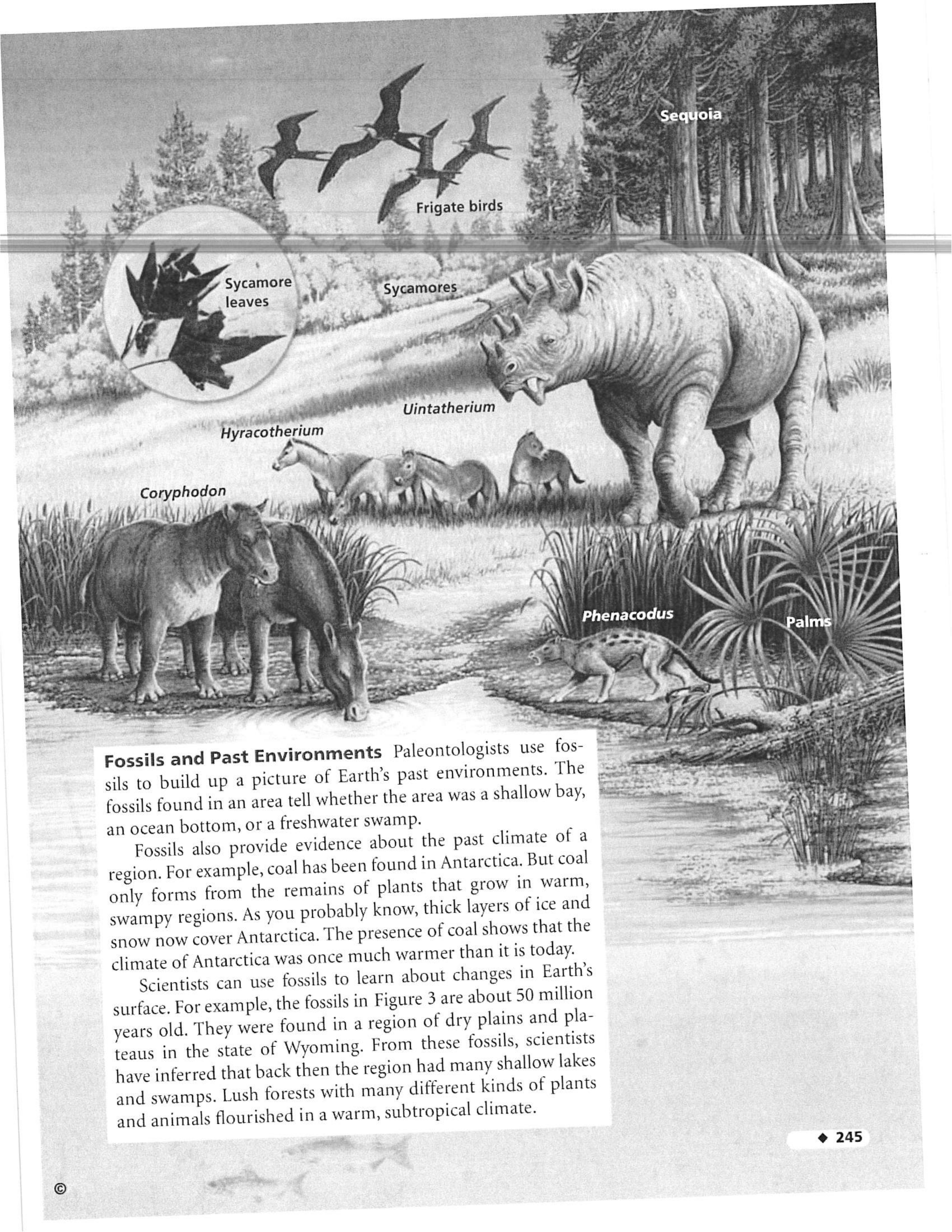
Change Over Time

Scientists who study fossils are called **paleontologists** (pay lee un TAHL uh jists). Paleontologists collect fossils from sedimentary rocks all over the world. They use this information to determine what past life forms were like. They want to learn what these organisms ate, what ate them, and in what kind of environment they lived.

Paleontologists also classify organisms. They group similar organisms together. They arrange organisms in the order in which they lived, from earliest to latest. Together, all the information that paleontologists have gathered about past life is called the fossil record. **The fossil record provides evidence about the history of life and past environments on Earth. The fossil record also shows that different groups of organisms have changed over time.**

FIGURE 3
Fossil Clues to Past Environments
Fossils of many different kinds of organisms were formed in this ancient lakeshore environment.
Inferring *How do you think the fossil of the bat was preserved?*



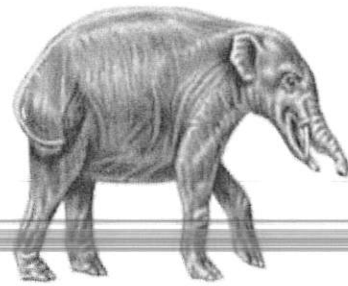


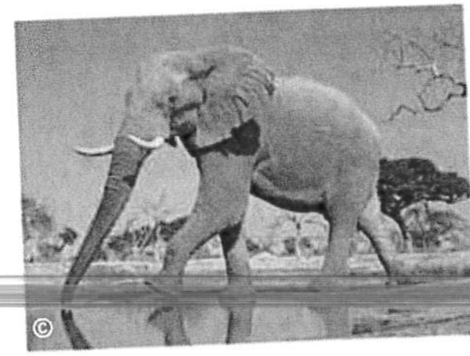
Fossils and Past Environments Paleontologists use fossils to build up a picture of Earth's past environments. The fossils found in an area tell whether the area was a shallow bay, an ocean bottom, or a freshwater swamp.

Fossils also provide evidence about the past climate of a region. For example, coal has been found in Antarctica. But coal only forms from the remains of plants that grow in warm, swampy regions. As you probably know, thick layers of ice and snow now cover Antarctica. The presence of coal shows that the climate of Antarctica was once much warmer than it is today.

Scientists can use fossils to learn about changes in Earth's surface. For example, the fossils in Figure 3 are about 50 million years old. They were found in a region of dry plains and plateaus in the state of Wyoming. From these fossils, scientists have inferred that back then the region had many shallow lakes and swamps. Lush forests with many different kinds of plants and animals flourished in a warm, subtropical climate.

FIGURE 4
Ancestry of the Elephant
From fossils, scientists have reconstructed the paleomastodon (left). This animal had a short trunk and short tusks on both upper and lower jaws. The paleomastodon is an ancestor of the modern elephant (right).
Inferring *Why is the paleomastodon only known from its fossils?*





Change and the Fossil Record The fossil record reveals a surprising fact: Fossils occur in a particular order. Older rocks contain fossils of simpler organisms. Younger rocks contain fossils of more complex organisms. In other words, the fossil record shows that life on Earth has evolved, or changed over time. Simple, one-celled organisms have given rise to complex plants and animals.

The fossil record provides evidence to support the theory of evolution. A **scientific theory** is a well-tested concept that explains a wide range of observations. **Evolution** is the gradual change in living things over long periods of time.

The fossil record shows that millions of types of organisms have evolved. But many others have become extinct. A type of organism is **extinct** if it no longer exists and will never again live on Earth.

Reading Checkpoint **What is a scientific theory?**

Section 1 Assessment

Target Reading Skill Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

HINT 1. a. **Defining** What is a fossil?
HINT b. **Summarizing** In general, how does a fossil form?
HINT c. **Relating Cause and Effect** Which parts of an organism are most likely to be preserved as fossils? Why?
HINT 2. a. **Listing** What are the five different kinds of fossils?
HINT b. **Explaining** How does a carbon film fossil form?
HINT c. **Comparing and Contrasting** How are petrified fossils similar to preserved remains? How are they different?
HINT 3. a. **Reviewing** What are two things that scientists can learn from the fossil record?
HINT b. **Making Generalizations** What does the fossil record show about how life has changed over time?

Lab zone At-Home Activity

Family Fossils A fossil is something old that has been preserved. With your parents' permission, look around your house for the oldest object you can find. Interview family members to determine how old the object is, why it has been preserved, and how it may have changed since it was new. Make a drawing of the object and bring it to class. Tell your class the story of this "fossil."

Section 2

The Relative Age of Rocks

Reading Preview

Key Concepts

- What is the law of superposition?
- How do geologists determine the relative age of rocks?
- How are index fossils useful to geologists?

Key Terms

- relative age • absolute age
- law of superposition
- extrusion • intrusion • fault
- unconformity • index fossil

Target Reading Skill

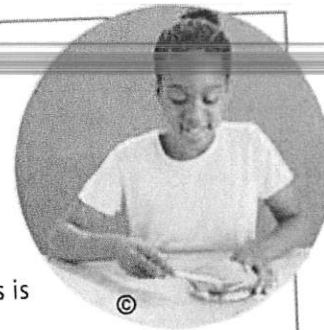
Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write answers to your questions.

Relative Age

Question	Answer
What does the position of rock layers reveal?	The position of rock layers shows . . .

Lab zone Discover Activity

Which Layer Is the Oldest?



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1. Make a stack of different-colored layers of clay. Each layer should be about the size and thickness of a pancake. If these flat layers are sediments, which layer of sediment was deposited first? (*Hint:* This is the oldest layer.)
2. Now form the stack into a dome by pressing it over a small rounded object, such as a small bowl. With a cheese-slicer or plastic knife, carefully cut off the top of the dome. Look at the layers that you have exposed. Which layer is the oldest?

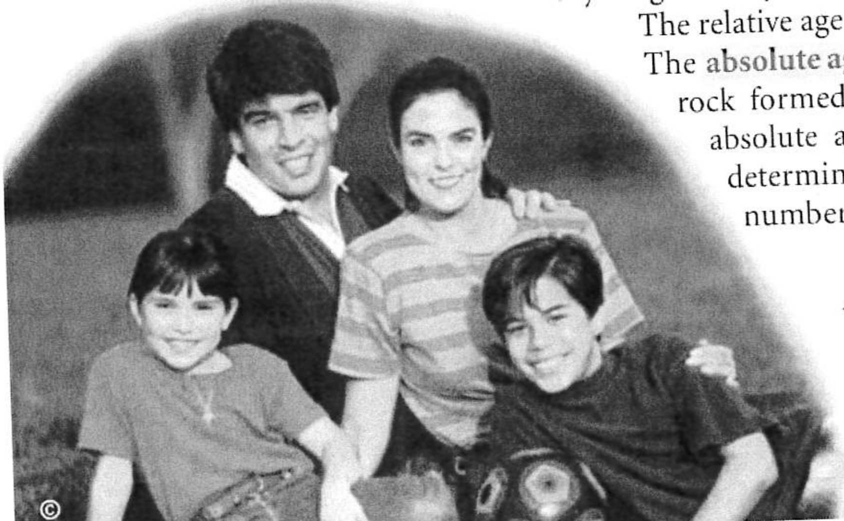
Think It Over

Inferring If you press the stack into a small bowl and trim away the clay that sticks above the edge, where will you find the oldest layer?

As sedimentary rock forms, the remains of organisms in the sediment may become fossils. Millions of years later, if you split open the rock, you might see the petrified bones of an extinct reptile or insect.

Your first question about a new fossil might be, "What is it?" Your next question would probably be, "How old is it?" Geologists have two ways to express the age of a rock and any fossil it contains. The **relative age** of a rock is its age compared to the ages of other rocks. You have probably used the idea of relative age when comparing your age with someone else's age. For example, if you say that you are older than your brother but younger than your sister, you are describing your relative age.

The relative age of a rock does not provide its absolute age. The **absolute age** of a rock is the number of years since the rock formed. It may be impossible to know a rock's absolute age exactly. But sometimes geologists can determine a rock's absolute age to within a certain number of years.



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◀ The age of each family member could be given as relative age or absolute age.

Discovery Channel School

A Trip Through Geologic Time

Video Preview
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Video Assessment

The Position of Rock Layers

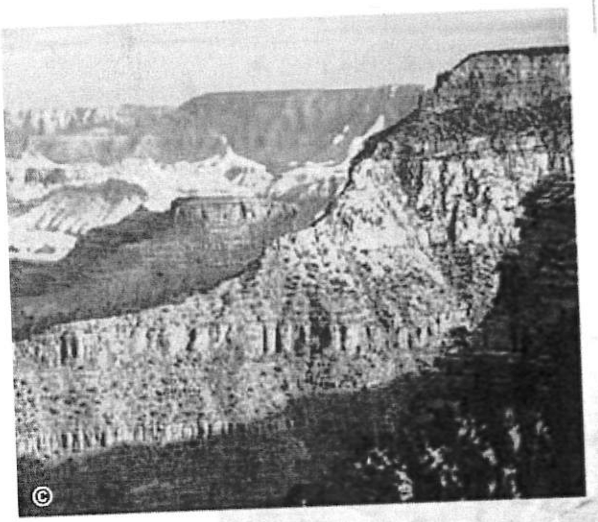
Have you ever seen rock layers of different colors on a cliff beside a road? What are these layers, and how did they form? The sediment that forms sedimentary rocks is deposited in flat layers one on top of the other. Over time, the sediment hardens and changes into sedimentary rock. These rock layers provide a record of Earth's geologic history.

