LESSON 19.1

# Getting Started

## Objectives

**19.1.1 Explain** what information fossils can reveal about ancient life.

**19.1.2 Differentiate** between relative dating and radiometric dating.

**19.1.3 Identify** the divisions of the geologic time scale.

**19.1.4 Describe** how environmental processes and living things have shaped life on Earth.

## Student Resources

**Study Workbooks A and B,** 19.1 Worksheets

**Spanish Study Workbook,** 19.1 Worksheets

BIOLOGY.com Lesson Overview • Lesson Notes
- Activities: Art in Motion, Visual Analogy
- Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 450–455.

## Activate Prior Knowledge

Ask students what they already know about fossils, and write their ideas on the board. *(Sample answers: fossils are ancient; most fossil organisms are extinct; fossils show organisms' structures.)*

Then, provide three or four photos or models of fossils for students to handle and inspect. Tell students they will learn more about fossils in this lesson.

## NATIONAL SCIENCE EDUCATION STANDARDS

**UNIFYING CONCEPTS AND PROCESSES**

I, II, III, IV, V

**CONTENT**

B.1, C.3.a, C.3.c, C.3.d, D.3

**INQUIRY**

A.1.b, A.1.c, A.2.a, A.2.d

# 19.1 The Fossil Record

### Key Questions

*What do fossils reveal about ancient life?*

*How do we date events in Earth's history?*

*How was the geologic time scale established, and what are its major divisions?*

*How have our planet's environment and living things affected each other to shape the history of life on Earth?*

### Vocabulary

extinct • paleontologist • relative dating • index fossil • radiometric dating • half-life • geologic time scale • era • period • plate tectonics

### Taking Notes

**Outline** Make an outline using the green and blue headings in this lesson. Fill in details as you read to help you organize the information in the lesson.

**THINK ABOUT IT** Fossils, the preserved remains or traces of ancient life, are priceless treasures. They tell of life-and-death struggles and of mysterious worlds lost in the mists of time. Taken together, the fossils of ancient organisms make up the history of life on Earth called the fossil record. How can fossils help us understand life's history?

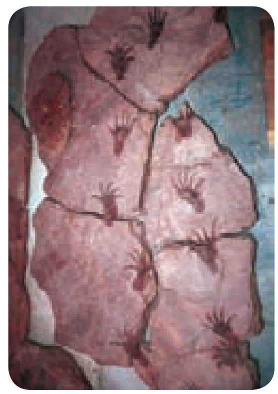
## Fossils and Ancient Life

***What do fossils reveal about ancient life?***

Fossils are the most important source of information about extinct species. An **extinct** species is one that has died out. Fossils vary enormously in size, type, and degree of preservation, and they form only under certain conditions. For every organism preserved as a fossil, many died without leaving a trace, so the fossil record is not complete.

**Types of Fossils** Fossils can be as large and perfectly preserved as an entire animal, complete with skin, hair, scales, or feathers. They can also be as tiny as bacteria, developing embryos, or pollen grains. Many fossils are just fragments of an organism—teeth, pieces of a jawbone, or bits of leaf. Sometimes an organism leaves behind trace fossils—casts of footprints, burrows, tracks, or even droppings. Although most fossils are preserved in sedimentary rocks, some are preserved in other ways, like the insect shown in **Figure 19–1.**

**FIGURE 19–1 Diversity of Fossils** There are all different types of fossils. A fossil can be a single bone, some footprints, or entire organisms.



▲ Dimetrodon footprints

▲ Insect preserved in amber



## UbD Teach for Understanding

**ENDURING UNDERSTANDING** The diversity of life is the result of ongoing evolutionary change. Species alive today have evolved from ancient common ancestors.

**GUIDING QUESTION** How do scientists use fossils to study Earth's history?

**EVIDENCE OF UNDERSTANDING** *After completing the lesson, give students the following assessment to show whether they understand one way scientists use fossils to study Earth's history.* Divide the class into small groups to design and build a model showing how index fossils in sedimentary rock layers are used to determine the relative ages of those layers and to correlate the ages of rock layers in different locations. Provide slabs of modeling clay or other materials to mimic rock layers. Also, provide leaves, bones, and small objects that students can embed in the "rock layers." Have each group explain how its model shows the use of index fossils.

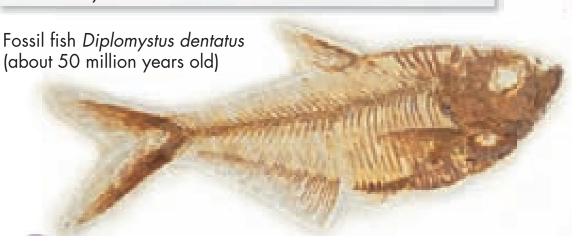
**Fossils in Sedimentary Rock** Most fossils are preserved in sedimentary rock. **Figure 19–2** shows how. ❶ Sedimentary rock usually forms when small particles of sand, silt, clay, or lime muds settle to the bottom of a river, lake, ocean, or other body of water. Sedimentary rock can also form from compacted desert sands. ❷ As sediments build up, they bury dead organisms that have sunk to the bottom. If the remains of these organisms are buried relatively quickly, they may not be scattered by scavengers. Usually, soft body structures decay quickly after death, so only wood, shells, bones, or teeth remain. These hard structures can be preserved if they are saturated or replaced with mineral compounds. Sometimes, however, organisms are buried so quickly that soft tissues are protected from aerobic decay. When this happens, fossils may preserve incredibly detailed imprints of soft-bodied animals and structures like skin or feathers.

