In this unit, students will study the concepts and principles of evolution and classification. Chapter 14 deals with the history of life on Earth, and some hypotheses about how life began. Chapter 15 discusses Darwin’s theory of evolution by natural selection. The role of natural selection in the evolution of new species is presented. Chapter 16 explores evidence of the ancestry of humans. Chapter 17 introduces taxonomy and the diversity of organisms.

Introducing the Unit
Have students look at the elephants in the photo and describe their successful adaptations. Tell students that they also will learn in this unit why the ancestors of birds may be extinct dinosaurs. Explain to students that as the environment changes, populations may adapt, migrate, or become extinct.

A WebQuest is an inquiry-based online project in which all information used by students is obtained from the Web. Students evaluate the information to complete the activity. Access the Unit 5 WebQuest at ca.bdel.glencoe.com/webquest

Discussion As students read the chapters in Unit 5, have them refer to the time line shown above. Ask students to consider how each new hominid fossil discovery advances our knowledge of human history and human ancestry. Have students research one of the latest hominid fossils or other fossil groups, such as early bird or dinosaur discoveries, and present their findings to the class.
### Advance Materials Planning

The following materials may need to be ordered a few weeks in advance of the planned activity.

**Chapter 14**
- **MiniLab 14.1** (p. 371) diatomaceous earth
- **Quick Demo** (p. 377) prepared slide of *Oscillatoria*
- **Additional Lab** (p. 382) 1% gelatin solution, 1% gum arabic solution, hydrochloric acid

**Chapter 15**
- **Additional Lab** (p. 408) culture of *Bacillus subtilis*, 3 tubes of nutrient agar, tube of streptomycin agar

**Chapter 16**
- **BioLab** (p. 436) casts of various hominid and age skulls

**Chapter 17**
- **MiniLab 17.1** (p. 446) dichotomous keys for local trees and shrubs
- **BioLab** (p. 460) identification guide for insects and other organisms

### Unit Projects

**Display**
*Visual-Spatial* Students can use photographs or illustrations from magazines and science journals to make a collage showing different living things. [L1 ELL]

**Interview**
*Linguistic* Students can interview nature professionals to find out how they care for the diverse life forms under their protection. Have students prepare their interview questions in advance. [L1]

**Using the Library**
*Intrapersonal* Students can read Chapter 17, which is “Galápagos Archipelago,” of *Voyage of the Beagle* by Charles Darwin to find out about the diversity of birds and reptiles in the Galápagos. [L3]
### Section Objectives

**Section 14.1** 2 sessions, 1 block

1. **Identify** the different types of fossils and how they are formed.
2. **Summarize** the major events of the geologic time scale.

**Section 14.2** 2 sessions, 1 block

3. **Analyze** early experiments that support the concept of biogenesis.
5. **Relate** hypotheses about the origin of cells to the environmental conditions of early Earth.

### National Science Standards

| UCP.1-4 | A.1, A.2; C.1, C.6 | B.2, B.3; C.1, C.3 | C.6; D.2; E.1; F.3, F.4; G.1-3 |

### State/Local Standards

| Biology/Life Sciences 8e, 8g | Investigation & Experimentation 1a, 1d, 1h, 1i |

### Advanced Lab and Demo Planning

**Student Labs:**

- **MiniLab 14.1,** p. 371: microscope slide, water, diatomaceous earth, microscope
- **Problem-Solving Lab 14.1,** p. 372
- **MiniLab 14.2,** p. 376: meterstick, 5-m strip of adding machine tape

**Teacher Demonstration:**

- **Quick Demo,** p. 377: microscope, living culture or prepared slide of *Oscillatoria*

**Student Labs:**

- **Problem-Solving Lab 14.2,** p. 384
- **Additional Lab,** p. 382: 1% gelatin solution, 3 droppers, 1% gum arabic solution, pH papers, microscopes, microscope slides, coverslips, 0.1M hydrochloric acid, test tubes, stirring rods
- **Investigate BioLab,** p. 386: See materials below.

