Chapter 6

The Environment and Change Over Time

THE BIG IDEA

How do species adapt to changing environments over time?

Inquiry

Bees or Flowers?

A type of orchid plant, called a bee orchid, produces this flower. You might have noticed that the flower looks like a bee.

- What is the advantage to the plant to have flowers that look like bees?
- How did the appearance of the flower develop over time?
- How do species adapt to changing environments over time?

Get Ready to Read

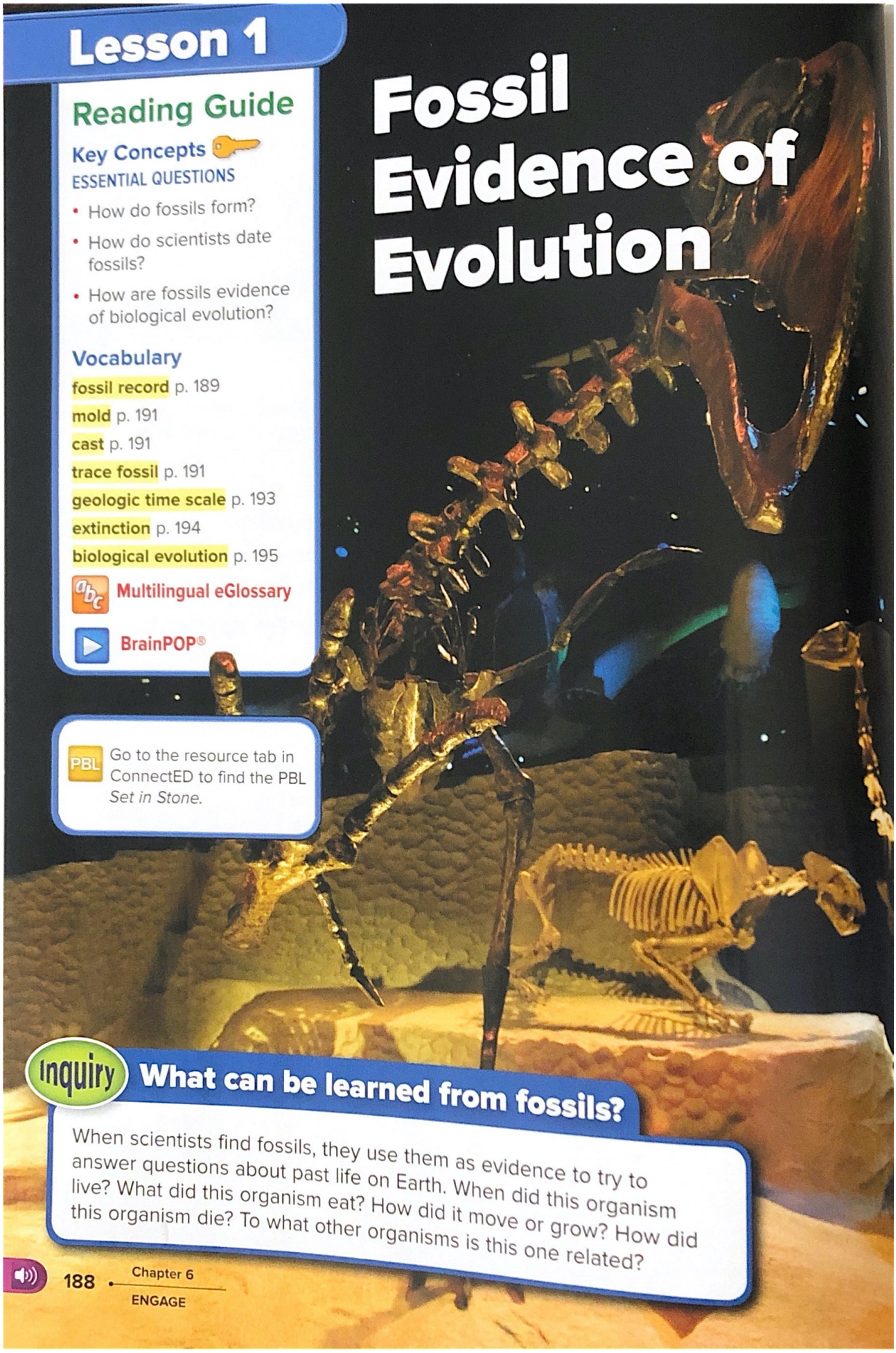
What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Original tissues can be preserved as fossils.
2. Organisms become extinct only in mass extinction events.
3. Environmental change causes variations in populations.
4. Variations can lead to adaptations.
5. Living species contain no evidence that they are related to each other.
6. Plants and animals share similar genes.