❸ As layers of sediment continue to build up over time, the remains are buried deeper and deeper. Over many years, water pressure gradually compresses the lower layers. This pressure, along with chemical activity, can turn the sediments into rock.

**What Fossils Can Reveal** Although the fossil record is incomplete, it contains an enormous amount of information for **paleontologists** (pay lee un TAHL uh jists), researchers who study fossils to learn about ancient life. **From the fossil record, paleontologists learn about the structure of ancient organisms, their environment, and the ways in which they lived.** By comparing body structures in fossils—a backbone, for example—to body structures in living organisms, researchers can infer evolutionary relationships and form hypotheses about how body structures and species have evolved. Bone structure and footprints can indicate how animals moved. Fossilized plant leaves and pollen suggest whether an area was a swamp, a lake, a forest, or a desert. Also, when different kinds of fossils are found together, researchers can sometimes reconstruct entire ancient ecosystems.

**In Your Notebook** *Construct a flowchart to explain how the remains of a snail might become fossilized in sedimentary rock.*

Fossil fish *Diplomystus dentatus* (about 50 million years old)



**BUILD Vocabulary**

**WORD ORIGINS** The words paleontology and **paleontologist** come from the Greek word *palaios*, meaning "ancient." A paleontologist studies the remains of ancient life.

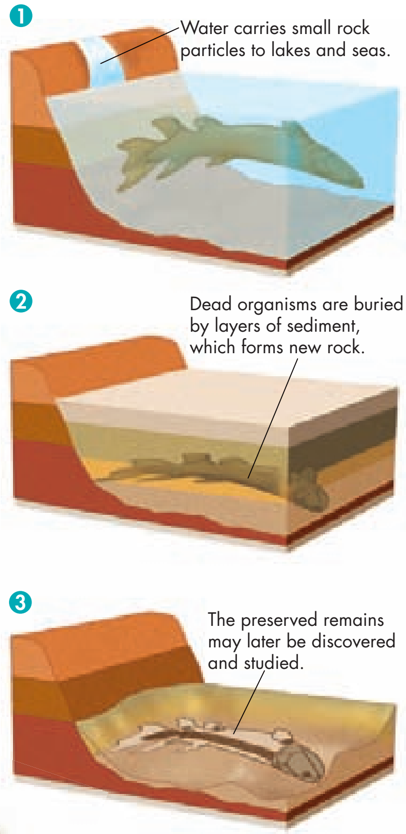



**FIGURE 19–2 Fossil Formation** Most fossils, like the fish shown here, form in sedimentary rock. **Interpret Photos** *What part of the fish has been preserved as a fossil?*

BIOLOGY.com Search Lesson 19.1 GO • Art in Motion



## How Science Works

**PLINY'S FOOTPRINTS**

The first dinosaur footprints ever discovered in the U.S. were found in 1802 by 12-year-old Pliny Moody in a field on his family's farm in western Massachusetts. While plowing, Pliny turned up a flat stone with footprints on it that resembled bird footprints. However, they were too large to have been made by any known living bird. Crowds came to see the footprints, and some people speculated that the prints had been made by giant ravens released by Noah from the ark. Prompted by Pliny's discovery, Edward Hitchcock, president of Amherst College in Massachusetts, began a 30-year search for more prints. Hitchcock was convinced that the tracks had been made by large, ostrichlike birds, and he called the prints ornithichites, which means "stony bird tracks." He called his new field of science ornithichnology, shortened to ichnology, the study of tracks and traces left by organisms.



# Teach

## Use Visuals

Have students use **Figure 19–2** to follow the process by which fossils form in sedimentary rock.

**Ask** Which body structures are most likely to become fossilized? *(hard structures such as shells, bones, or teeth)* Why? *(Hard structures are less susceptible to decay than soft tissues are.)*

**Ask** What turns layers of sediments into rock? *(Pressure and chemical activity turn sediment to rock.)*

**Ask** What can paleontologists infer from fossils? *(Sample answers: how body structures or species evolved, what an ancient ecosystem was like)*

### DIFFERENTIATED INSTRUCTION

**LPR Less Proficient Readers** Divide the class into groups, and have a member of each group read aloud the internal captions in **Figure 19–2.** Instruct each group to write three questions about the process of fossil formation. Each group should then swap questions with another group and answer the new set of questions. Then, use the groups' questions for a review of the fossilization process.