**Teacher Demonstration:**

- **Quick Demo,** p. 381: 2 bouillon cubes, 2 flasks, water, rubber stopper

**Student Lab:**

- **Investigate BioLab,** p. 386: shoe box with lid, 100 pennies, graph paper

### Key to Teaching Strategies

**L1** Level 1 activities should be appropriate for students with learning difficulties.

**L2** Level 2 activities should be within the ability range of all students.

**L3** Level 3 activities are designed for above-average students.

**ELL** ELL activities should be within the ability range of English Language Learners.

**COOP LEARN** Cooperative Learning activities are designed for small group work.
### Reproducible Masters and Transparencies

<table>
<thead>
<tr>
<th>Unit 5 <strong>FAST FILE Resources</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproducible Masters Technology and Transparencies</td>
</tr>
<tr>
<td>Unit 5 <strong>FAST FILE Resources</strong></td>
</tr>
<tr>
<td>MiniLab Worksheet, pp. 3, 4</td>
</tr>
<tr>
<td>BioLab Worksheet, pp. 5–6</td>
</tr>
<tr>
<td>Reinforcement and Study Guide in English, pp. 7–8</td>
</tr>
<tr>
<td>Reinforcement and Study Guide in Spanish, pp. 11–12</td>
</tr>
<tr>
<td>Concept Mapping, p. 15</td>
</tr>
<tr>
<td>Critical Thinking/Problem Solving, p. 16</td>
</tr>
<tr>
<td>Transparency Worksheets, pp. 17, 21–22</td>
</tr>
<tr>
<td><strong>Reading Essentials for Biology, Section 14.1</strong></td>
</tr>
<tr>
<td>Laboratory Manual, pp. 83–84, 85–86</td>
</tr>
<tr>
<td><strong>Section Focus Transparency 35</strong></td>
</tr>
<tr>
<td><strong>Reteaching Skills Transparency 23</strong></td>
</tr>
</tbody>
</table>

### Technology

| **Interactive Chalkboard CD-ROM: Section 14.1 Presentation** |
| **TeacherWorks™ CD-ROM** |
| **Guided Reading Audio Summaries MP3** |

| **Interactive Chalkboard CD-ROM: Section 14.2 Presentation** |
| **TeacherWorks™ CD-ROM** |
| **Guided Reading Audio Summaries MP3** |

| **Interactive Chalkboard: Chapter 14 Assessment** |
| **MindJogger Videoquizzes DVD/VHS** |
| **ExamView® Pro Test Bank CD-ROM** |
| **TeacherWorks™ CD-ROM** |
| **Succeeding on National Standards CD-ROM** |

---

**Legend:**
- Transparency
- CD-ROM
- MP3
- Videocassette
- DVD

**Indicates materials created specifically for California.**
The History of Life

What You’ll Learn
- You will examine how rocks and fossils provide evidence of changes in Earth’s organisms.
- You will correlate the geologic time scale with biological events.
- You will sequence the steps by which small molecules may have produced living cells.

Why It’s Important
Knowing the geological history of Earth and understanding ideas about how life began provide background for an understanding of the theory of evolution.

Understanding the Photo
Erupting volcanoes and lava flows, such as this one in Hawaii, may provide a model for conditions on early Earth.

Demo
To elicit students’ preconceptions about lava, allow them to handle samples of aa and pahoehoe lava, pumice, and obsidian. Ask students why these igneous rocks are so different. The cooling rates are different for these four, due to differences in temperature and dissolved gas content. Pahoehoe flows are smooth and ropey, while aa flows are blocky and rough. Obsidian is formed when lava cools extremely quickly into a glass. Pumice forms when the lava contains a lot of dissolved gases.
The Record of Life

Early History of Earth

What was early Earth like? Some scientists suggest that it was probably very hot. The energy from colliding meteorites could have heated its surface, while both the compression of minerals and the decay of radioactive materials heated its interior. Volcanoes might have frequently spewed lava and gases, relieving some of the pressure in Earth's hot interior. These gases helped form Earth's early atmosphere. Although it probably contained no free oxygen, water vapor and other gases, such as carbon dioxide and nitrogen, most likely were present. If ancient Earth's atmosphere was like this, you would not have survived in it.