Lesson 1

Fossil Evidence of Evolution



Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- How do fossils form?
- How do scientists date fossils?
- How are fossils evidence of biological evolution?

Vocabulary

fossil record p. 189
mold p. 191
cast p. 191
trace fossil p. 191
geologic time scale p. 193
extinction p. 194
biological evolution p. 195

Multilingual eGlossary

BrainPOP®

PBL Go to the resource tab in ConnectED to find the PBL *Set in Stone*.

Inquiry What can be learned from fossils?

When scientists find fossils, they use them as evidence to try to answer questions about past life on Earth. When did this organism live? What did this organism eat? How did it move or grow? How did this organism die? To what other organisms is this one related?

Launch Lab

20 minutes

How do fossils form?

Evidence from fossils helps scientists understand how organisms have changed over time. Some fossils form when impressions left by organisms in sand or mud are filled in by sediments that harden.

1. Read and complete a lab safety form.
2. Place a **container of moist sand** on top of **newspaper.** Press a **shell** into the moist sand. Carefully remove the shell. Brush any sand on the shell onto the newspaper.
3. Observe the impression, and record your observations in your Science Journal.
4. Pour **plaster of paris** into the impression. Wait for it to harden.
   ⚠ *The mix gets hot as it sets—do not touch it until it has hardened.*
5. Remove the shell fossil from the sand, and brush it off.
6. Observe the structure of the fossil, and record your observations.

Think About This

1. What effect did the shell have on the sand?
2. **Key Concept** What information do you think someone could learn about the shell and the organism that lived inside it by examining the fossil?

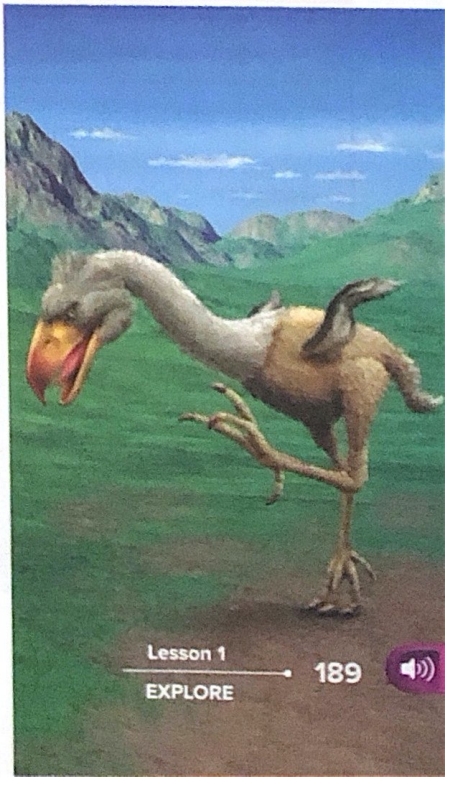
The Fossil Record

On your way to school, you might have seen an oak tree or heard a robin. Although these organisms shed leaves or feathers, their characteristics remain the same from day to day. It might seem as if they have been on Earth forever. However, if you were to travel a few million years back in time, you would not see oak trees or robins. You would see different species of trees and birds. That is because species change over time.

You might already know that fossils are the remains or evidence of once-living organisms. *The* **fossil record** *is made up of all the fossils ever discovered on Earth.* It contains millions of fossils that represent many thousands of species. Most of these species are no longer alive on Earth. The fossil record provides evidence that species have changed over time. Fossils help scientists picture what these species looked like. **Figure 1** shows how scientists think the giant bird *Titanus* might have looked when it was alive. The image is based on fossils that have been discovered and are represented in the photo on the previous page.