### ELL Focus on ELL: Extend Language

**BEGINNING AND INTERMEDIATE SPEAKERS** Have ELL students work in pairs or small groups to complete an **ELL Frayer Model** for five of the lesson vocabulary terms. Students should start with the term's definition, then add a drawing or visual representation, examples, and, finally, a translation of the definition into their native language. At the conclusion of the lesson, ask each pair or group to choose one completed ELL Frayer Model to share with the class.

**Study Wkbks A/B,** Appendix S26, ELL Frayer Model. **Transparencies,** ELL Frayer Model GO10.

BIOLOGY.com Students can use the **Art in Motion: Fossil Formation** animation to learn more about fossil formation.

## Answers

**FIGURE 19–2** bones

**IN YOUR NOTEBOOK** Flowcharts should be based on the steps in **Figure 19–2.** They might indicate that soft parts of the snail decayed quickly and the hard shell was replaced by minerals as it was buried.

## Teach continued

### Use Visuals

Use **Figure 19–3** to explore some strengths and weaknesses of using index fossils for relative dating.

**Ask** Which index fossil is found in all three locations? *(D)*

**Ask** At Location 2, what likely happened to the first layer seen in Location 1? *(It eroded.)*

**DIFFERENTIATED INSTRUCTION**

L1 **Struggling Students** Help students understand the concept of relative dating by using the analogy of a messy desk. Tell students that on a desk at home, there is a teacup on top of a half-written essay, which is on top of an open geology textbook, which is on top of a birthday card from a friend. Finally, at the very bottom of the pile, is a graded math test. You may wish to draw these "layers" on the board.

**Ask** Which happened first, the student drank a cup of tea or started the essay? *(The student started the essay.)* How do you know? *(because the teacup was on top of the essay)*

**Ask** What could you infer about the date of the student's birthday? *(It happened sometime after the math test, but sometime before the student read from the geology book.)*

## Dating Earth's History

***How do we date events in Earth's history?***

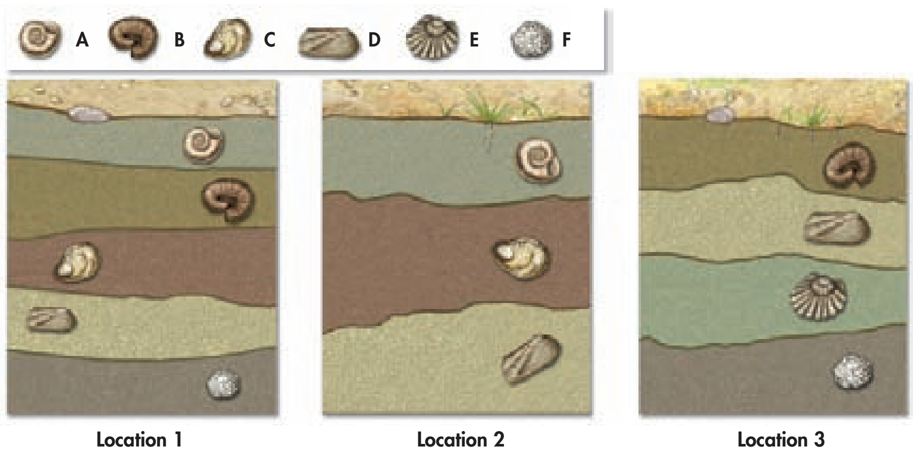
The fossil record wouldn't be as useful without a time scale to tell us what happened when. Researchers use several techniques to date rocks and fossils.

**Relative Dating** Since sedimentary rock is formed as layers of sediment are laid on top of existing sediments, lower layers of sedimentary rock, and fossils they contain, are generally older than upper layers. **Relative dating** places rock layers and their fossils in a temporal sequence, as shown in **Figure 19–3.** **Relative dating allows paleontologists to determine whether a fossil is older or younger than other fossils.**

To help establish the relative ages of rock layers and their fossils, scientists use index fossils. **Index fossils** are distinctive fossils used to establish and compare the relative ages of rock layers and the fossils they contain. A useful index fossil must be easily recognized and will occur only in a few rock layers (meaning the organism lived only for a short time), but these layers will be found in many places (meaning the organism was widely distributed). Trilobites, a large group of distinctive marine organisms, are often used as index fossils. There are more than 15,000 recognized species of trilobite. Together, they can be used to establish the relative dates of rock layers spanning nearly 300 million years.

**Radiometric Dating** Relative dating is important, but provides no information about a fossil's absolute age in years. One way to date rocks and fossils is radiometric dating. **Radiometric dating** relies on radioactive isotopes, which decay, or break down, into stable isotopes at a steady rate. A **half-life** is the time required for half of the radioactive atoms in a sample to decay. After one half-life, half of the original radioactive atoms have decayed, as shown in **Figure 19–4.**

**FIGURE 19–3 Index Fossils** Each of these fossils is an index fossil. If the same index fossil is found in two widely separated rock layers, the rock layers are probably similar in age. **Draw Conclusions** *Using the index fossils shown, determine which layers are "missing" from each location. Layers may be missing because they were never formed, or because they were eroded.*






## Check for Understanding

**FOLLOW-UP PROBES**

Check students' understanding of relative dating and radiometric dating.