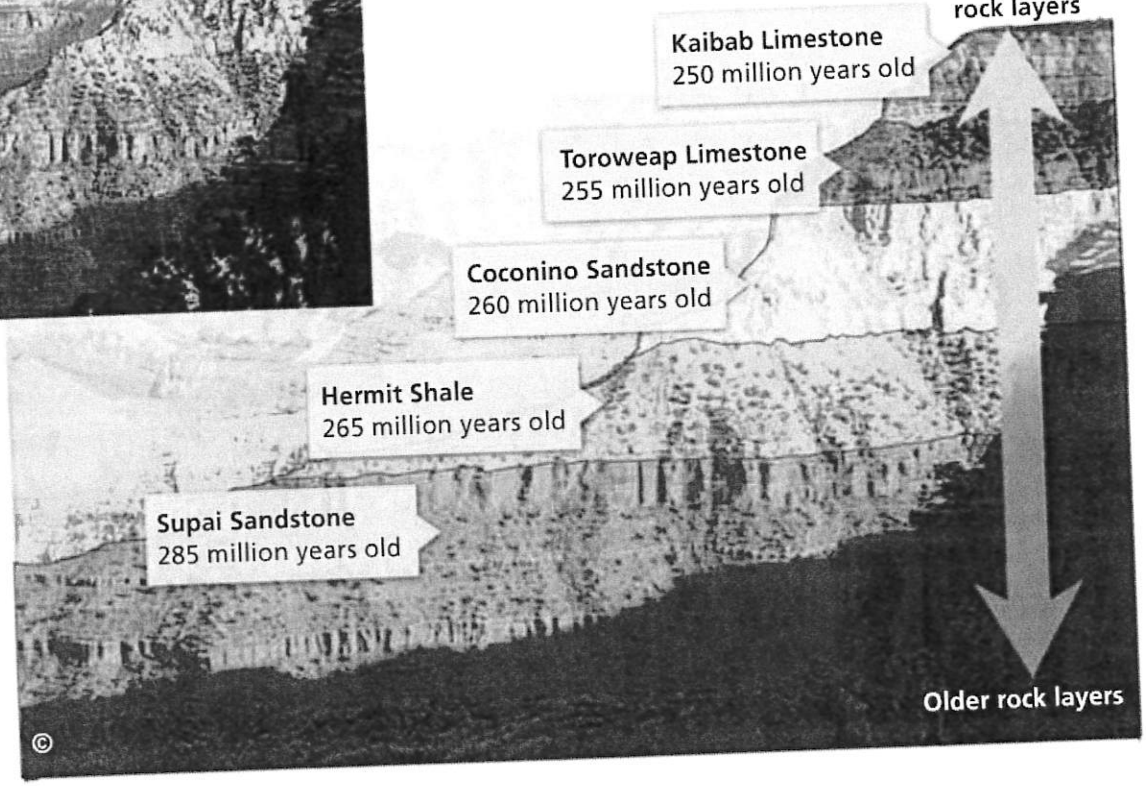
It can be difficult to determine the absolute age of a rock. So geologists use a method to find a rock's relative age. Geologists use the law of superposition to determine the relative ages of sedimentary rock layers. **According to the law of superposition, in horizontal sedimentary rock layers the oldest layer is at the bottom. Each higher layer is younger than the layers below it.**

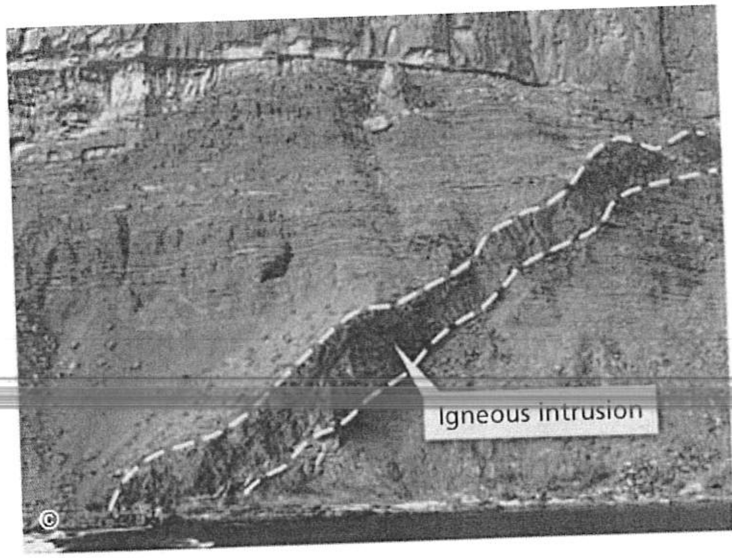
The walls of the Grand Canyon in Arizona illustrate the law of superposition. You can see some of the rock layers found in the Grand Canyon in Figure 5. The deeper down you go in the Grand Canyon, the older the rocks.

Reading Checkpoint Why do sedimentary rocks have layers?

FIGURE 5
The Grand Canyon
More than a dozen rock layers make up the walls of the Grand Canyon. You can see five layers clearly in the photograph. Applying Concepts *In which labeled layers would you find the oldest fossils? Explain.*







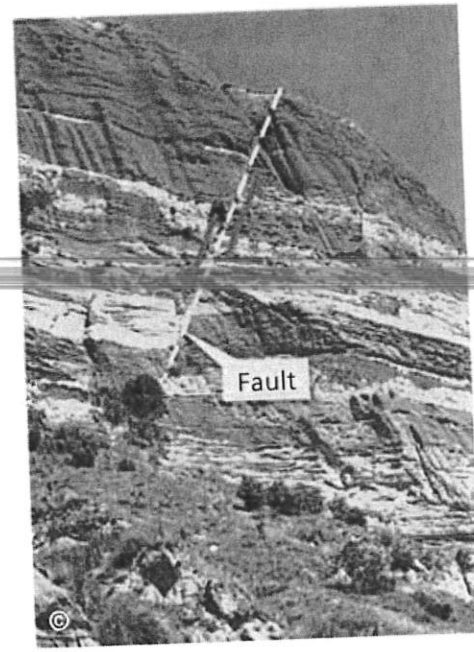


FIGURE 6
Intrusions and Faults
Intrusions and faults give clues to the relative ages of rocks. An intrusion (left) cuts through rock layers. Rock layers are broken and shifted along a fault (right).

Determining Relative Age

There are other clues besides the position of rock layers to the relative ages of rocks. **To determine relative age, geologists also study extrusions and intrusions of igneous rock, faults, and gaps in the geologic record.**

Clues From Igneous Rock Igneous rock forms when magma or lava hardens. Magma is molten material beneath Earth's surface. Magma that flows onto the surface is called lava.

Lava that hardens on the surface is called an **extrusion.** An extrusion is always younger than the rocks below it.

Beneath the surface, magma may push into bodies of rock. There, the magma cools and hardens into a mass of igneous rock called an **intrusion.** An intrusion is always younger than the rock layers around and beneath it. Figure 6 shows an intrusion. Geologists study where intrusions and extrusions formed in relation to other rock layers. This helps geologists understand the relative ages of the different types of rock.

Clues From Faults More clues come from the study of faults. A **fault** is a break in Earth's crust. Forces inside Earth cause movement of the rock on opposite sides of a fault.

A fault is always younger than the rock it cuts through. To determine the relative age of a fault, geologists find the relative age of the youngest layer cut by the fault.

Movements along faults can make it harder for geologists to determine the relative ages of rock layers. You can see in Figure 6 how the rock layers no longer line up because of movement along the fault.

Lab zone Try This Activity

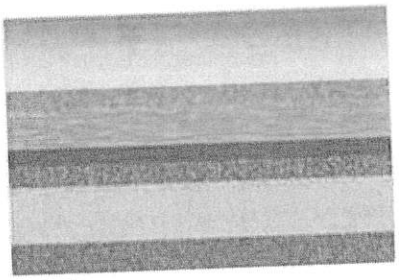
Sampling a Sandwich

Your teacher will give you a sandwich that represents rock layers in Earth's crust.

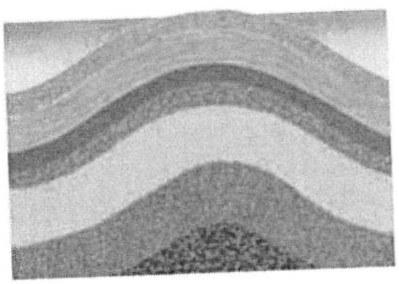
1. Use a round, hollow, uncooked noodle as a coring tool. Push the noodle through the layers of the sandwich.
2. Pull the noodle out of the sandwich. Break the noodle gently to remove your core sample.
3. Draw a picture of what you see in each layer of the core.

Making Models Which layer of your sandwich is the "oldest"? The "youngest"? Why do you think scientists study core samples?

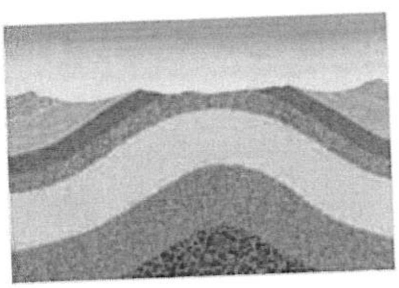
FIGURE 7
Unconformity
An unconformity occurs where erosion wears away layers of sedimentary rock. Other rock layers then form on top.
Sequencing *What two processes must take place before an unconformity can form?*



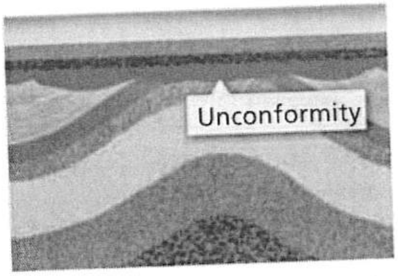
1 Sedimentary rocks form in horizontal layers.



2 Folding tilts the rock layers.



3 The surface is eroded.



4 New sediment is deposited, forming rock layers above the unconformity.

Gaps in the Geologic Record The geologic record of sedimentary rock layers is not always complete. Deposition slowly builds layer upon layer of sedimentary rock. But some of these layers may erode away, exposing an older rock surface. Then deposition begins again, building new rock layers.

The surface where new rock layers meet a much older rock surface beneath them is called an **unconformity.** An unconformity is a gap in the geologic record. An unconformity shows where some rock layers have been lost because of erosion. Figure 7 shows how an unconformity forms.

Reading Checkpoint **What is an unconformity?**

Using Fossils to Date Rocks

To date rock layers, geologists first give a relative age to a layer of rock at one location. Then they can give the same age to matching layers of rock at other locations.

Certain fossils, called index fossils, help geologists match rock layers. To be useful as an **index fossil,** a fossil must be widely distributed and represent a type of organism that existed only briefly. A fossil is considered widely distributed if it occurs in many different areas. Geologists look for index fossils in layers of rock. **Index fossils are useful because they tell the relative ages of the rock layers in which they occur.**

Geologists use particular types of organisms as index fossils—for example, certain types of ammonites. Ammonites (AM uh nyts) were a group of hard-shelled animals. Ammonites evolved in shallow seas more than 500 million years ago and became extinct about 65 million years ago.

Ammonite fossils make good index fossils for two reasons. First, they are widely distributed. Second, many different types of ammonites evolved and then became extinct after a few million years.

Geologists can identify the different types of ammonites through differences in the structure of their shells. Based on these differences, geologists can identify the rock layers in which a particular type of ammonite fossil occurs.

You can use index fossils to match rock layers. Look at Figure 8, which shows rock layers from four different locations. Notice that two of the fossils are found in only one of these rock layers. These are the index fossils.