The fossil record is enormous, but it is still incomplete. Scientists think it represents only a small fraction of all the organisms that have ever lived on Earth.

Figure 1 Based on fossil evidence, scientists can recreate the physical appearance of species that are no longer alive on Earth.



Fossil Formation

If you have ever seen vultures or other animals eating a dead animal, you know they leave little behind. Any soft **tissues** animals do not eat, bacteria break down. Only the dead animal's hard parts, such as bones, shells, and teeth, remain. In most instances, these hard parts also break down over time. However, under rare conditions, some become fossils. The soft tissues of animals and plants, such as skin, muscles, or leaves, can also become fossils, but these are even more rare. Some of the ways that fossils can form are shown in **Table 1.**

Reading Check Why is it rare for soft tissue to become a fossil?

SCIENCE USE V. COMMON USE

tissue

Science Use similar cells that work together and perform a function

Common Use a piece of soft, absorbent paper

Mineralization

After an organism dies, its body could be buried under mud, sand, or other sediments in a stream or river. If minerals in the water replace the organism's original material and harden into rock, a fossil forms. This process is called mineralization. Minerals in water also can filter into the small spaces of a dead organism's tissues and become rock. Most mineralized fossils are of shell or bone, but wood can also become a mineralized fossil, as shown in **Table 1.**

Carbonization

In carbonization, a fossil forms when a dead organism is compressed over time and pressure drives off the organism's liquids and gases. As shown in **Table 1,** only the carbon outline, or film, of the organism remains.

Table 1 Fossils form in several ways.

Visual Check What types of organisms or tissues are often preserved as carbon films?

Table 1 How Fossils Form

	Mineralization	Carbonization
Description	Rock-forming minerals, such as calcium carbonate ($CaCO_3$), in water filled in the small spaces in the tissue of these pieces of petrified wood. Water also replaced some of the wood's tissue. Mineralization can preserve the internal structures of an organism.	Fossil films made by carbonization are usually black or dark brown. Fish, insects, and plant leaves, such as this fern frond, are often preserved as carbon films.
Example		

Molds and Casts

Sometimes when an organism dies, its shell or bone might make an impression in mud or sand. When the sediment hardens, so does the impression. *The impression of an organism in a rock is called a* **mold.** Sediments can later fill in the mold and harden to form a cast. *A* **cast** *is a fossil copy of an organism in a rock.* A single organism can form both a mold and a cast, as shown in **Table 1.** Molds and casts show only external features of organisms.

Trace Fossils

Evidence of an organism's movement or behavior–not just its physical structure–also can be preserved in rock. *A* **trace fossil** *is the preserved evidence of the activity of an organism.* For example, an organism might walk across mud. The tracks, such as the ones shown in **Table 1,** can fossilize if they are filled with sediment that hardens.

Original Material

In rare cases, the original tissues of an organism can be preserved. Examples of original-material fossils include mammoths frozen in ice and saber-toothed cats preserved in tar pits. Fossilized remains of ancient humans have been found in bogs. Most of these fossils are younger than 10,000 years old. However, the insect encased in amber in **Table 1** is millions of years old. Scientists also have found original tissue preserved in the bone of a dinosaur that lived 70 million years ago (mya).

Key Concept Check List the different ways fossils can form.

WORD ORIGIN

fossil
from Latin *fossilis,* means "to obtain by digging"

Molds and Casts	Trace Fossils	Original Material
When sediments hardened around this buried trilobite, a mold formed. Molds are usually of hard parts, such as shells or bone. If a mold is later filled with more sediments that harden, the mold can form a cast.	These footprints were made when a dinosaur walked across mud that later hardened. This trace fossil might provide evidence of the speed and weight of the dinosaur.	If original tissues of organisms are buried in the absence of oxygen for long periods of time, they can fossilize. The insect in this amber became stuck in tree sap that later hardened.
		