**Ask** Why would a paleontologist use radiometric dating instead of relative dating? *(to determine absolute age rather than relative age)*

**ADJUST UNDERSTANDING**

If students struggle with distinguishing between relative and absolute age, give them familiar examples, such as: Sam is younger than his parents. *(relative age)* Sam is 14 years old. *(absolute age)* Then, ask students to come up with a pair of examples on their own. Read some of the best examples to the class.

### Answers

**FIGURE 19–3** In Location 1, the layer with index fossil E is missing. Location 2 is missing the layers with index fossils B, E, and F. Location 3 is missing the layers with index fossils A and C.

After another half-life, another half of the remaining radioactive atoms will have decayed. **Radiometric dating uses the proportion of radioactive to stable isotopes to calculate the age of a sample.**

Different radioactive isotopes decay at different rates, so they have different half-lives. Elements with short half-lives are used to date recent fossils. Elements with long half-lives are used for dating older fossils. To understand this, think of timing sports events. For a 50-yard dash, a coach depends on the fast-moving second hand of a stopwatch. To time a marathon, slower-moving hour and minute hands are also important.

A number of radioactive isotopes are used to determine the ages of rocks and fossils. An isotope known as carbon-14 is particularly useful for directly dating organisms that lived in the recent past. Carbon-14 is produced at a steady rate in the upper atmosphere, so air generally contains a tiny amount of it, in addition to the much more common stable, nonradioactive form, carbon-12. Plants take carbon-14 in when they absorb carbon dioxide during photosynthesis, and animals acquire it when they eat plants or other animals. Once an organism dies, it no longer takes in this isotope, so its age can be determined by the amount of carbon-14 still remaining in tissues such as bone, hair, or wood. Carbon-14 has a half-life of roughly 5730 years, so its use is limited to organisms that lived in the last 60,000 years.

Older fossils can be dated indirectly by dating the rock layers in which they are found. Isotopes with much longer half-lives are used for this purpose, including potassium-40 (half-life: 1.26 billion years, shown in **Figure 19–4**), uranium-238 (4.5 billion years), and rubidium-87 (48.8 billion years). Over many years, geologists have combined the use of these and other isotope methods to make increasingly accurate estimates of the ages of geological formations. These studies have provided direct physical evidence for the ages of the index fossils used to identify periods of Earth history.

**In Your Notebook** *Explain why carbon-14 can't be used to estimate the age of very old fossils.*

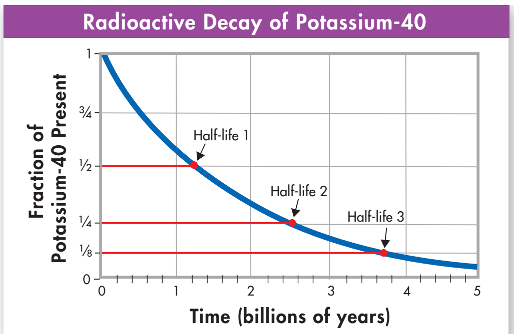



**FIGURE 19–4 Radioactive Decay** A half-life is the time it takes half the radioactive atoms in a sample to decay. The half-life of potassium-40 is 1.26 billion years.

## Quick Lab GUIDED INQUIRY

### Modeling Half-Life

1. Construct a data table or spreadsheet with two columns and five rows. Label the columns Spill Number and Number of Squares Returned. Take a sheet of paper, and cut out 100 1-cm squares. Place an *X* on each square, and put all the squares in a cup.
2. Mix the squares in the cup, and spill them out.
3. Remove all the squares that have an *X* showing. Count the squares left, record the number, and return the remaining squares to the cup.
4. Repeat steps 2 and 3 until there are five or fewer squares left. Make a graph of your results with the number of spills on the *x*-axis and the number of squares remaining after each spill on the *y*-axis.

**Analyze and Conclude**

**1. Analyze Data** How many spills did you need to remove half the squares? To remove three fourths?

**2. Calculate** If each spill represents one year, what is the half-life of the squares? MATH



## Quick Lab

**PURPOSE** Students will analyze data and calculate the half-life of a model radioactive element.

**MATERIALS** 1-cm grid paper, scissors, plastic or paper cup

**PLANNING** Explain that, on average, about half of the remaining squares will be removed each time that step 3 is repeated.