Reading Checkpoint **What characteristics must a fossil have to be useful as an index fossil?**

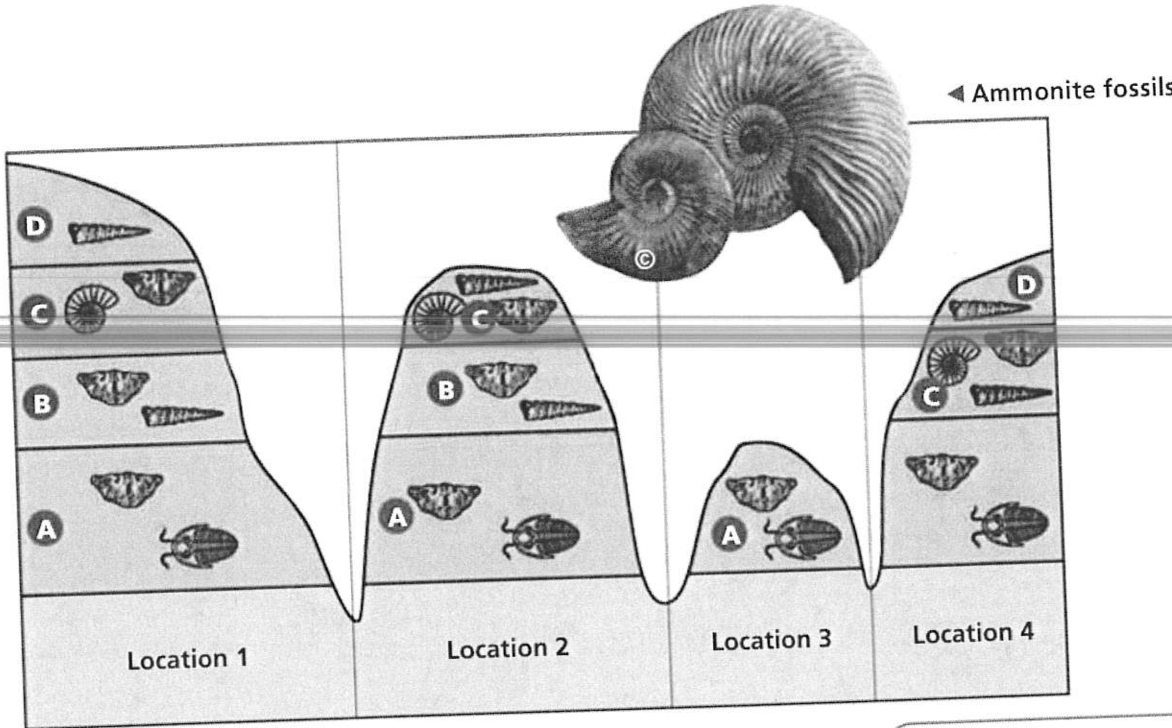


FIGURE 8
Using Index Fossils
Scientists use index fossils to match up rock layers at locations that may be far apart. The ammonites in layer C are index fossils. **Interpreting Diagrams** *Can you find another index fossil in the diagram? (Hint: Look for a fossil that occurs in only one time period, but in several different locations.)*

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active art
For: Index Fossils activities
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Section 2 Assessment

Vocabulary Skill Use Clues to Determine Meaning Reread the definition of *extrusion.* Identify two phrases that help you understand the meaning of *extrusion.*

Reviewing Key Concepts

HINT
1. a. **Defining** In your own words, define the terms *relative age* and *absolute age.*

HINT
   b. **Explaining** What is the law of superposition?

HINT
   c. **Inferring** A geologist finds a cliff where the edges of several different rock layers can be seen. Which layer is the oldest? Explain.

HINT
2. a. **Reviewing** Besides the law of superposition, what are three types of clues to the relative age of rock layers?

HINT
   b. **Comparing and Contrasting** Compare and contrast extrusions and intrusions.

HINT
   c. **Sequencing** An intrusion crosses an extrusion. Which layer is the older? Explain.

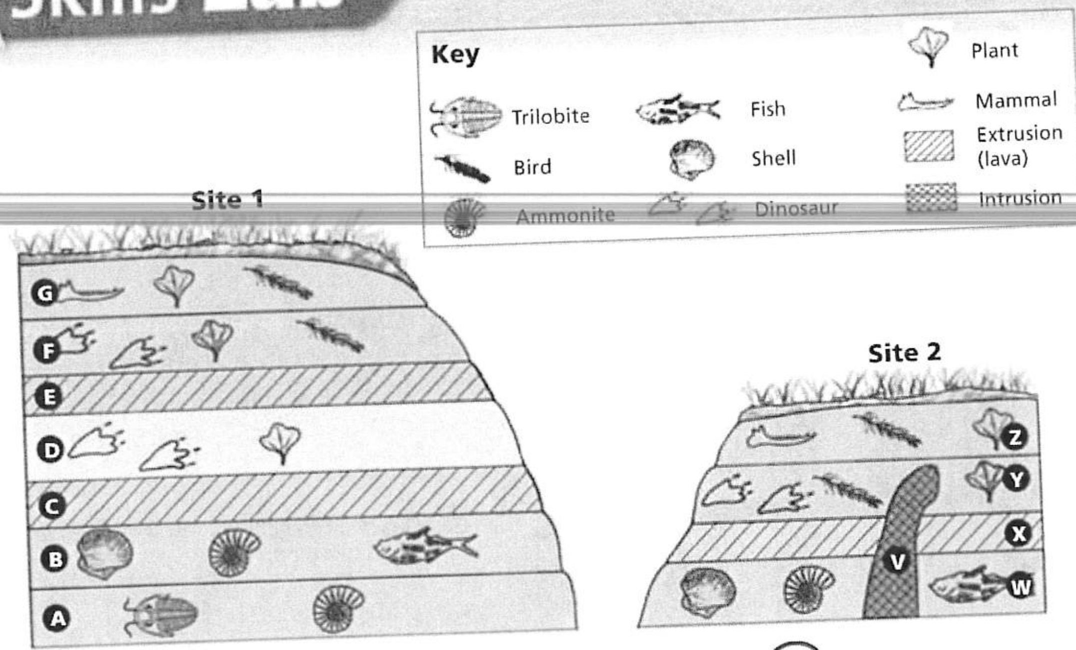
HINT
3. a. **Defining** What is an index fossil?

HINT
   b. **Applying Concepts** The fossil record shows that horseshoe crabs have existed with very little change for about 200 million years. Would horseshoe crabs be useful as an index fossil? Explain why or why not.

Lab zone At-Home Activity

Drawer to the Past Collect ten items out of a drawer full of odds and ends such as keys, coins, receipts, photographs, and souvenirs. Have your family members put them in order from oldest to newest. What clues will you use to determine their relative ages? How can you determine the oldest object of all? List the ten items in order of their relative age. Do you know the absolute age of any of the items?

Lab zone **Skills Lab**



Finding Clues to Rock Layers

Problem

How can you use fossils and geologic features to interpret the relative ages of rock layers?

Skills Focus

interpreting data, drawing conclusions

Procedure

1. Study the rock layers at Sites 1 and 2. Write down the similarities and differences between the layers at the two sites.
2. List the kinds of fossils that are found in each rock layer of Sites 1 and 2.

Analyze and Conclude

Site 1

1. Interpreting Data What "fossil clues" in layers A and B indicate the kind of environment that existed when these rock layers were formed? How did the environment change in layer D?
2. Drawing Conclusions Which layer is the oldest? How do you know?
3. Drawing Conclusions Which of the layers formed most recently? How do you know?
4. Inferring Why are there no fossils in layers C and E?
5. Observing What kind of fossils are found in layer F?

Site 2

6. Inferring Which layer at Site 1 might have formed at the same time as layer W at Site 2?
7. Interpreting Data What clues show an unconformity or gap in the horizontal rock layers? Which rock layers are missing? What might have happened to these rock layers?
8. Drawing Conclusions Which is older, intrusion V or layer Y? How do you know?
9. Communicating Write a journal entry describing how the environment at Site 2 changed over time. Starting with the earliest layer, describe the types of organisms, their environment, and how the environment changed.

More to Explore

Draw a sketch similar to Site 2 and include a fault that cuts across the intrusion. Have a partner then identify the relative age of the fault, the intrusion, and the layers cut by the fault.

Section 3

Integrating Chemistry

Radioactive Dating

Reading Preview

Key Concepts

- What happens during radioactive decay?
- What can be learned from radioactive dating?

Key Terms

- atom
- element
- radioactive decay
- half-life

Target Reading Skill

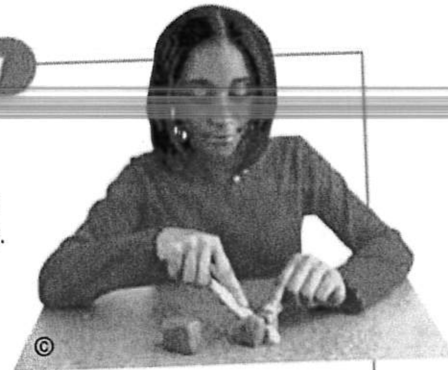
Identifying Main Ideas As you read the Determining Absolute Ages section, write the main idea in a graphic organizer like the one below. Then write three supporting details that give examples of the main idea.

Main Idea

Using radioactive dating, scientists can determine . . .		
Detail	Detail	Detail

Lab zone Discover Activity

How Long Till It's Gone?



1. Make a small cube—about 5 cm × 5 cm × 5 cm —from modeling clay.
2. Carefully use a knife to cut the clay in half. Put one half of the clay aside.
3. Cut the clay in half two more times. Each time you cut the clay, put one half of it aside.

Think It Over

Predicting How big will the remaining piece of clay be if you repeat the process several more times?

In Australia, scientists have found sedimentary rocks that contain some of the world's oldest fossils. These are fossils of stromatolites (stroh MAT uh lyts). Stromatolites are the remains of reefs built by organisms similar to present-day bacteria. Sediment eventually covered these reefs. As the sediment changed to rock, so did the reefs. Using absolute dating, scientists have determined that some stromatolites are more than 3 billion years old. To understand absolute dating, you need to learn more about the chemistry of rocks.

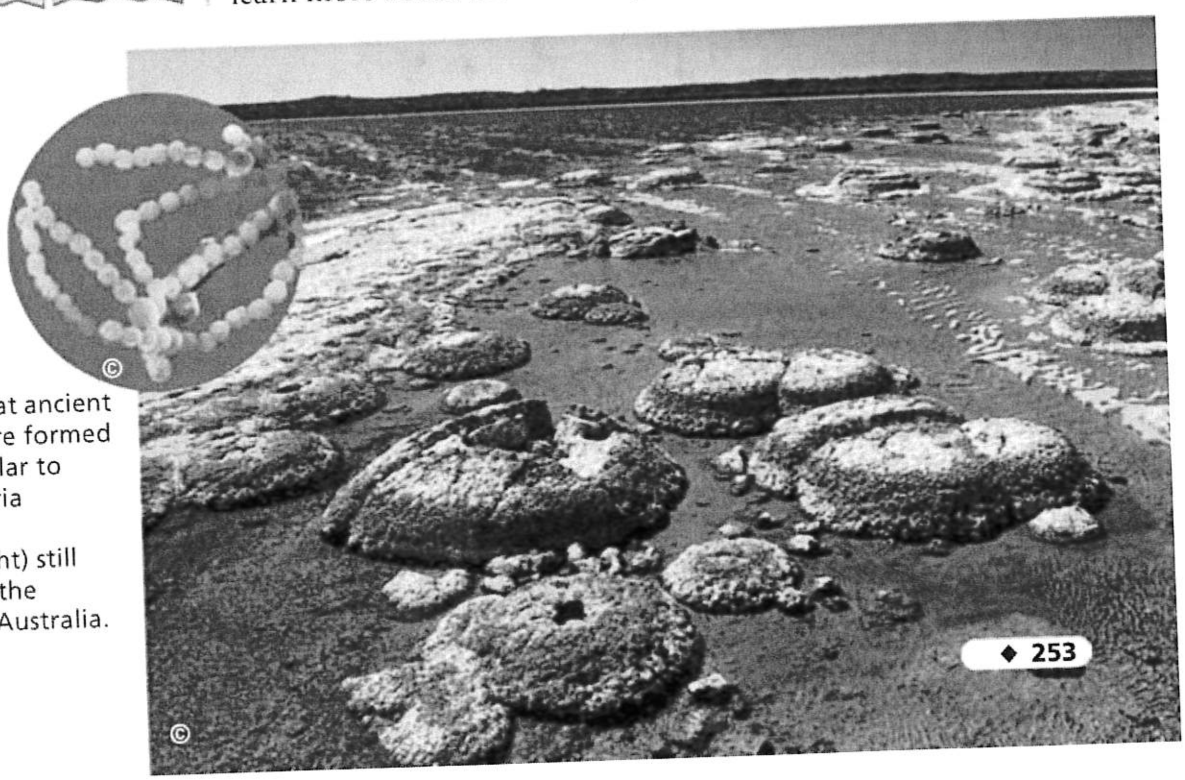


FIGURE 9
Stromatolites
Scientists think that ancient stromatolites were formed by organisms similar to blue-green bacteria (above). Modern stromatolites (right) still form reefs along the western coast of Australia.