Dating Fossils

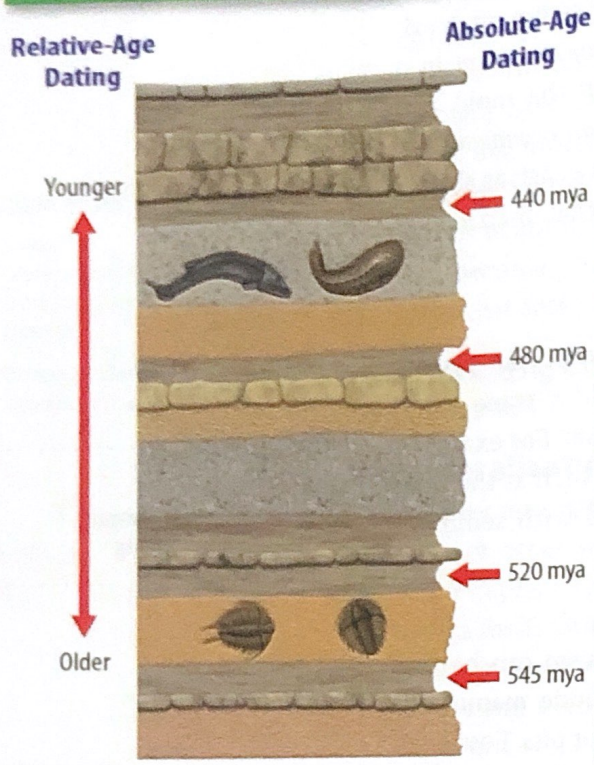


Figure 2 If the age of the igneous layers is known, as shown above, it is possible to estimate the age of the sedimentary layers—and the fossils they contain—between them.

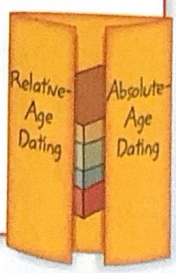
Visual Check What is the estimated age of the trilobite fossils (bottom layer of fossils)?

REVIEW VOCABULARY

isotopes
atoms of the same element that have different numbers of neutrons

FOLDABLES

Make a small shutterfold book. Label it as shown. Under the left tab describe relative-age dating. Under the right tab describe absolute-age dating.



Determining a Fossil's Age

Scientists cannot date most fossils directly. Instead, they date the rocks the fossils are embedded inside. Rocks erode or are recycled over time. However, scientists can determine ages for most of Earth's rocks.

Relative-Age Dating

How does your age compare to the ages of those around you? You might be younger than a brother but older than a sister. This is your relative age. Similarly, a rock is either older or younger than rocks nearby. In relative-age dating, scientists determine the relative order in which rock layers were deposited. In an undisturbed rock formation, they know that the bottom layers are oldest and the top layers are youngest, as shown in **Figure 2.** Relative-age dating helps scientists determine the relative order in which species have appeared on Earth over time.

Key Concept Check How does relative-age dating help scientists learn about fossils?

Absolute-Age Dating

Absolute-age dating is more precise than relative-age dating. Scientists take advantage of radioactive decay, a natural clocklike process in rocks, to learn a rock's absolute age, or its age in years. In radioactive decay, unstable **isotopes** in rocks change into stable isotopes over time. Scientists measure the ratio of unstable isotopes to stable isotopes to find the age of a rock. This ratio is best measured in igneous rocks.

Igneous rocks form from volcanic magma. Magma is so hot that it is rare for parts of organisms in it to remain and form fossils. Most fossils form in sediments, which become sedimentary rock. To measure the age of sedimentary rock layers, scientists calculate the ages of igneous layers above and below them. In this way, they can estimate the ages of the fossils embedded within the sedimentary layers, as shown in **Figure 2.**

Fossils over Time

How old do you think Earth's oldest fossils are? You might be surprised to learn that evidence of microscopic, unicellular organisms has been found in rocks 3.7 billion years old in Greenland. Researchers think that these fossils are stromatolites, which are moundlike structures formed by bacteria.

The Geologic Time Scale

It is hard to keep track of time that is millions and billions of years long. Scientists organize Earth's history into a time line called the geologic time scale. *The* **geologic time scale** *is a chart that divides Earth's history into different time units.* The longest time units in the geological time scale are eons. As shown in Figure 3, Earth's history is divided into four eons. Earth's most recent eon–the Phanerozoic (fa nuh ruh ZOH ihk) eon–is subdivided into three eras, also shown in Figure 3.