About 4.4 billion years ago, Earth might have cooled enough for the water in its atmosphere to condense. This might have led to millions of years of rainstorms with lightning—enough rain to fill depressions that became Earth's oceans. Some scientists propose that life originated in Earth's oceans between 3.9 and 3.4 billion years ago.
Can scientists be sure that Earth formed in this way? No, they cannot. There is no direct evidence of the earliest years of Earth's history. The physical processes of Earth constantly destroy and form rocks. The oldest rocks that have been found on Earth formed about 3.9 billion years ago. Although rocks cannot provide information about Earth's infancy, they are an important source of information about the diversity of life that has existed on the planet.

Fossils—Clues to the past

If you've ever visited a zoo or toured a botanical garden, you've seen evidence of the diversity of life. But the millions of species living today are probably only a small fraction of all the species that ever existed. About 95 percent of the species that have existed are extinct—they no longer live on Earth. Among other techniques, scientists study fossils to learn about ancient species. A fossil is evidence of an organism that lived long ago.

Because fossils can form in many different ways, there are many types of fossils, as you can see in Table 14.1. Use the MiniLab on the next page to observe some marine fossils under your microscope.

Paleontologists—Detectives to the past

The study of fossils is a lot like solving a mystery. Paleontologists (pay lee AHN TAHY uh jists), scientists who study ancient life, are like detectives who use fossils to understand events that happened long ago. They use fossils to determine the kinds of organisms that lived during the past and sometimes to learn about their behavior. For example, fossil bones and

<table>
<thead>
<tr>
<th>Table 14.1 Some Types of Fossils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossils Types</strong></td>
</tr>
<tr>
<td>Trace fossils</td>
</tr>
<tr>
<td>Casts</td>
</tr>
<tr>
<td>Molds</td>
</tr>
<tr>
<td>Petrified/Permineralized fossils</td>
</tr>
<tr>
<td>Amber-preserved or frozen fossils</td>
</tr>
</tbody>
</table>

Motonori Matuyama (1884–1958) first discovered these reversals. Because these polarity changes have been dated in volcanic rocks, the magnetic polarity of some sedimentary successions can be used to estimate the ages of the rock layers.
teeth can indicate the size of animals, how they moved, and what they ate.

Paleontologists also study fossils to gain knowledge about ancient climate and geography. For example, when scientists find a fossil like the one in Figure 14.1, which resembles a present-day plant that lives in a mild climate, they may reason that the ancient environment was also mild.

By studying the condition, position, and location of rocks and fossils, geologists and paleontologists can make deductions about the geography of past environments. You can use the Problem-Solving Lab on the next page to try to solve a fossil mystery.

**Reading Check** Infer how fossil teeth could be used to determine an animal's diet.

### Fossil formation

For fossils to form, organisms usually have to be buried in mud, sand, or clay soon after they die. These particles are compressed over time and harden into a type of rock called sedimentary rock. Today, fossils still form at the bottoms of lakes, streams, and oceans.

Most fossils are found in sedimentary rocks. These rocks form at relatively low temperatures and pressures that may prevent damage to the organism. How do these fossils become visible millions of years later?

### MiniLab 14.1

**Observe and Infer**

**Marine Fossils** Certain sedimentary rocks are formed almost totally from the fossils of once-living marine or ocean organisms called diatoms. These sedimentary rocks usually form in oceans, but can be lifted above sea level during periods of geological change.

**Procedure**

1. Prepare a wet mount of a small amount of diatomaceous earth. **CAUTION:** Use care in handling microscope slides and coverslips. Do not breathe in dry diatomaceous earth.
2. Examine the material under low-power magnification.
3. Draw several of the different shapes you see.
4. Compare the shapes of the fossils you observe to present-day diatoms shown in the photograph. Remember, however, that the fossils you observe are probably only pieces of the whole organism.

**Analysis**

1. **Describe** Describe the appearance of fossil diatoms.
2. **Compare and Contrast** How are fossil diatoms similar to and different from the diatoms in the photo? Can you use these similarities and differences to predict how diatoms have changed over time? Explain your answer.
3. **Infer** What part of the original diatom did you observe under the microscope? How did this part survive millions of years? Why were the fossils you observed broken?