Radioactive Decay

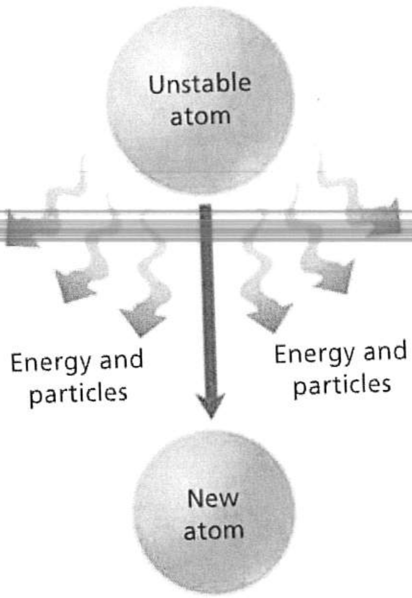


FIGURE 10
Radioactive Decay
In the process of radioactive decay, an atom releases energy and particles as it changes to a new kind of atom.

Rocks are a form of matter. All the matter you see, including rocks, is made of tiny particles called **atoms.** When all the atoms in a particular type of matter are the same, the matter is an **element.** Carbon, oxygen, iron, lead, and potassium are just some of the more than 110 currently known elements.

Most elements are stable. They do not change under normal conditions. But some elements exist in forms that are unstable. Over time, these elements break down, or decay, by releasing particles and energy in a process called **radioactive decay.** These unstable elements are said to be radioactive. **During radioactive decay, the atoms of one element break down to form atoms of another element.**

Radioactive elements occur naturally in igneous rocks. Scientists use the rate at which these elements decay to calculate the rock's age. You calculate your age based on a specific day—your birthday. What's the "birthday" of a rock? For an igneous rock, that "birthday" is when it first hardens to become rock. As a radioactive element within the igneous rock decays, it changes into another element. So the composition of the rock changes slowly over time. The amount of the radioactive element goes down. But the amount of the new element goes up.

The rate of decay of each radioactive element is constant—it never changes. This rate of decay is the element's half-life. The **half-life** of a radioactive element is the time it takes for half of the radioactive atoms to decay. You can see in Figure 11 how a radioactive element decays over time.

Reading Checkpoint **What is the meaning of the term "half-life"?**

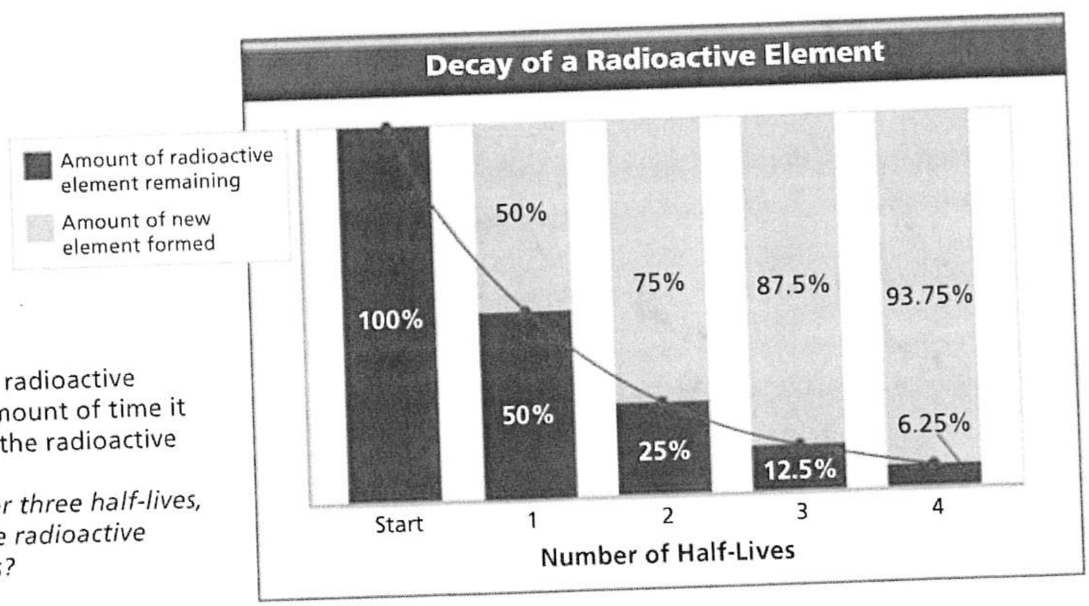


FIGURE 11
The half-life of a radioactive element is the amount of time it takes for half of the radioactive atoms to decay.
Calculating *After three half-lives, how much of the radioactive element remains?*

Elements Used in Radioactive Dating		
Radioactive Element	Half-life (years)	Dating Range (years)
Carbon-14	5,730	500–50,000
Potassium-40	1.3 billion	50,000–4.6 billion
Rubidium-87	48.8 billion	10 million–4.6 billion
Thorium-232	14 billion	10 million–4.6 billion
Uranium-235	713 million	10 million–4.6 billion
Uranium-238	4.5 billion	10 million–4.6 billion

FIGURE 12
The half-lives of different radioactive elements vary greatly.

Determining Absolute Ages

Geologists use radioactive dating to determine the absolute ages of rocks. In radioactive dating, scientists first determine the amount of a radioactive element in a rock. Then they compare that amount with the amount of the stable element into which the radioactive element decays. Figure 12 lists several common radioactive elements and their half-lives.

Potassium–Argon Dating Scientists often date rocks using potassium-40. This form of potassium decays to stable argon-40 and has a half-life of 1.3 billion years. Potassium-40 is useful in dating the most ancient rocks because of its long half-life.

Carbon-14 Dating A radioactive form of carbon is carbon-14. All plants and animals contain carbon, including some carbon-14. As plants and animals grow, carbon atoms are added to their tissues. After an organism dies, no more carbon is added. But the carbon-14 in the organism's body decays. It changes to stable nitrogen-14. To determine the age of a sample, scientists measure the amount of carbon-14 that is left in the organism's remains. From this amount, they can determine its absolute age. Carbon-14 has been used to date fossils such as frozen mammoths, as well as pieces of wood and bone. Carbon-14 even has been used to date the skeletons of prehistoric humans.

Carbon-14 is very useful in dating materials from plants and animals that lived up to about 50,000 years ago. Carbon-14 has a half-life of only 5,730 years. For this reason, it can't be used to date very ancient fossils or rocks. The amount of carbon-14 left would be too small to measure accurately.

Math Skills

Percentage What percentage of a radioactive element will be left after 3 half-lives? First, multiply $\frac{1}{2}$ three times to determine what fraction of the element will remain.

$$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$$

You can convert this fraction to a percentage by setting up a proportion:

$$\frac{1}{8} = \frac{d\%}{100\%}$$

To find the value of d, begin by cross multiplying, as for any proportion:

$$1 \times 100 = 8 \times d$$

$$d = \frac{100}{8}$$

$$d = 12.5\%$$

Practice Problems What percentage of a radioactive element will remain after 5 half-lives?

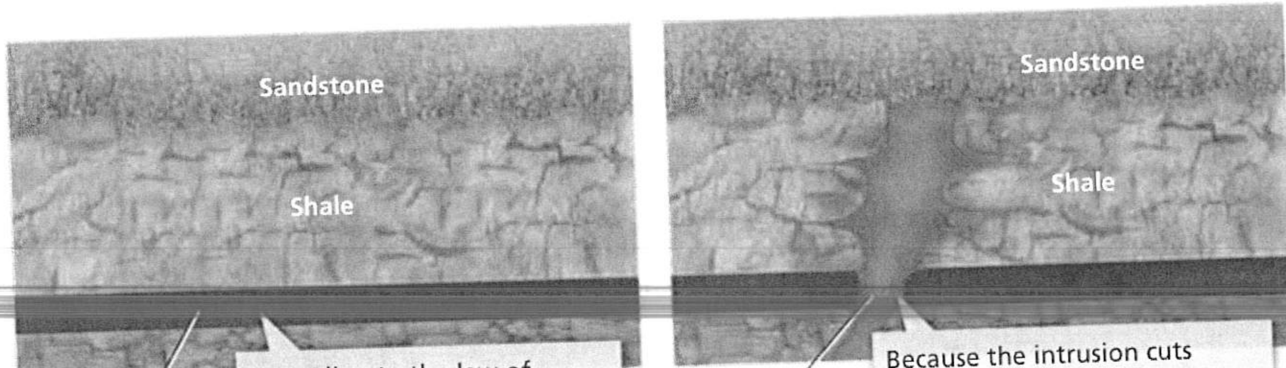


FIGURE 13
Inferring the Age of Rocks
A layer of shale forms above an extrusion (left). Later (right), an intrusion crosses the shale.
Inferring *What can you infer about the age of the shale?*

Radioactive Dating of Rock Layers Radioactive dating works well for igneous rocks, but not for sedimentary rocks. The rock particles in sedimentary rocks are from other rocks, all of different ages. Radioactive dating would provide the age of the particles. It would not provide the age of the sedimentary rock.

How, then, do scientists date sedimentary rock layers? They date the igneous intrusions and extrusions near the sedimentary rock layers. Look at Figure 13. As you can see, sedimentary rock (sandstone) above an igneous intrusion must be younger than that intrusion.

Reading Checkpoint **What are two types of radioactive dating?**

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Section 3 Assessment

Vocabulary Skill Use Clues to Determine Meaning Reread the definition of *radioactive decay*, and the text near the definition. In your own words, explain what *radioactive decay* means.

Reviewing Key Concepts

HINT 1. a. Defining In your own words, define the term *radioactive element*.

HINT b. Describing How does the composition of a rock containing a radioactive element change over time?

HINT c. Applying Concepts How is a radioactive element's rate of decay like the ticking of a clock? Explain.

HINT 2. a. Identifying What method do geologists use to determine the absolute age of a rock?

HINT b. Explaining Why is it difficult to determine the absolute age of a sedimentary rock?

HINT c. Problem Solving A geologist finds a fossil in a layer of sedimentary rock that lies in between two igneous extrusions. How could the geologist determine the age of the fossil?

Math Practice

3. Percentage What percentage of a radioactive element will remain after 7 half-lives?

Section 4

The Geologic Time Scale

Reading Preview

Key Concepts

- Why is the geologic time scale used to show Earth's history?
- What are the different units of the geologic time scale?
- What were the major events of the Paleozoic, Mesozoic, and Cenozoic Eras?

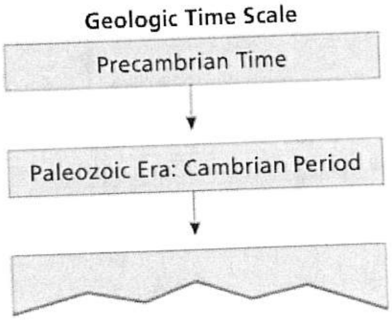
Key Terms

- geologic time scale
- era
- period
- invertebrate
- vertebrate
- amphibian
- reptile
- mass extinction
- mammal

Target Reading Skill

Sequencing As you read, make a flowchart like the one below that shows the eras and periods of geologic time. Write the name of each era and period in the flowchart in the order in which it occurs.

Geologic Time Scale



Lab zone Discover Activity

This Is Your Life!

1. Make a list of about 10 to 15 important events that you remember in your life.
2. On a sheet of paper, draw a timeline to represent your life. Use a scale of 3.0 cm to 1 year.
3. Write each event in the correct year along the timeline.
4. Now divide the timeline into parts that describe major periods in your life, such as preschool years, elementary school years, and middle school years.

Think It Over

Making Models Along which part of your timeline are most of the events located? Which period of your life does this part of the timeline represent? Why do you think this is so?

Imagine squeezing Earth's 4.6-billion-year history into a 24-hour day. Earth forms at midnight. About seven hours later, the earliest one-celled organisms appear. Over the next 14 hours, simple, soft-bodied organisms such as jellyfish and worms develop. A little after 9:00 P.M.—21 hours later—larger, more complex organisms evolve in the oceans. Reptiles and insects first appear about an hour after that. Dinosaurs arrive just before 11:00 P.M., but are extinct by 11:30 P.M. Modern humans don't appear until less than a second before midnight!

The Geologic Time Scale

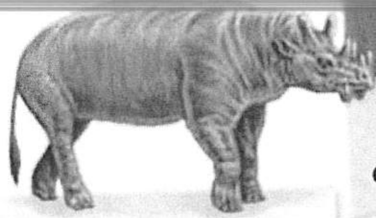
Months, years, or even centuries aren't very helpful for thinking about Earth's long history. **Because the time span of Earth's past is so great, geologists use the geologic time scale to show Earth's history.** The geologic time scale is a record of the life forms and geologic events in Earth's history. You can see this time scale in Figure 14.

Scientists first developed the geologic time scale by studying rock layers and index fossils worldwide. With this information, scientists placed Earth's rocks in order by relative age. Later, radioactive dating helped determine the absolute age of the divisions in the geologic time scale.