Reading Check What is the geologic time scale?

Dividing Time

You might have noticed in Figure 3 that neither eons nor eras are equal in length. When scientists began developing the geologic time scale in the 1800s, they did not have absolute-age dating methods. To mark time boundaries, they used fossils. Fossils provided an easy way to mark time. Scientists knew that different rock layers contained different types of fossils. Some of the fossils scientists use to mark the time boundaries are shown in Figure 3.

Often, a type of fossil found in one rock layer did not appear in layers above it. Even more surprising, entire collections of fossils in one layer were sometimes absent from layers above them. It seemed as if whole communities of organisms had suddenly disappeared.

Reading Check What do scientists use to mark boundaries in the geologic time scale?

Personal Tutor

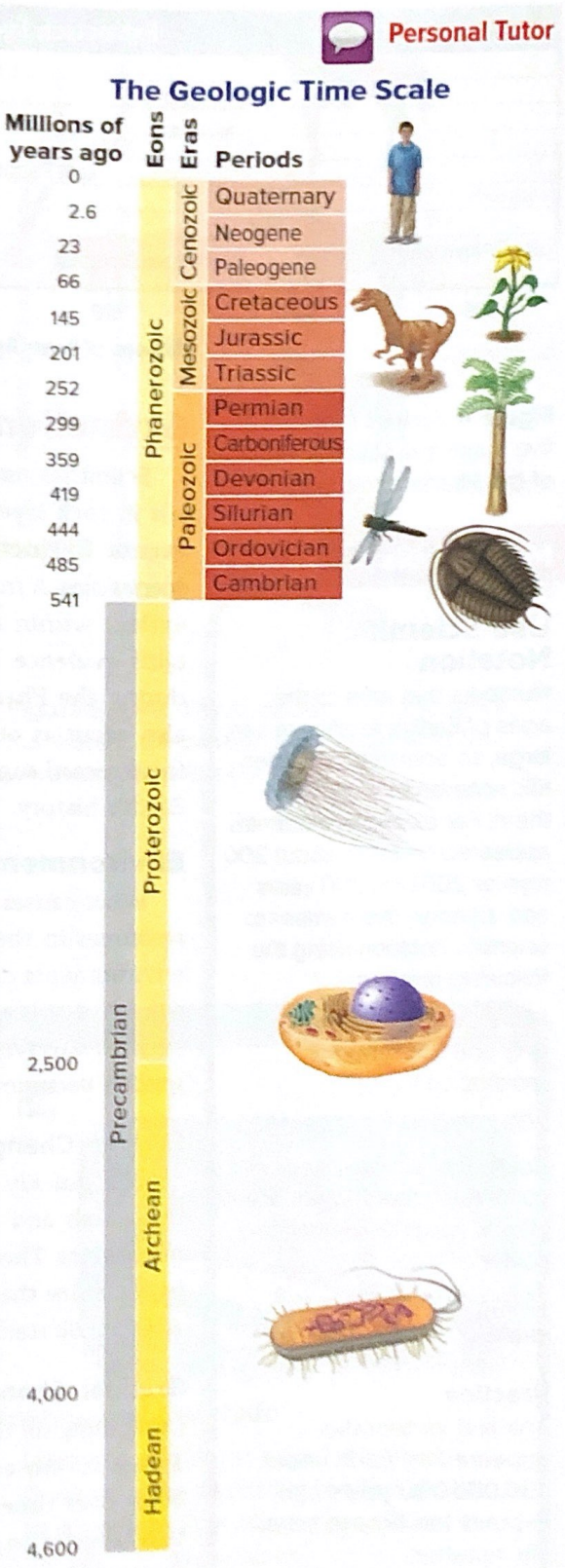


Figure 3 The Phanerozoic eon began about 540 million years ago and continues to the present day. It contains most of Earth's fossil record.