### Figure 14.1

This fossil leaf is from rocks about 200 million years old (A). They are remarkably similar to the leaves of *Ginkgo biloba* (B), trees that are planted as ornamentals throughout the United States.

**MiniLab 14.1**

The type of fossil teeth can show whether an animal was an herbivore, carnivore, or omnivore.

**Purpose**

Students will observe fossil diatoms and compare them with modern species of diatoms.

**Process Skills**

Observe and infer, compare and contrast, apply concepts

**Safety Precautions**

Do not breathe in dry diatomaceous earth. Do not rub eyes during activity. Wash hands thoroughly when finished with activity.

**Teaching Strategies**

- Remind students to handle glass microscope slides carefully and place broken slides in the container for broken glass.
- Remind students that they are looking at fragments of the silica-containing cell walls of diatoms.
- Have students use a very small amount of the diatomaceous earth for better viewing.

**Expected Results**

Students should see broken cell walls of many different shapes.

**Analysis**

1. *answers will vary—rod-shaped, glasslike, circular, boatlike, needle-shaped, ridged or scored surface*
2. Although broken, the fossil diatoms look similar and therefore diatoms have probably changed little over time.
3. The cell walls were visible because they did not decompose. The weight of water and sediments crushed them.

**Modified Assessment**

**Performance** Have students determine shapes and sizes of diatoms in their sample. Use the Performance Task Assessment List for Making Observations and Inferences in PASC, p. 89. **ELL**
Purpose
Students will analyze a situation and evaluate its explanations.

Background
It is assumed that the fossil ferns grew in similar temperate climates as the modern fern species.

Process Skills
analyze information, draw a conclusion, judge, think critically

Teaching Strategies
Review the appearance of Gondwanaland.

Thinking Critically
1. It’s unlikely that ferns could grow in Antarctica’s current cold temperatures. The presence of these fern fossils must mean that Antarctica was much warmer at one time.
2. not reasonable; It is unlikely that mutations could result in ferns adapted to extreme cold.
3. reasonable; Antarctica may have been closer to the equator and thus, its climate would have been warmer.

Modified Assessment
Skill Ask students to suggest other reasons why fern fossils are in Antarctica. Use the Performance Task Assessment List for Designing an Experiment in PASC, p. 95.

Caption Question Answer
Figure 14.2 There could have been faulting or folding to overturn the sequence.

To answer the question, look at Figure 14.3. Fossils are not usually found in other types of rock because of the ways those rocks form. For example, metamorphic rocks form when heat, pressure, and chemical reactions change other rocks. The conditions under which metamorphic rocks form often destroy any fossils that were in the original sedimentary rock.

Radiometric dating
Scientists use a variety of methods to determine the age of fossils. One method is a technique called relative dating. To understand relative dating, imagine yourself stacking newspapers at home. As each day’s newspaper is added to the stack, the stack becomes taller. If the stack is left undisturbed, the newspapers at the bottom are older than ones at the top.

The relative dating of rock layers uses the same principle. In Figure 14.2, you see fossils in different layers of rock. If the rock layers have not been disturbed, the layers at the surface must be younger than the deeper layers. The fossils in the top layer must also be younger than those in deeper layers. Using this principle, scientists can determine relative age and the order of appearance of the species that are preserved as fossils in the layers.

INCLUSION STRATEGIES
Learning Disabled Have students obtain a small leaf and a dead insect. Place each into its own small plastic container that is half-filled with water. Place the containers in a freezer. After 24 hours, remove them. Describe how the leaf and the insect look. Compare frozen fossils to molds or casts.

ELL
The Fossilization Process

Few organisms become fossilized because, without burial, bacteria and fungi immediately decompose their dead bodies. Occasionally, however, organisms do become fossils in a process that usually takes many years. Most fossils are found in sedimentary rocks.

Critical Thinking
Describe how the movements of Earth might expose a fossil.

A Protoceratops* drinking at a river falls into the water and drowns. *An adult Protoceratops was about 2.4 meters long (8 feet).

B Sediments from upstream rapidly cover the body, slowing its decomposition. Minerals from the sediments seep into the body.