FIGURE 14

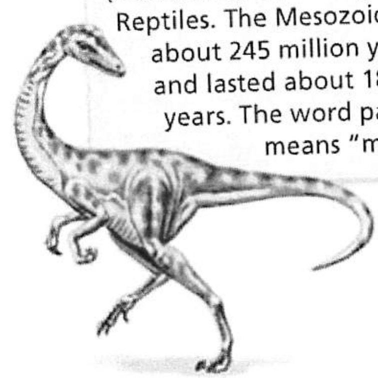
The Geologic Time Scale

The eras and periods of the geologic time scale are used to date the events in Earth's long history. Interpreting Diagrams *How long ago did the Paleozoic Era end?*



Cenozoic Era
The Cenozoic (sen uh ZOH ik) began about 66 million years ago and continues to the present. The word part *ceno-* means "recent," and *-zoic* means "life." Mammals became common during this time.

Mesozoic Era
People often call the Mesozoic (mez uh ZOH ik) the Age of Reptiles. The Mesozoic began about 245 million years ago and lasted about 180 million years. The word part *meso-* means "middle."



Paleozoic Era
The Paleozoic (pay lee uh ZOH ik) began about 544 million years ago and lasted for 300 million years. The word part *paleo-* means "ancient or early."

Geologic Time Scale

Era	Period	Millions of Years Ago	Duration (millions of years)
Cenozoic	*Quaternary*	1.8	1.8 to present
	Tertiary	66.4	65
Mesozoic	*Cretaceous*	144	78
	Jurassic	208	64
	Triassic	245	37
Paleozoic	*Permian*	286	41
	Carboniferous	360	74
	Devonian	408	48
	Silurian	438	30
	Ordovician	505	67
	Cambrian	544	39
Precambrian			*544 million years ago–4.6 billion years ago*

Divisions of Geologic Time

As geologists studied the fossil record, they found major changes in life forms at certain times. They used these changes to mark where one unit of geologic time ends and the next begins. Therefore the divisions of the geologic time scale depend on events in the history of life on Earth.

When speaking of the past, what names do you use for different spans of time? You probably use names such as century, decade, year, month, week, and day. Scientists use similar divisions for the geologic time scale.

Geologic time begins with a long span of time called Precambrian Time (pree KAM bree un). Precambrian Time, which covers about 88 percent of Earth's history, ended about 544 million years ago. **After Precambrian Time, the basic units of the geologic time scale are eras and periods.** Geologists divide the time between Precambrian Time and the present into three long units of time called **eras.** They are the Paleozoic Era, the Mesozoic Era, and the Cenozoic Era.

Eras are subdivided into units of geologic time called **periods.** You can see in Figure 14 that the Mesozoic Era includes three periods: the Triassic Period, the Jurassic Period, and the Cretaceous Period.

The names of many of the geologic periods come from places around the world where geologists first described the rocks and fossils of that period. For example, the name Cambrian refers to Cambria, the old Roman name for Wales.

Reading Checkpoint To what era does the Jurassic Period belong?

FIGURE 15
Fossil of the Quaternary Period
This saber-toothed cat lived during the Quaternary Period.

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FIGURE 16
Paleontologist at Work
This paleontologist in Australia is uncovering fossil animals from late Precambrian Time.

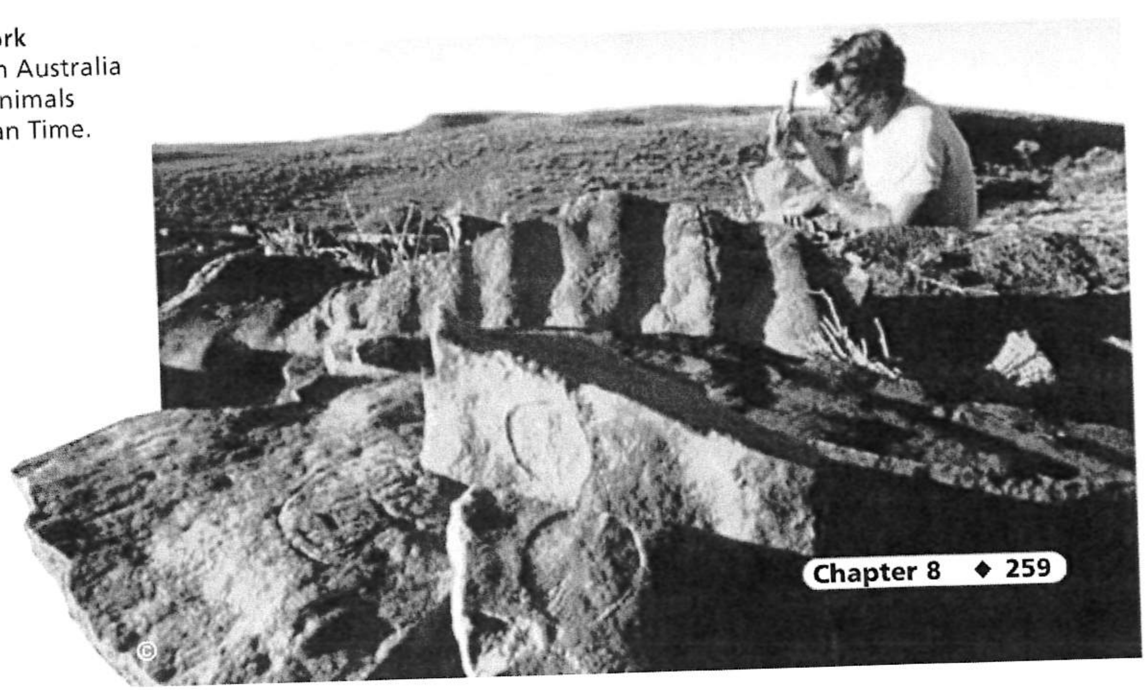

FIGURE 17
Early Earth
This artist's illustration shows Earth shortly after the moon formed. Notice the rocky objects from space striking Earth, and the molten rock flowing over the surface.

Early Earth

Precambrian Time begins when the Earth formed, about 4.6 billion years ago. Scientists hypothesize that early Earth was very hot. Over time, however, the outer layers cooled and became solid. Less than 500 million years after Earth's formation, rock on the surface formed continents.

At this time, the atmosphere, which is the blanket of gases surrounding Earth, was made up mostly of the gases nitrogen, carbon dioxide, and water vapor. There was little oxygen.

Scientists cannot pinpoint when or where life began. **But scientists have found fossils of single-celled organisms in rocks that formed about 3.5 billion years ago. These earliest life forms were probably similar to present-day bacteria.** Unlike most organisms today, these single-celled organisms did not need oxygen. Scientists hypothesize that all other forms of life on Earth arose from these simple organisms.

About 2.5 billion years ago, many organisms began using energy from the sun to make their own food. This process is called photosynthesis. Among these early photosynthetic organisms were cyanobacteria. These bacteria, which were once called blue-green algae, have been extremely successful. They are still alive today, and they have changed very little.

One product of photosynthesis is oxygen. Organisms released oxygen into the atmosphere. The amount of oxygen in the air slowly increased. Processes in the atmosphere changed some of this oxygen into a form called ozone. The ozone layer blocked out some of the ultraviolet rays of the sun. Shielded from the ultraviolet rays, organisms could live on land.

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Visit: www.SciLinks.org
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The Paleozoic Era

Your science class is on a very unusual field trip. You are in a time machine that has taken you back to the beginning of the Paleozoic Era. The time machine is now moving forward, toward the present. You are about to see a period of rapid change.

The Cambrian Explosion In the Cambrian Period, life took a big leap forward. **At the beginning of the Paleozoic Era, many different kinds of organisms evolved.** Paleontologists call this event the Cambrian Explosion because so many new life forms appeared within a relatively short time. For the first time, many organisms had hard parts, including shells and outer skeletons. Many animals, such as sponges, jellyfish, and worms, were invertebrates. **Invertebrates** are animals without backbones.

Scientists infer that at this time, all animals lived in the sea. Fossils provide evidence of a watery environment. That is because many Cambrian fossils are similar to modern sea animals. For example, brachiopods were small animals with two shells. Brachiopods looked like modern clams. Therefore, like clams, brachiopods probably lived in water.

Vertebrates Arise During the Ordovician (awr duh VISH ee un) and Silurian (sih LOOR ee un) periods, invertebrates shared the seas with a new type of organism. **Jawless fishes evolved. Jawless fishes were the first vertebrates.** A **vertebrate** is an animal that has a backbone. These early fishes had sucker-like mouths.

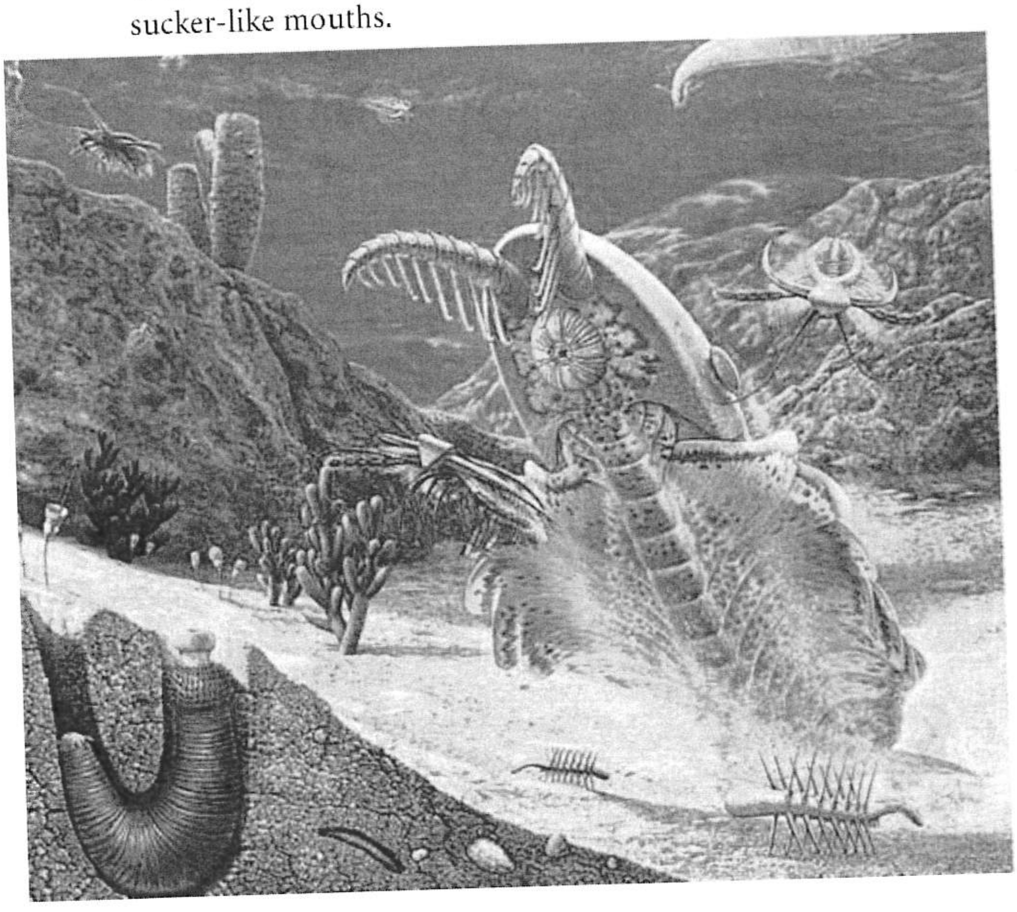


FIGURE 18
The Cambrian Explosion
During the early Cambrian period, Earth's oceans were home to many strange organisms unlike any animals that are alive today.

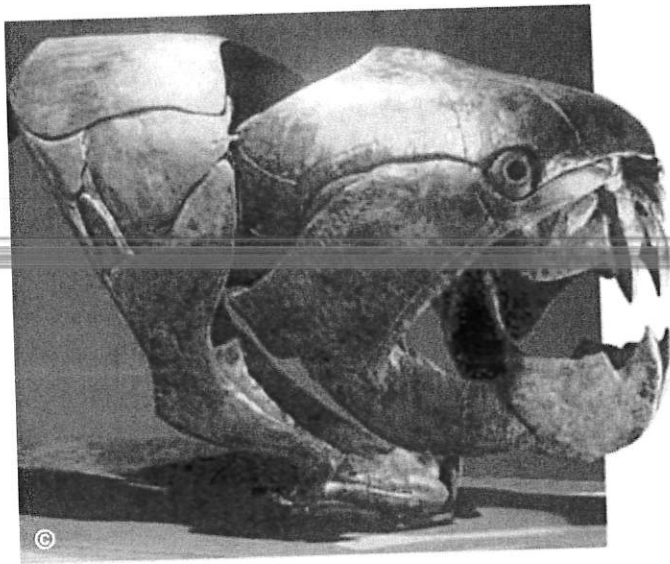


FIGURE 19
Devonian Armored Fish
Paleontologists have found fossils of huge armored fish, like this *Dunkleosteus*, that lived during the Devonian Period.