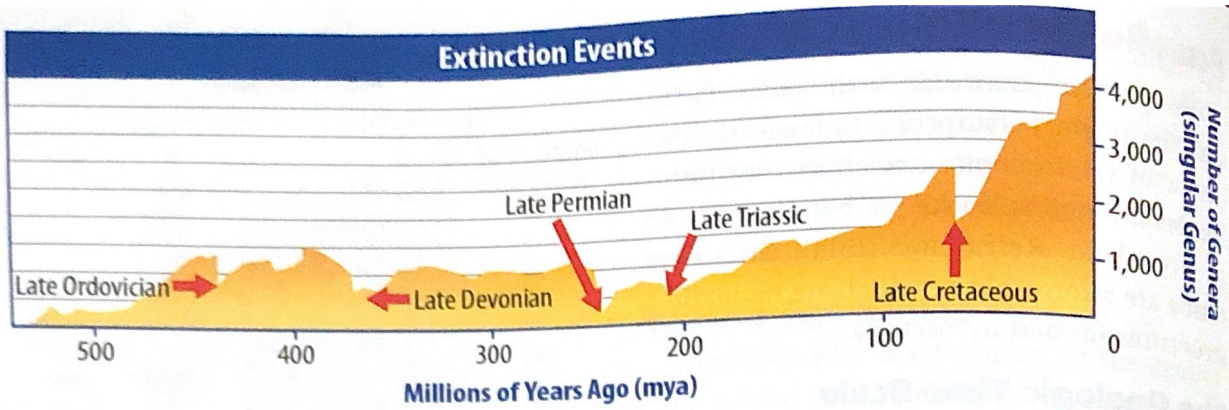


Figure 4 Arrows mark the five major extinction events of the Phanerozoic eon.

Math Skills

Use Scientific Notation

Numbers that refer to the ages of Earth's fossils are very large, so scientists use scientific notation to work with them. For example, mammals appeared on Earth about 200 mya or 200,000,000 years ago. Change this number to scientific notation using the following process.

Move the decimal point until only one nonzero digit remains on the left.

200,000,000 = 2.00000000

Count the number of places you moved the decimal point (8) and use that number as a power of ten.

200,000,000 = 2.0×10^8 years.

Practice

The first vertebrates appeared on Earth about 490,000,000 years ago. Express this time in scientific notation.

Math Practice

Personal Tutor

Extinctions

Scientists now understand that sudden disappearances of fossils in rock layers are evidence of extinction (ihk STINGK shun) events. **Extinction** *occurs when the last individual organism of a species dies.* A mass extinction occurs when many species become extinct within a few million years or less. The fossil record contains evidence that five mass extinction events have occurred during the Phanerozoic eon, as shown in **Figure 4.** Extinctions also occur at other times, on smaller scales. Evidence from the fossil record suggests extinctions have been common throughout Earth's history.

Environmental Change

What causes extinctions? Populations of organisms depend on resources in their environment for food and shelter. Sometimes environments change. After a change happens, individual organisms of a species might not be able to find the resources they need to survive. When this happens, the organisms die, and the species becomes extinct.

Sudden Changes Extinctions can occur when environments change quickly. A volcanic eruption or a meteorite impact can throw ash and dust into the atmosphere, blocking sunlight for many years. This can affect global climate and food webs. Scientists hypothesize that the impact of a huge meteorite 65 million years ago contributed to the extinction of dinosaurs.

Gradual Changes Not all environmental change is sudden. Depending on the location, Earth's tectonic plates move between 1 and 15 cm each year. As plates move and collide with each other over time, mountains form and oceans develop. If a mountain range or an ocean isolates a species, the species might become extinct if it cannot find the resources it needs. Species also might become extinct if sea level changes.

Reading Check What is the relationship between extinction and environmental change?

Extinctions and Evolution

The fossil record contains clear evidence of the extinction of species over time. But it also contains evidence of the appearance of many new species. How do new species arise?

Many early scientists thought that each species appeared on Earth independently of every other species. However, as more fossils were discovered, patterns in the fossil record began to emerge. Many fossil species in nearby rock layers had similar body plans and similar structures. It appeared as if they were related. For example, the series of horse fossils in Figure 5 suggests that the modern horse is related to other extinct species. These species changed over time in what appeared to be a sequence. Change over time is evolution. **Biological evolution** *is the change over time in populations of related organisms.* Charles Darwin developed a theory about how species evolve from other species. You will read about Darwin's theory in the next lesson.