**ANALYZE AND CONCLUDE**

1. About half the squares will be removed in one spill; about three fourths of the squares will be removed in two spills.
2. one year

LESSON 19.1

## Connect to Earth Science

Many students will not understand why scientists need to use relative dating. Explain that while radiometric dating provides an absolute age, it is far more complicated than simply running a test on a fossil. Unless the fossil sample is fairly young and can be carbon-14 dated, it cannot be dated directly. Geologists must radiometricly date the rock in which the fossil sits. But that, too, is complicated because most fossils occur in sedimentary rock and dating sedimentary rock will give you the age of the rock that served as the source for the sediment—not the age of the sedimentary rock itself. The only rock that can be dated reliably is igneous rock (rock formed from lava). In most situations, geologists use a mix of absolute dating of igneous rock and relative dating of layers to estimate fossil ages.

**Ask** If a fossil sits in sedimentary rock that is directly below a layer of 15-million-year-old igneous rock, what can be inferred about the fossil's age? (*The fossil is older than 15 million years.*)

## DIFFERENTIATED INSTRUCTION

**L3 Advanced Students** Have your advanced students make a graph similar to **Figure 19–4** that shows the radioactive decay of carbon-14. The *x*-axis should be in thousands of years, with points at 5730 (half-life 1), 11,460 (half-life 2), 17,190 (half-life 3), and 22,920 (half-life 4).

**Ask** If a fossil is 20,000 years old, how much C-14 would you expect to be left in the sample? *(between 1/4 and 1/8)*

**Ask** Why would a scientist need to rely on other dating methods if a fossil is much older than 60,000 years? *(There would be no detectable amount of C-14 left in the fossil.)*

## Answers

**IN YOUR NOTEBOOK** Carbon-14 has a relatively short half-life of 5730 years. After about 60,000 years, so little carbon-14 remains in fossils that it cannot be used to accurately assess the age of the fossils.

LESSON 19.1

## Teach continued

### Use Visuals

Use **Figure 19–5** to introduce students to the geologic time scale. Check that they understand how to read the table and calculate the lengths of individual periods.

**Ask** What is the name of the oldest time interval on the scale? *(Precambrian Time)*

**Ask** What are the periods of the Paleozoic Era, from oldest to most recent? *(Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian)*

**Ask** When did the Cretaceous Period end? *(65.5 million years ago)*

#### DIFFERENTIATED INSTRUCTION

**L1 Special Needs** Some students may need help understanding that periods make up an era and eras make up an eon. Work with them to complete sentences such as: The Paleogene, Neogene, and Quaternary Periods make up the *(Cenozoic)* Era. The Mesozoic Era is made up of the *(Triassic, Jurassic, and Cretaceous)* Periods.

**LPR Less Proficient Readers** Pair less-proficient readers with students who can read proficiently. Have students in each pair work together using the **Think-Pair-Share** strategy to answer questions that require interpreting the geologic time scale.

**Ask** Calculate the length of the Cretaceous Period. *(146–65.5 = 80.5 million years)*

**Ask** When did the Paleozoic Era begin, and when did it end? *(It began 542 million years ago, and it ended 251 million years ago.)*

**Ask** In what period do we live? *(Quaternary)*

**Study Wkbks A/B,** Appendix S14, Think-Pair-Share.



## Geologic Time Scale

***How was the geologic time scale established, and what are its major divisions?***

Geologists and paleontologists have built a time line of Earth's history called the **geologic time scale.** The most recent version is shown in **Figure 19–5. The geologic time scale is based on both relative and absolute dating. The major divisions of the geologic time scale are eons, eras, and periods.**

**Establishing the Time Scale** By studying rock layers and index fossils, early paleontologists placed Earth's rocks and fossils in order according to their relative age. As they worked, they noticed major changes in the fossil record at boundaries between certain rock layers. Geologists used these boundaries to determine where one division of geologic time ended and the next began. Years later, radiometric dating techniques were used to assign specific ages to the various rock layers. This time scale is constantly being tested, verified, and adjusted.

**FIGURE 19–5 Geologic Time Scale** The basic divisions of the geologic time scale are eons, eras, and periods. Precambrian time was the name originally given to all of Earth's history before the Phanerozoic Eon. Note that the Paleogene and Neogene are sometimes called the Tertiary period. However, this term is generally considered outdated.

**Geologic Time Scale**

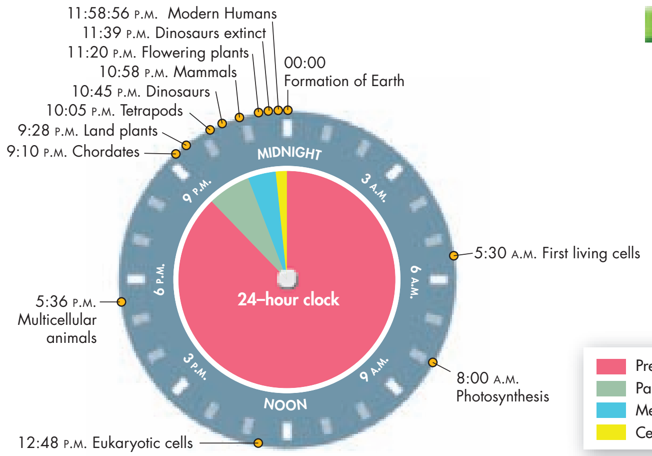
| | Eon | Era | Period | Time (millions of years ago) |
|---|---|---|---|---|
| | Phanerozoic | Cenozoic | Quaternary | 1.8–present |
| | | | Neogene | 23–1.8 |
| | | | Paleogene | 65.5–23 |
| | | Mesozoic | Cretaceous | 146–65.5 |
| | | | Jurassic | 200–146 |
| | | | Triassic | 251–200 |
| | | Paleozoic | Permian | 299–251 |
| | | | Carboniferous | 359–299 |
| | | | Devonian | 416–359 |
| | | | Silurian | 444–416 |
| | | | Ordovician | 488–444 |
| | | | Cambrian | 542–488 |
| Precambrian Time | Proterozoic | | | 2500–542 |
| | Archean | | | 4000–2500 |
| | Hadean | | | About 4600–4000 |