Life Reaches Land Until the Silurian Period, only one-celled organisms lived on the land. But during the Silurian Period, plants became abundant. These first, simple plants grew low to the ground in damp areas. By the Devonian Period (dih VOH nee un), plants that could grow in drier areas had evolved. Among these plants were the earliest ferns. The first insects also appeared during the Silurian Period.

Both invertebrates and vertebrates lived in the Devonian seas. Even though the invertebrates were more numerous, the Devonian Period is often called the Age of Fishes. Every main group of fishes was present in the oceans at this time. Most fishes now had jaws, bony skeletons, and scales on their bodies. Some fishes, like the one in Figure 19, were huge. Sharks appeared in the late Devonian Period.

During the Devonian Period, vertebrates began to invade the land. The first vertebrates to crawl onto land were lungfish with strong, muscular fins. The first amphibians evolved from these lungfish. An **amphibian** (am FIB ee un) is an animal that lives part of its life on land and part of its life in water.

The Carboniferous Period Throughout the rest of the Paleozoic, life expanded over Earth's continents. Other vertebrates evolved from the amphibians. For example, small reptiles developed during the Carboniferous Period. **Reptiles** have scaly skin and lay eggs with tough, leathery shells. Some types of reptiles became very large during the later Paleozoic.

FIGURE 20
The Coal Forest
Forests of the Carboniferous Period later formed coal deposits. Predicting *What types of fossils would you expect to find from the Carboniferous Period?*

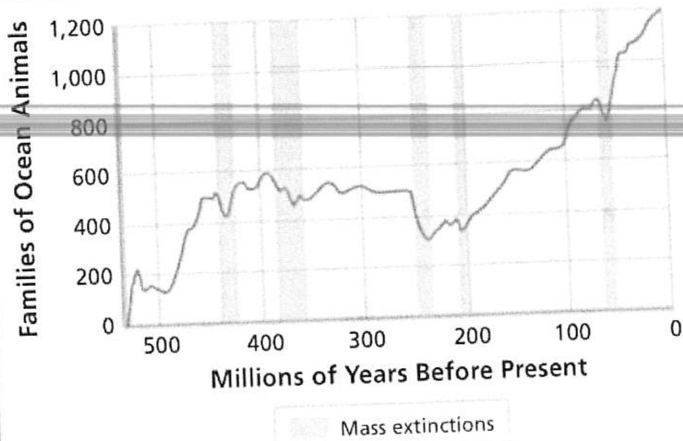
Math Analyzing Data

Mass Extinctions

The graph shows how the number of families of animals in Earth's oceans has changed.

1. **Reading Graphs** What variable is shown on the x-axis? On the y-axis of the graph?
2. **Interpreting Data** How long ago did the most recent mass extinction occur?
3. **Interpreting Data** Which mass extinction produced the greatest drop in the number of families of ocean animals?
4. **Relating Cause and Effect** In general, how did the number of families change between mass extinctions?

Mass Extinctions Since the Cambrian Period



During the Carboniferous Period, winged insects evolved into many forms, including huge dragonflies. Giant ferns and cone-bearing plants formed vast swampy forests called "coal forests." The remains of these plants formed thick deposits of sediment that changed into coal over millions of years.

Mass Extinction Ends the Paleozoic At the end of the Paleozoic Era, many kinds of organisms died out. This was a **mass extinction**, in which many types of living things became extinct at the same time. **The mass extinction, known as the Permian extinction, affected both plants and animals on land and in the seas.** Scientists do not know what catastrophic event caused the mass extinction, but many kinds of organisms suddenly became extinct. As much as 90 percent of marine species may have died out.

The Supercontinent Pangaea Scientists hypothesize that climate change resulting from continental drift may have caused the mass extinction at the end of the Paleozoic. **During the Permian Period, about 260 million years ago, Earth's continents moved together to form a great landmass, or supercontinent, called Pangaea** (pan JEE uh). The formation of Pangaea caused deserts to expand in the tropics. At the same time, sheets of ice covered land closer to the South Pole. Many organisms could not survive the new climate. After Pangaea formed, it broke apart again.

Reading Checkpoint What was Pangaea?

Go Online active art

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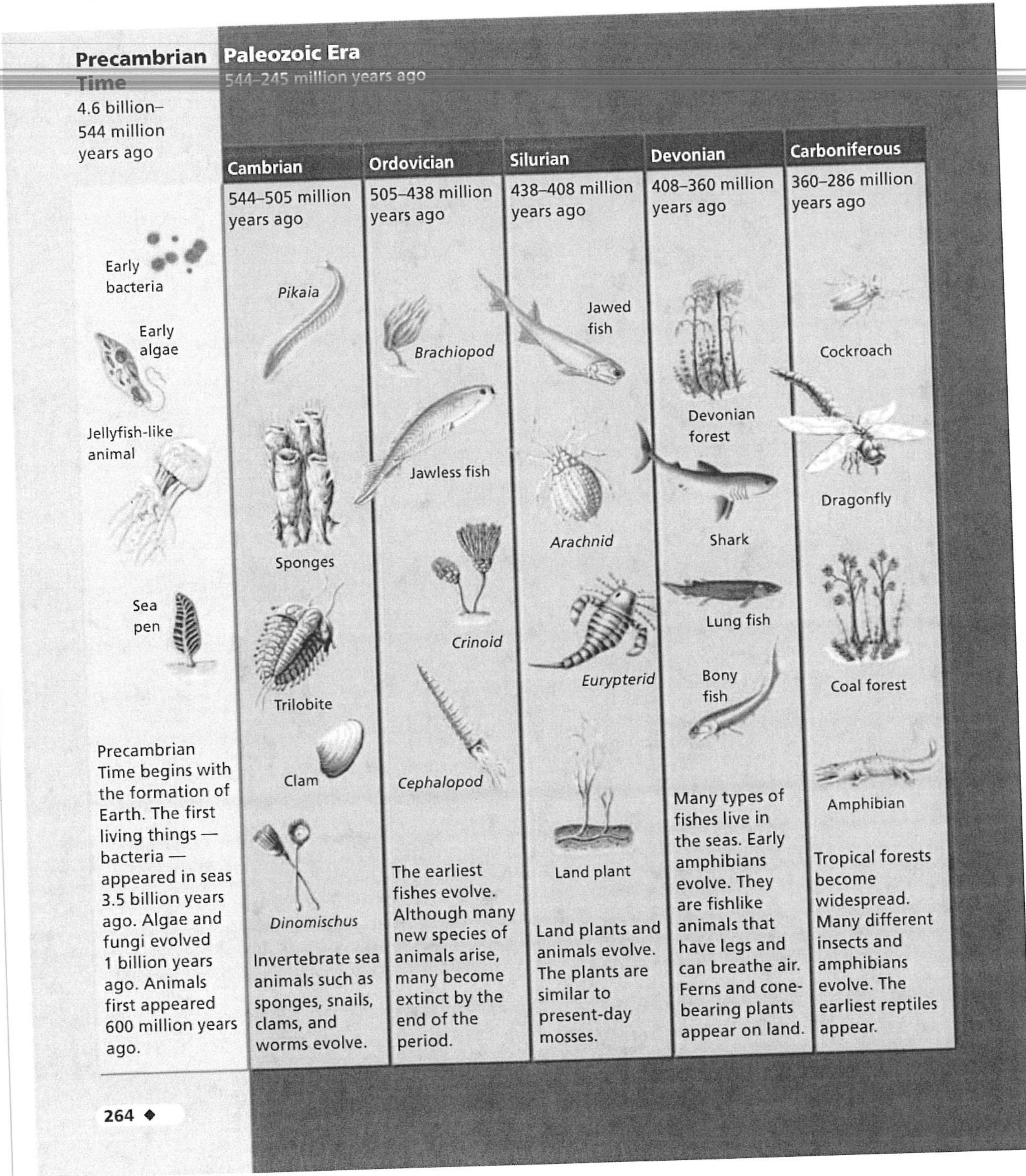
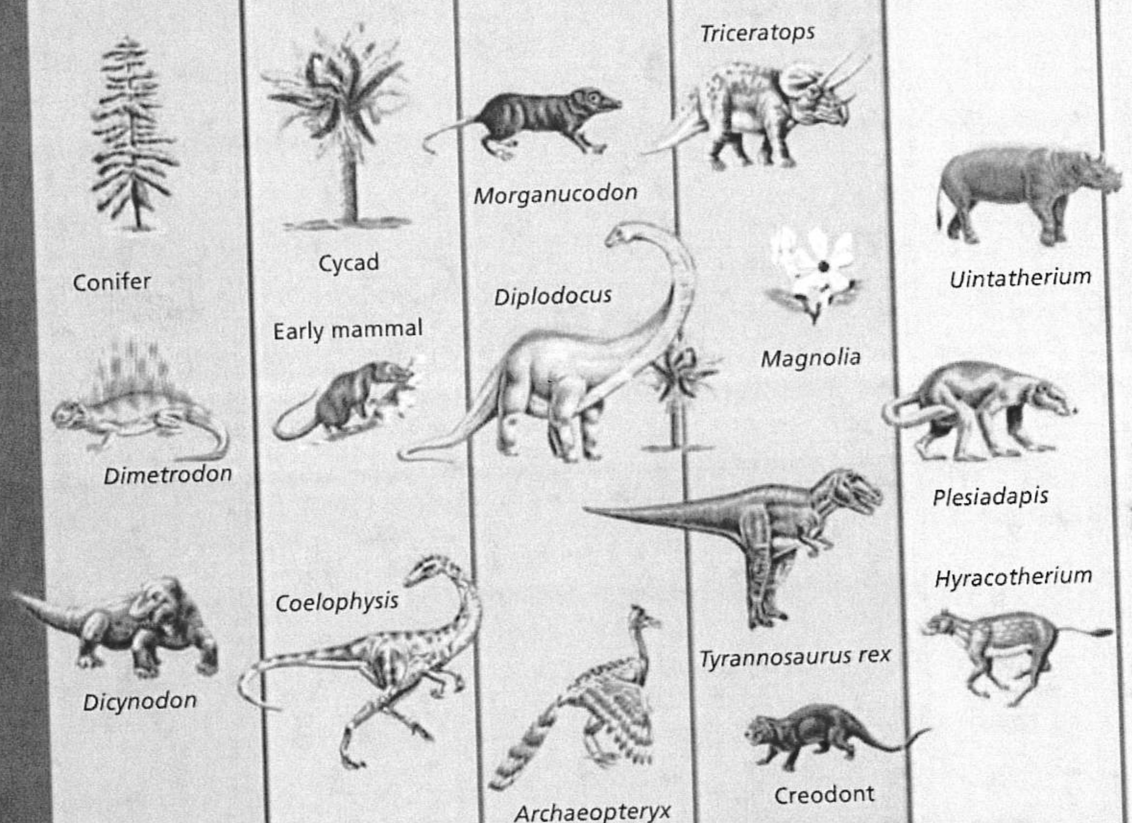
FIGURE 21
The Geologic Time Scale
Sequencing Events *Which organisms appear first—amphibians or fishes?*



Mesozoic Era
245–66 million years ago

Cenozoic Era
66 million years ago to the present



Permian	Triassic	Jurassic	Cretaceous	Tertiary	Quaternary
286–245 million years ago	245–208 million years ago	208–144 million years ago	144–66 million years ago	66–1.8 million years ago	1.8 million years ago to the present
Seed plants, insects, and reptiles become common. Reptile-like mammals appear. At the end of the period, most sea animals and amphibians become extinct.	The first dinosaurs evolve. First turtles and crocodiles appear. Mammals first appear. Cone-bearing trees and palmlike trees dominate forests.	Large dinosaurs roam the world. The first birds appear. Mammals become more common and varied.	The first flowering plants appear. At the end of the period, a mass extinction causes the disappearance of many organisms, including the dinosaurs.	New groups of animals, including the first monkeys and apes, appear. Flowering plants become the most common kinds of plants. First grasses appear.	Mammals, flowering plants, and insects dominate land. Humans appear. Later in the period, many large mammals, including mammoths, become extinct.

FIGURE 22
Flying Reptile
Dimorphodon was a flying reptile that lived during the Jurassic Period. Like dinosaurs, flying reptiles became extinct at the end of the Cretaceous period.
Comparing and Contrasting *How is* Dimorphodon *similar to the bird in Figure 23?*

The Mesozoic Era

Millions of years flash by as your time machine travels. Watch out—there's a dinosaur! You're observing an era that you've read about in books and seen in movies.