Key Concept Check How are fossils evidence of biological evolution?

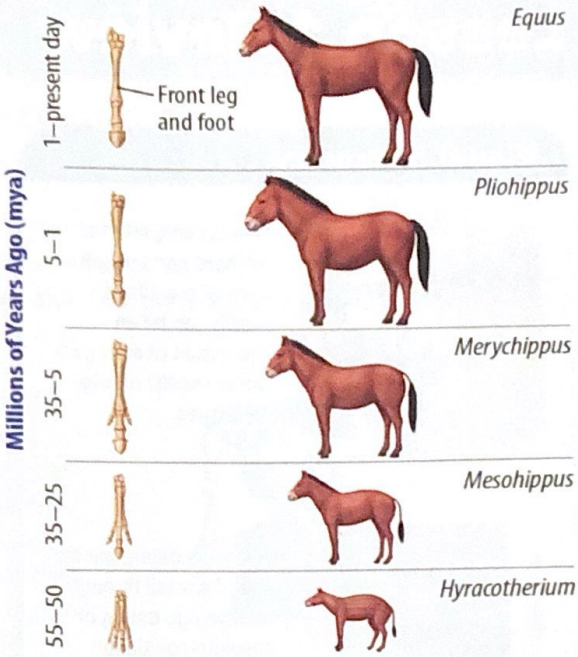


Figure 5 The fossil record is evidence that horses descended from organisms for which only fossils exist today.

MiniLab

20 minutes

How do species change over time?

Over long time periods on Earth, certain individuals within populations of organisms were able to survive better than others.

1. Choose a species from the **Species I.D. Cards.**
2. On **chart paper,** draw six squares in a row and number them 1–6, respectively. Use **colored pencils** and **markers** to make a comic strip showing the ancestral and present-day forms of your species in frames 1 and 6.
3. Use information from the I.D. Card to show what you think would be the progression of changes in the species in frames 2–5.
4. In speech bubbles, explain how each change helped the species to survive.

Analyze and Conclude

1. **Infer** why a scientist would identify a fossil from the species in the first frame of your cartoon as the ancestral form of the present-day species.
2. **Key Concept** How would the fossils of the species at each stage provide evidence of biological change over time?

Lesson 1 Review

Online Quiz
Virtual Lab

Visual Summary

Fossils can consist of the hard parts or soft parts of organisms. Fossils can be an impression of an organism or consist of original tissues.

Scientists determine the age of a fossil through relative-age dating or absolute-age dating.

Scientists use fossils as evidence that species have changed over time.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Original tissues can be preserved as fossils.
2. Organisms become extinct only in mass extinction events.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

1. All of the fossils ever found on Earth make up the _____.
2. When the last individual of a species dies, _____ occurs.
3. **Use the term** *biological evolution* in a sentence.

Understand Key Concepts

4. Which is the preserved evidence of the activity of an organism?

   A. cast **C.** fossil film
   B. mold **D.** trace fossil

5. **Explain** why the hard parts of organisms fossilize more often than soft parts.
6. **Draw and label** a diagram that shows how scientists date sedimentary rock layers.

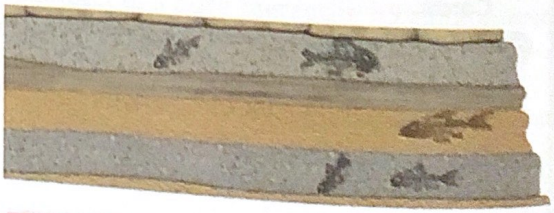
Interpret Graphics

7. **Identify** Copy and fill in the table below to provide examples of changes that might lead to an extinction event.

Sudden changes	
Gradual changes	

Critical Thinking

8. **Infer** If the rock layers shown below have not been disturbed, what type of dating method would help you determine which layer is oldest? Explain.



Math Skills

Math Practice

9. Dinosaurs disappeared from Earth about 65,000,000 years ago. Express this number in scientific notation.