## How Science Works

#### WILLIAM SMITH AND RELATIVE DATING

William Smith was born in 1769 at a period of great industrial development in England. By 1793, Smith had become a surveyor and was one of many at work digging canals to transport coal throughout England to feed its industries. Smith observed many fossils during canal excavations and noticed that certain fossils were always in a particular order. In time, he made a connection between the ages of rocks and the fossils buried in them. He also determined that rocks contained fossils in a specific sequence (the principle of faunal succession). His observations were a foundation for what would eventually become the geologic time scale. Smith went on to draw and publish the first map that showed the detailed geological stratification of England.




VISUAL ANALOGY

GEOLOGIC TIME AS A CLOCK

**FIGURE 19–6** It can be hard to think in terms of billions or even millions of years. To help visualize the enormous span of time since Earth formed, look at the 24-hour clock here. It compresses the history of Earth into a 24-hour period. Notice the relative length of Precambrian Time—almost 22 hours. **Use Analogies** *Using this model, about what time did life appear? The first plants? The first humans?*

**Divisions of the Geologic Time Scale** Divisions of geologic time have different lengths. The Cambrian Period, for example, began 542 million years ago and continued until 488 million years ago, which makes it 54 million years long. The Cretaceous Period was 80 million years long.

Geologists now recognize four eons. The Hadean Eon, during which the first rocks formed, spans the time from Earth's formation to about 4 billion years ago. The Archean Eon, during which life first appeared, followed the Hadean. The Proterozoic Eon began 2.5 billion years ago and lasted until 542 million years ago. The Phanerozoic (fan ur uh ZOH ic) Eon began at the end of the Proterozoic and continues to the present.

Eons are divided into **eras.** The Phanerozoic Eon, for example, is divided into the Paleozoic, Mesozoic, and Cenozoic Eras. And eras are subdivided into **periods,** which range in length from nearly 100 million years to just under 2 million years. The Paleozoic Era, for example, is divided into six periods, including the Permian Period.

**Naming the Divisions** Divisions of the geologic time scale were named in different ways. The Cambrian Period, for example, was named after Cambria—an old name for Wales, where rocks from that time were first identified. The Carboniferous ("carbon-bearing") Period is named for large coal deposits that formed during that time.

Geologists started to name divisions of the time scale before any rocks older than the Cambrian Period had been identified. For this reason, all of geologic time before the Cambrian was simply called Precambrian Time. Precambrian Time, however, actually covers about 90 percent of Earth's history, as shown in **Figure 19–6.**

**MYSTERY CLUE**

Paleontologists discovered dramatic changes in the fossil record at the end of the Permian Period. What methods do you think they used to date that change at 251 million years ago?

BIOLOGY.com Search Lesson 19.1 GO • Visual Analogy



LESSON 19.1

## VISUAL ANALOGY

Use **Figure 19–6** to reinforce the concept of geologic time. Have students look at the parts of the clock face and the time intervals.

**Ask** How does this clock differ from most clocks in everyday use? *(A regular clock shows 12 hours; this clock shows 24 hours. Regular clocks do not include the geologic time scale.)*

**Ask** How does the clock model geologic time? *(It compares the length of geologic time to a 24-hour day.)*

Divide the class into small groups to look closely at the color key and the events of the 24-hour clock. Challenge each group to write two questions. Use the questions to start a class discussion. Have students compare the clock model to the geologic time scale shown in **Figure 19–5.**

### DIFFERENTIATED INSTRUCTION

L1 **Special Needs** Many students have difficulty with scale or magnitude, especially understanding billions and millions of years. Getting them to envision what a billion years is like can help visual learners in particular. A football field of 100 yards can be marked off by having students stand at intervals representing each division of the geologic time scale. Each yard represents approximately 46 million years.

L1 **Struggling Students** If students struggle with the 24-hour clock analogy for geologic time, have them work with a partner to make a **Timeline** with the same intervals and labels that are on the clock model. Make sure students label the left end of the timeline *Formation of Earth.* When finished, they should understand that the greater the space between markings on the timeline, the longer the time between geologic events.