The Triassic Period Some living things survived the Permian mass extinction. These organisms became the main forms of life early in the Triassic Period (try AS ik). Plants and animals that survived included fish, insects, reptiles, and cone-bearing plants called conifers. **Reptiles were so successful during the Mesozoic Era that this time is sometimes called the Age of Reptiles.** About 225 million years ago, the first dinosaurs appeared. Mammals also first appeared during the Triassic Period. A **mammal** is a warm-blooded vertebrate that feeds its young milk. Mammals probably evolved from warm-blooded reptiles. The mammals of the Triassic Period were very small.

The Jurassic Period During the Jurassic Period (joo RAS ik), dinosaurs became the dominant animals on land. Scientists have identified several hundred different kinds of dinosaurs. Some were plant eaters, while others were meat eaters. Dinosaurs "ruled" Earth for about 150 million years.

One of the first birds, called *Archaeopteryx*, appeared during the Jurassic Period. The name *Archaeopteryx* means "ancient winged thing." Many paleontologists now think that birds evolved from dinosaurs.

Reading Checkpoint What is a mammal?

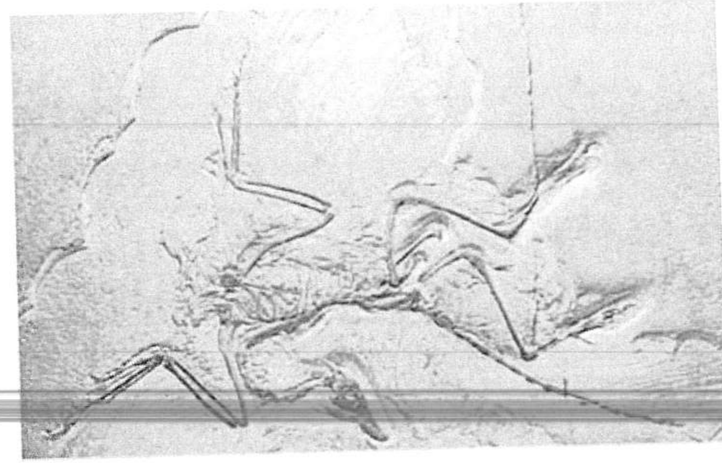


FIGURE 23
Early Bird
The artist of the illustration (left) has given *Archaeopteryx* colorful feathers. From a fossil (right), paleontologists can tell that *Archaeopteryx* was about 30 centimeters long, had feathers and teeth, and also had claws on its wings.

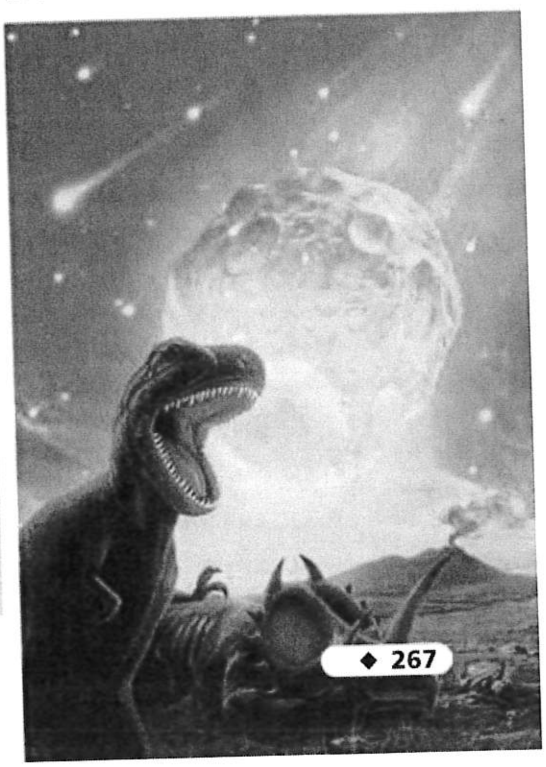
The Cretaceous Period Reptiles, including dinosaurs, were still the dominant vertebrates throughout the Cretaceous Period (krih TAY shus). Flying reptiles and birds competed for places in the sky. The hollow bones and feathers of birds made them better adapted to their environment than the flying reptiles, which became extinct during the Cretaceous Period. The Cretaceous Period also brought new forms of life. Flowering plants like the ones you see today evolved. Unlike the conifers, flowering plants produce seeds that are inside a fruit. The fruit helps the seeds disperse.

Another Mass Extinction Catastrophic, or destructive, events have changed the history of life on Earth. Catastrophic happenings can include volcanoes erupting or objects from space hitting Earth. **At the close of the Cretaceous Period, about 65 million years ago, another mass extinction occurred. Some scientists hypothesize that this mass extinction, known as the Cretaceous-Tertiary (K-T) extinction, occurred when an object from space struck Earth.** This object may have been an asteroid. Asteroids are rocky masses that orbit the sun between Mars and Jupiter.

When the asteroid hit Earth, the impact threw huge amounts of dust and water vapor into the atmosphere. Many organisms on land and in the oceans died immediately. Dust and heavy clouds blocked sunlight around the world for years. Without sunlight, organisms' habitats changed. Plants died, and plant-eating animals starved. This mass extinction wiped out over half of all plant and animal groups. No dinosaurs survived.

Not all scientists agree that an asteroid impact alone caused the mass extinction. Some scientists think that climate changes caused by increased volcanic activity were partly responsible.

FIGURE 24
The End of the Dinosaurs
Many scientists hypothesize that during the Cretaceous an asteroid hit Earth near the present-day Yucatán Peninsula, in southeastern Mexico.



Lab zone Try This **Activity**

Life and Times

1. Place these events in their correct order: continental glaciers retreat; first fish appear; oldest fossils form; human ancestors appear; invertebrate "explosion" occurs; dinosaurs become extinct; Pangaea forms.
2. Draw a timeline and graph these dates:
   - 3.5 billion years ago
   - 544 million years ago
   - 400 million years ago
   - 260 million years ago
   - 65 million years ago
   - 3.5 million years ago
   - 20,000 years ago

   Choose a scale so the oldest date fits on the paper.

Interpreting Data Match each event with the correct date on your timeline. How does the time since the dinosaurs became extinct compare with the time since the oldest fossil formed?

The Cenozoic Era

Your voyage through time continues on through the Cenozoic Era—often called the Age of Mammals. During the Mesozoic Era, mammals had a hard time competing with dinosaurs for food and places to live. **The extinction of dinosaurs created an opportunity for mammals. During the Cenozoic Era, mammals evolved to live in many different environments—on land, in water, and even in the air.**

The Tertiary Period During the Tertiary Period, Earth's climates were generally warm. In the oceans, marine mammals such as whales evolved. On land, flowering plants, insects, and mammals flourished. When grasses evolved, they provided food for grazing mammals. These were the ancestors of today's cattle, deer, sheep, and other grass-eating mammals. Some mammals and birds became very large.

The Quaternary Period The mammals that had evolved during the Tertiary Period eventually faced a changing environment. **Earth's climate cooled, causing a series of ice ages during the Quaternary Period.** Thick continental glaciers advanced and retreated over parts of Europe and North America. Then, about 20,000 years ago, Earth's climate began to warm. Over thousands of years, the continental glaciers melted, except in Greenland and Antarctica.

FIGURE 25
Ice-Age Environment
Large mammals roamed the ice-free parts of North America during the Ice Ages of the Quaternary Period.

In the oceans, algae, coral, mollusks, fish, and mammals thrived. Insects and birds shared the skies. On land, flowering plants and mammals such as bats, cats, dogs, cattle, and humans—just to name a few—became common.

The fossil record suggests that modern humans, or *Homo sapiens,* may have evolved as early as 100,000 years ago. By about 12,000 to 15,000 years ago, humans had migrated around the world to every continent except Antarctica.

Your time machine has now arrived back in the present. You and all organisms on Earth are living in the Quaternary Period of the Cenozoic Era. Is this the end of evolution and the changing of Earth's surface? No, these processes will continue as long as Earth exists. But you'll have to take your time machine into the future to see just what happens!

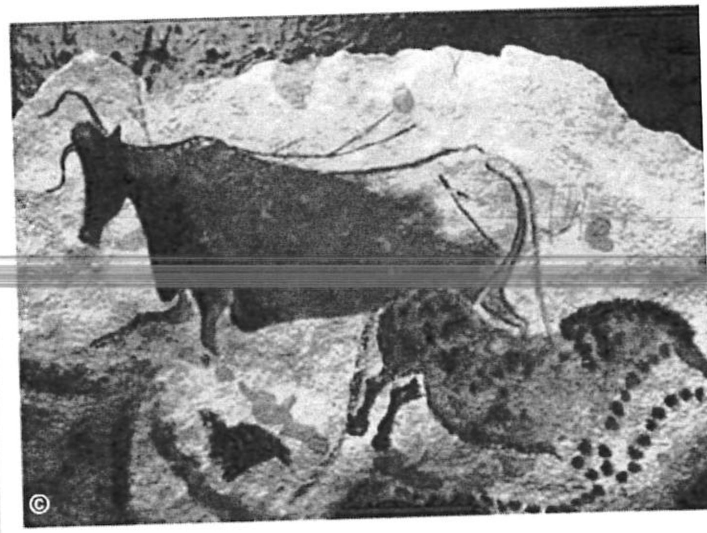


FIGURE 26
Ice Age Art
An early ancestor of modern humans painted these beautiful images of animals in a cave in France more than 15,000 years ago.

Reading Checkpoint **How did Earth's climate change during the Quaternary Period?**

Section 4 Assessment

Target Reading Skill Create Outlines Use your outline of this section to help answer the questions below.

Reviewing Key Concepts

HINT 1. a. Defining What is the geologic time scale?

HINT b. Inferring What information did geologists use to develop the geologic time scale?

HINT 2. a. Reviewing When did the earliest organisms appear on Earth?

HINT b. Relating Cause and Effect How did early photosynthetic organisms change Earth's atmosphere?

HINT 3. a. Listing List the periods of the Paleozoic.

HINT b. Describing How did organisms change during the first period of the Paleozoic?

HINT c. Relating Cause and Effect What event do scientists think may have caused the mass extinction at the end of the Paleozoic?

HINT 4. a. Reviewing Which group of animals was dominant during the Mesozoic Era?

HINT b. Inferring How was their small size helpful to the mammals of the Mesozoic?

c. Developing Hypotheses Many scientists think that the asteroid impact at the end of the Cretaceous prevented plant growth for many years. Although many dinosaurs were plant eaters, some were meat eaters. Develop a hypothesis to explain why all dinosaurs became extinct. HINT

5. a. Identifying What term do scientists apply to the Cenozoic Era? HINT

b. Inferring What conditions allowed so many different kinds of mammals to evolve during the Cenozoic Era? HINT

Writing in Science

Description Suppose that you are going on a tour of Earth during one era of geologic time. Write a paragraph describing the organisms and environments that you see on the tour. Your tour should include at least one stop in each geologic period of the era.

Lab zone **Skills Lab**

As Time Goes By

Problem

How can you make a scale model of geologic time?

Skills

measuring, calculating, making models

Materials

- worksheet with 2,000 asterisks
- one ream of paper

Procedure

PART 1 Table A

1. Copy Table A into your lab notebook. Figure how long ago these historic events happened and write the answers on your chart.
2. Obtain a worksheet with 2,000 asterisks printed on it. Each asterisk represents one year. The first asterisk at the top represents one year ago.
3. Starting from this asterisk, circle the asterisk that represents how many years ago each event in Table A occurred.
4. Label each circled asterisk to indicate the event.
5. Obtain a ream of copy paper. There are 500 sheets in a ream. If each sheet had 2,000 asterisks on it, there would be a total of 1 million asterisks. Therefore, each ream would represent 1 million years.

Table A: Historic Events

Event	Date	Number of Years Ago
You are born.		
One of your parents is born.		
First space shuttle sent into space.	1981	
Neil Armstrong first walks on the moon.	1969	
World War I ends.	1918	
Civil War ends.	1865	
Declaration of Independence is signed.	1776	
Columbus crosses Atlantic Ocean.	1492	
Leif Ericson visits North America.	1000	

Table B: Geologic Events			
Event	Number of Years Ago	Reams or Sheets of Paper	Thickness of Paper
Last ice age ends.	10,000		
Whales evolve.	50 million		
Pangaea begins to break up.	225 million		
First vertebrates develop.	530 million		
Multicellular organisms (algae) develop.	1 billion		
Single-celled organisms develop.	3.5 billion		
Oldest known rocks form.	4.0 billion		
Earth forms.	4.6 billion		

PART 2 Table B

6. Copy Table B into your lab notebook. Determine how much paper in reams or sheets would be needed to represent the events in geologic time found in Table B. (*Hint:* Recall that each ream represents 1 million years.)
7. Measure the thickness of a ream of paper. Use this thickness to calculate how thick a stack of paper would need to be to represent how long ago each geologic event occurred. (*Hint:* Use a calculator to multiply the thickness of the ream of paper by the number of reams.) Enter your results in Table B.