**Study Wkbks A/B,** Appendix S15, Timeline.

BIOLOGY.com Have students further explore the analogy by using **Visual Analogy: Geologic Time as a Clock.**

MYSTERY CLUE Paleontologists would have used radiometric dating. If students seem uncertain about the answer, have them compare the limitations of relative dating and radiometric dating. Students can go online to **Biology.com** to gather their evidence.

## Answers

**FIGURE 19–6** life: 5:30 A.M.; first land plants: 9:28 P.M.; humans: 11:58:56 P.M.

## UbD Check for Understanding

**ORAL QUESTIONING**

Allow students to refer to **Figures 19–5** and **19–6** to answer these questions.

- Using the table model, which eon lasted from 4000 million years ago to 2500 million years ago? *(the Archean Eon )*
- Using the clock model, which event occurred more recently, sexual reproduction or the formation of oxygen from photosynthesis? *(sexual reproduction)*
- Which eon do we live in? *(the Phanerozoic Eon)*

**ADJUST INSTRUCTION**

If students have difficulty answering these questions, ask more direct questions for which they can give an answer by pointing to a location on one of the time scales.

# Teach continued

## Lead a Discussion

Read aloud the Key Question, and ask students to respond. *(Students should point out that geological forces have changed organisms' habitats throughout history, and living things themselves act on the land, water, and atmosphere of Earth.)* Write the headings *Physical Forces* and *Biological Forces* on the board, and ask students to provide examples of these forces. List their examples under the appropriate forces. Then, for each example, challenge students to infer how it affected the history of life on Earth.

### DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Some students may have difficulty understanding how organisms are affected when their environments change. Refer students to **Figure 19–7.** First, help students locate the equator and the South Pole on the first map and find what is now South America. Remind students about the climates at the equator and the South Pole. Then, have students find South America in the subsequent maps and note how that continent moved in relation to the equator and the South Pole.

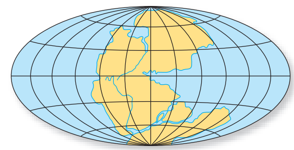
**Ask** How do you think the climate of South America changed as that continent moved? *(It became warmer.)*

**Ask** What effect do you think the climate change would have had on the plants and animals in South America over time? *(Organisms with adaptations enabling them to survive in the changed climate would have become predominant.)*

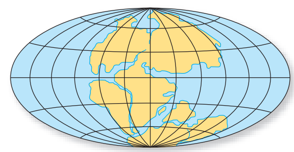
L3 **Advanced Students** Have a small group of students prepare a short "refresher course" on plate tectonics and continental drift and present it to the class. Ask the students to include visuals in their presentation.



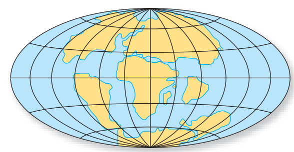
**FIGURE 19–7 The Changing Face of Earth** Over the last 225 million years, the face of the Earth has changed dramatically.



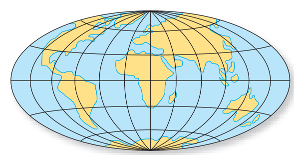
**End of Permian Period** At the end of the Permian Period, Earth's continents collided to form one giant landmass called Pangaea.



**Triassic Period** During the Triassic Period, Pangaea started to break apart and form separate land masses.



**End of Cretaceous Period** By the end of the Cretaceous Period, the continents as we know them began to drift apart.



**Present Day**

## Life on a Changing Planet

***How have our planet's environment and living things affected each other to shape the history of life on Earth?***

Today, it's easy to think of places on Earth where the environment is relatively constant from year to year. Arizona is dry, coastal Washington State is wet, Antarctica is cold, and the Sahara is hot. But this was not always the case. Earth's physical environment has undergone striking changes in its history, and many of these changes have affected life in dramatic ways.

**Physical Forces** Climate is one of the most important aspects of the physical environment, and Earth's climate has been anything but constant over the history of life. Many of these changes were triggered by fairly small shifts in global temperature. For example, during the global "heat wave" of the Mesozoic era, average global temperatures were only 6°C to 12°C higher than they were in the twentieth century. During the great ice ages, which swept across the globe as recently as 10,000 years ago, temperatures were only about 5°C cooler than they are now. Yet, these temperature shifts had far-reaching effects on living things.

Geological forces have also transformed life on Earth, building mountains and even moving whole continents. Remember that local climates are influenced by the interactions of wind and ocean currents with geological features like mountains and plains. Volcanic forces have altered landscapes over much of Earth, even producing entire islands that provide new habitats. The Hawaiian Islands, home to scores of unique plant and animal species, are a perfect example of how volcanic islands can alter the course of evolution. **Building mountains, opening coastlines, changing climates, and geological forces have altered habitats of living organisms repeatedly throughout Earth history.**

Over the long term, the process of continental drift has produced even more dramatic changes in Earth's biological landscape. As shown in **Figure 19–7,** continents have collided to form "super continents," and then drifted apart again, profoundly changing the flow of ocean currents. Continental drift has also affected the distribution of fossils and living organisms worldwide. For example, the continents of Africa and South America are now separated by the Atlantic Ocean. But fossils of *Mesosaurus*, an aquatic reptile, have been found in Africa and South America. The presence of these fossils on both continents reflects the fact that both were joined at one time. The theory of **plate tectonics** explains these movements as the result of solid "plates" moving slowly, as little as 3 cm a year, over Earth's mantle.