Analyze and Conclude

1. **Measuring** Measure the height of your classroom. How many reams of paper would you need to reach the ceiling? How many years would the height of the ceiling represent? Which geologic events listed in Table B would fall on a ream of paper inside your classroom?
2. **Calculating** At this scale, how many classrooms would have to be stacked on top of each other to represent the age of Earth? The time when vertebrates appeared?
3. **Calculating** How many times higher would the thickness of the stack be for the age of Earth than for the breakup of Pangaea?
4. **Making Models** On your model, how could you distinguish one era or period from another? How could you show when particular organisms evolved and when they became extinct?
5. **Communicating** Is the scale of your model practical? What would be the advantages and disadvantages of a model that fit geologic time on a timeline 1 meter long?

More to Explore

This model represents geologic time as a straight line. Can you think of other ways of representing geologic time graphically? Using colored pencils, draw your own version of the geologic time scale so that it fits on a single sheet of typing paper. (*Hint:* You could represent geologic time as a wheel, a ribbon, or a spiral.)

Chapter 8 Study Guide

The BIG Idea

Earth's history Evidence from rocks shows that life has existed on Earth for billions of years and how Earth has changed over time.

1 Fossils

Key Concepts

Most fossils form when living things die and are buried by sediments. The sediments slowly harden into rock and preserve the shapes of the organisms.

Fossils found in rock include molds and casts, petrified fossils, carbon films, and trace fossils. Other fossils form when the remains of organisms are preserved in substances such as tar, amber, or ice.

The fossil record provides evidence about the history of life and past environments on Earth. The fossil record also shows that different groups of organisms have changed over time.

Key Terms

fossil
sedimentary rock
mold
cast
petrified fossil
carbon film
trace fossil
paleontologist
scientific theory
evolution
extinct

2 The Relative Age of Rocks

Key Concepts

According to the law of superposition, in horizontal sedimentary rock layers the oldest layer is at the bottom. Each higher layer is younger than the layers below it.

To determine relative age, geologists also study extrusions and intrusions of igneous rock, faults, and gaps in the geologic record.

Index fossils are useful because they tell the relative ages of the rock layers in which they occur.

Key Terms

relative age
absolute age
law of superposition
extrusion
intrusion
fault
unconformity
index fossil

3 Radioactive Dating

Key Concepts

During radioactive decay, the atoms of one element break down to form atoms of another.

Geologists use radioactive dating to determine the absolute ages of rocks.

Key Terms

atom
element
radioactive decay
half-life

4 The Geologic Time Scale

Key Concepts

Geologists use the geologic time scale to show the time span of Earth's history.

After Precambrian Time, the basic units of the geologic time scale are eras and periods.

Scientists have found fossils of single-celled organisms in rocks that formed about 3.5 billion years ago.

At the beginning of the Paleozoic Era, many different kinds of organisms evolved.

During the Devonian Period, vertebrates began to invade the land.

During the Permian Period, about 260 million years ago, the supercontinent Pangaea formed.

Reptiles were so successful during the Mesozoic Era that this time is sometimes called the Age of Reptiles.

At the close of the Cretaceous Period, about 65 million years ago, a mass extinction occurred.

During the Cenozoic Era, mammals evolved to live in many different environments.

Earth's climate cooled, causing a series of ice ages during the Quaternary Period.

Key Terms

geologic time scale
era
period
invertebrate
vertebrate
amphibian
reptile
mass extinction
mammal

Review and Assessment

Go Online
PHSchool.com
For: Self-Assessment
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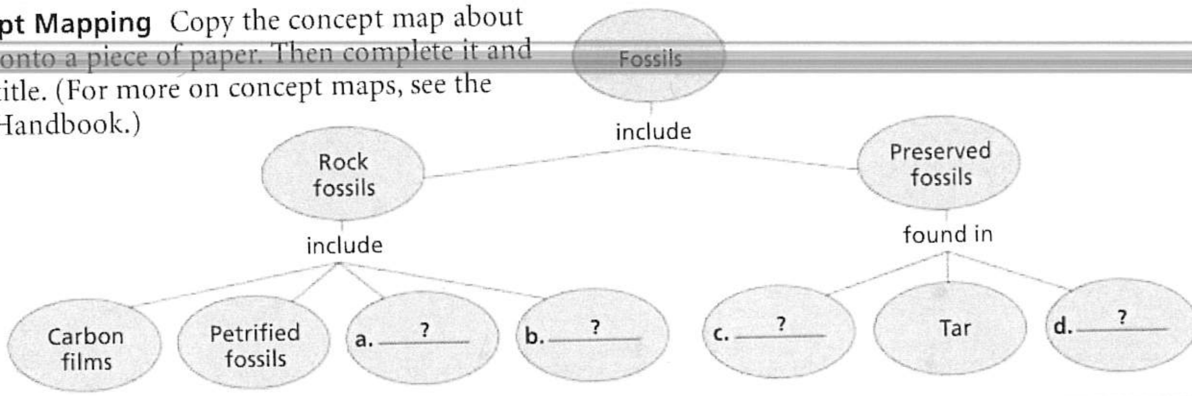
Web Code: cpa-0008

Organizing Information

Concept Mapping Copy the concept map about fossils onto a piece of paper. Then complete it and add a title. (For more on concept maps, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

HINT 1. A hollow area in sediment in the shape of all or part of an organism is called a
- a. mold.
- b. cast.
- c. trace fossil.
- d. carbon film.

HINT 2. A gap in the geologic record formed when sedimentary rocks cover an eroded surface is called a(n)
- a. intrusion.
- b. unconformity.
- c. fault.
- d. extrusion.

HINT 3. The time it takes for half of a radioactive element's atoms to decay is a(n)
- a. era.
- b. half-life.
- c. relative age.
- d. absolute age.

HINT 4. The geologic time scale is subdivided into
- a. relative ages.
- b. absolute ages.
- c. unconformities.
- d. eras and periods.

HINT 5. An animal that doesn't have a backbone is called a(n)
- a. vertebrate.
- b. mammal.
- c. invertebrate.
- d. amphibian.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. A dinosaur footprint in rock is an example of a <u>trace fossil</u>. HINT

7. A <u>carbon film</u> is a fossil in which minerals have replaced all or part of an organism. HINT

8. The <u>relative age</u> of something is the exact number of years since an event has occurred. HINT

9. The principle of <u>uniformitarianism</u> states that the same processes that operate today operated in the past. HINT

10. Scientists think dinosaurs became extinct as part of a(n) <u>intrusion</u> at the end of the Cretaceous Period. HINT

Writing in Science

Field Guide Write a field guide for visitors to the Grand Canyon. In your guide, explain how geologists have learned about Earth's past by studying the canyon walls and the fossils they contain.

Discovery Channel School

A Trip Through Geologic Time
- Video Preview
- Video Field Trip
- ▶ Video Assessment

Review and Assessment

Checking Concepts

11. How does a petrified fossil form?
12. Which organism has a better chance of leaving a fossil: a jellyfish or a bony fish? Explain.
13. Describe a process that could cause an unconformity.
14. What evidence would a scientist use to determine the absolute age of a fossil found in a sedimentary rock?
15. What was Earth's early atmosphere like?
16. How did Earth's environments change from the Tertiary Period to the Quarternary Period? Explain.

Thinking Critically

17. **Applying Concepts** Paleontologists find a trilobite fossil in a rock layer at the top of a hill in South America. Then they find the same kind of fossil in a rock layer at the bottom of a cliff in Africa. What could the paleontologists conclude about the two rock layers?
18. **Problem Solving** Which of the elements in the table below would be better to use in dating a fossil from Precambrian time? Explain.

Radioactive Elements

Element	Half-life (years)
Carbon-14	5,730
Uranium-235	713 million

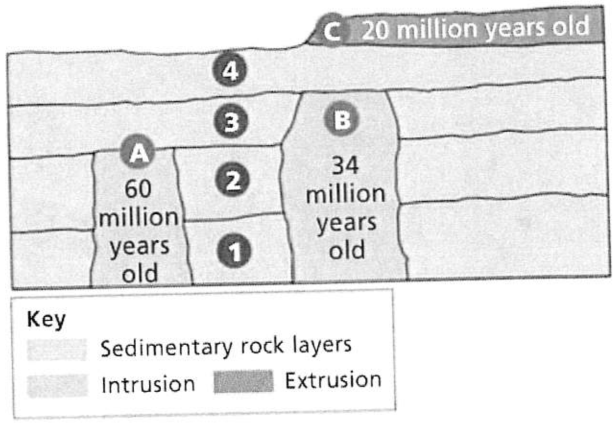
19. **Relating Cause and Effect** When Pangaea formed, the climate changed and the land on Earth became drier. How was this climate change more favorable to reptiles than amphibians?
20. **Making Judgments** If you see a movie in which early humans fight giant dinosaurs, how would you judge the scientific accuracy of that movie? Give reasons for your judgment.

Math Practice

21. **Percentage** What percentage of a radioactive element will remain after 9 half-lives?

Applying Skills

Use the diagram of rock layers below to answer Questions 22–25.



22. **Inferring** According to the Law of Superposition, which is the oldest layer of sedimentary rock? Which is the youngest? How do you know?
23. **Measuring** What method did a scientist use to determine the age of the intrusion and extrusion?
24. **Interpreting Data** What is the relative age of layer 3? (*Hint:* With what absolute ages can you compare it?)
25. **Interpreting Data** What is the relative age of layer 4?

Lab zone Chapter Project

Performance Assessment You have completed your illustrations for the timeline and travel brochure. Now you are ready to present the story of the geologic time period you researched. Be sure to include the awesome sights people will see when they travel to this time period. Don't forget to warn them of any dangers that await them. In your journal, reflect on what you have learned about Earth's history.

GA Preparing for the CRCT

Test-Taking Tip

Answering a Constructed-Response Question

A constructed-response question asks you to compose an answer in your own words. Read the question carefully and note the type of information your response should contain. Your answer should address all the specific points asked for in the question. Before you begin writing, organize the information for your response.

Sample Question

Compare preserved remains and trace fossils. Give an example of each type of fossil.

Answer

Both preserved remains and trace fossils provide evidence of ancient life forms. However, with preserved remains, an organism has been fossilized with little or no change. An example of preserved remains would be an insect in amber. A trace fossil preserves evidence of an organism, not the organism itself. The footprint of a dinosaur would be an example of a trace fossil.

Choose the letter of the best answer.

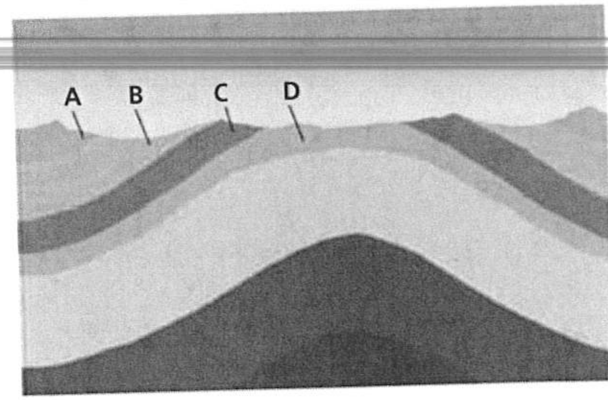
1. A geologist finds identical index fossils in a rock layer in the Grand Canyon in Arizona and in a rock layer in northern Utah, more than 675 kilometers away. What inference can she make about the ages of the two rock layers?
   - **A** the rock layer in the Grand Canyon is older
   - **B** the rock layer in Utah is older
   - **C** the two rock layers are about the same age
   - **D** no inferences

   S6E5.f

2. What should you use so that the geologic time scale covering Earth's 4.6 billion year history can be drawn as a straight line on a poster board one meter high?
   - **A** 1 cm = 1 million years
   - **B** 1 cm = 10,000 years
   - **C** 1 cm = 100,000 years
   - **D** 1 cm = 50,000,000 years

   S6E5.f

Use the diagram below and your knowledge of science to answer Question 3.



3. According to the law of superposition, the youngest layer of rock in this diagram is
   - **A** Layer A
   - **B** Layer B
   - **C** Layer C
   - **D** Layer D

   S6E5.e

4. What was used by geologists to define the beginnings and ends of the divisions of the geologic time scale?
   - **A** radioactive dating
   - **B** major changes in life forms
   - **C** types of rocks present
   - **D** volcanic events

   S6E5.f

5. A leaf falls into a shallow lake and is rapidly buried in the sediment that changes to rock over millions of years. Which type of fossil would be formed?
   - **A** mold and cast
   - **B** carbon film
   - **C** trace fossil
   - **D** amber

   S6E5.f

Constructed Response

6. Describe two methods geologists use to determine the age of a rock. In your answer, be sure to mention igneous rock, sedimentary rock, the law of superposition, index fossils, radioactive decay, and half-life.

   S6E5.c