544 Chapter 19 • Lesson 1

## How Science Works

### ALFRED WEGENER AND CONTINENTAL DRIFT

Not every new observation in science gains acceptance overnight. Alfred Wegener was greeted with some hostility in 1912 when he presented his hypothesis of continental displacement, or drift, before the Geological Association in Frankfurt, Germany. Wegener was trained as a meteorologist, but his curiosity opened him to a multidisciplinary interest in Earth as a whole. He observed that the shapes of continents look like pieces of a puzzle that might have fit together at one time. The presence of similar fossils on widely separated continents had also been observed. He hypothesized that Earth's landmasses had been connected and then separated, in a process called continental drift. At the time, however, he could not explain how these changes had occurred. Wegener died in 1930. It wasn't until the 1960s that the theory of plate tectonics proposed how continental drift could take place.

Forces from space have even altered Earth's physical environment. There is strong evidence that comets and large meteors have crashed into Earth many times in the past. Some of these impacts may have been so violent that they kicked enough dust and debris in the atmosphere to cause, or contribute to, worldwide extinctions of organisms on land and in the water.

**Biological Forces** Although we think of life as reacting to Earth's physical environment, in many cases life actually plays a major role in shaping that environment. Iron deposits in ancient sedimentary rock indicate that Earth's early oceans contained large amounts of soluble iron and little oxygen. The first photosynthetic organisms began absorbing carbon dioxide and releasing large amounts of oxygen. Our planet has never been the same since then. Earth cooled as carbon dioxide levels dropped. The iron content of the oceans fell, as iron ions reacted with oxygen to form insoluble compounds that settled to the ocean floor. These changes affected climate and ocean chemistry in many ways. **The actions of living organisms over time have changed conditions in the land, water, and atmosphere of planet Earth.**

Even today, organisms shape the landscape as they build soil from rock and sand. Plants, animals, and microorganisms are active players in global cycles of key elements, including carbon, nitrogen, and oxygen. Earth is a living planet, and its physical environment reflects that fact.

## 19.1 Assessment

### Review Key Concepts

1. a. **Explain** What can a paleontologist learn from fossils?
   b. **Relate Cause and Effect** Why have so few organisms become fossilized?
2. a. **Review** What are the two ways in which geologists determine the age of fossils?
   b. **Draw Conclusions** Many more fossils have been found since Darwin's day, giving us a more complete record of life's history. How would this information make relative dating more accurate?
3. a. **Explain** How are eras and periods related?
   b. **Interpret Visuals** Use **Figure 19–5** to determine when the Silurian Period began and how long it lasted.
4. a. **Review** Describe three processes that have affected the history of life on Earth.
   b. **Relate Cause and Effect** Describe two ways in which continental drift has affected organisms.

### VISUAL THINKING

5. Look at the fossil bat in the photograph below. Describe the fossil. What can you infer about how the organism moved? Explain your answer.

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## Assess and Remediate

**EVALUATE UNDERSTANDING**

Call on students to define vocabulary terms used in this lesson. After each term has been defined, call on another student to explain how it is related to fossils or the fossil record. Then, have students complete the 19.1 Assessment.

**REMEDIATION SUGGESTION**

**L1 Struggling Students** If students have trouble answering **Question 2b,** restate the question as, How would finding more fossils in rock layers make relative dating more accurate?

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

## Assessment Answers

**1a.** A paleontologist can learn about the structure of ancient organisms, their environment, and the way they lived.

**1b.** Fossils form only under highly specific and relatively rare conditions, such as the rapid burial of organisms in sediments. Further, organisms with hard parts fossilize far more often than organisms without.

**2a.** relative dating, based on the placement of fossils in rock layers; and radiometric dating using radioactive elements

**2b.** Sample answer: More fossils would make relative dating more accurate, because a greater number and variety of fossils could be compared to index fossils.

**3a.** Eras are divided into periods.

**3b.** It began 444 million years ago and lasted about 28 million years.

**4a.** Earth's plates have moved and carried organisms with them; collisions with giant asteroids tossed up dust and blocked the sun's energy; production of oxygen by photosynthetic bacteria and removal of carbon dioxide changed the atmosphere.

**4b.** When landmasses collide and mountain ranges rise, new climates and niches are created and species are redistributed.

**VISUAL THINKING**

**5.** Sample answer: The fossil appears to be a vertebrate, has a tail, and has forelimbs longer and sturdier than its hind limbs. It probably depended on its forelimbs to move about, possibly by flying.