C Over time, additional layers of sediment compress the sediments around the body, forming rock. Minerals eventually replace all the body’s bone material.

D Earth movements or erosion may expose the fossil millions of years after it formed.

E After discovery, scientists carefully extract the fossil from the surrounding rock.

Fossil Preservation: Kinesthetic

1. Place fresh fruit, such as strawberries or orange slices, in an open plastic container. Cover the fruit with water and place the container in a freezer.

2. Put the same amount and types of fruit in a similar container. Leave the container undisturbed at room temperature.

3. After three days, observe all the fruit. Summarize your observations and draw a conclusion about any differences you observe between the containers.

Purpose

Students will study some of the geological and biological processes involved in fossil formation.

Teaching Strategies

- Point out that an organism’s remains are subjected to destructive environmental factors, such as bacterial decay, heat, cold, and pressure. Therefore, the number and quality of fossils is limited.
- Have students make a flowchart of the events that lead to the formation of fossils.

Visual Learning

Visual-Spatial: Sedimentation allows fossils to form. Model the process using objects and sediments of various sizes and weights placed in a 2-L plastic container three-quarters full of water. Shake the container. Have students observe what occurs. Explain that over time, pressure and other physical and chemical changes can result in the formation of fossils.

Critical Thinking

Earth’s surface can rupture during earthquakes and some rock layers can fold over others. Uplift by faulting or folding may expose layers containing fossils to erosion. The slow erosion of rock may uncover fossils.
Recall that radioactive isotopes are atoms with unstable nuclei that break down, or decay, over time, giving off radiation. A radioactive isotope forms a new isotope after it decays. The rate at which a radioactive isotope decays is related to the half-life of the isotope. The half-life is the length of time needed for half of the atoms of the isotope to decay.

Scientists try to determine the approximate ages of rocks by comparing the amount of a radioactive isotope and the new isotope into which it decays. For example, suppose that when a rock forms it contains a radioactive isotope that decays to half its original amount in one million years. Today, if the rock contains equal amounts of the original radioactive isotope and the new isotope into which it decays, then the rock must be about 1 million years old.

Scientists use potassium-40, a radioactive isotope that decays to argon-40, to date rocks containing potassium-bearing minerals. Based on chemical analysis, chemists have determined that potassium-40 decays to half its original amount in 1.3 billion years.

Scientists use carbon-14 to date fossils.
less than 50,000 years old. Again, based on chemical analysis, they know that carbon-14 decays to half its original amount in 5730 years.

Use the BioLab at the end of this chapter to simulate this dating technique. Scientists always analyze many samples of a rock using as many methods as possible to obtain consistent values for the rock's age. Errors can occur if the rock has been heated, causing some of the radioactive isotopes to be lost or gained. If this occurs, the age obtained will be inaccurate.

A Trip Through Geologic Time

By examining sequences containing sedimentary rock and fossils and dating some of the igneous or metamorphic rocks that are found in the sequences, scientists have put together a chronology, or calendar, of Earth's history. This chronology, called the geologic time scale, is based on evidence from Earth's rocks and fossils.

The geologic time scale

Rather than being based on months or even years, the geologic time scale is divided into four large sections that you see in Figure 14.4—the Precambrian (pree KAM bree un), the Paleozoic (pahl uh ZOH ihk) Era, the Mesozoic (me zuh ZOH ihk) Era, and the Cenozoic (se nuh ZOH ihk) Era. An era is a large division in the scale and represents a very long period of time. Each era is subdivided into periods.

The divisions in the geologic time scale are distinguished by the organisms that lived during that time interval. The fossil record indicates that there were several episodes of mass extinction that fall between time divisions. A mass extinction is an event that occurs when many organisms disappear from the fossil record almost at once.

The geologic time scale begins with the formation of Earth about 4.6 billion years ago. To understand the large size of this number, try the MiniLab on the next page, and also try scaling down

<table>
<thead>
<tr>
<th>Triassic</th>
<th>Jurassic</th>
<th>Cretaceous</th>
<th>Tertiary</th>
<th>Quaternary</th>
</tr>
</thead>
<tbody>
<tr>
<td>248</td>
<td>206</td>
<td>144</td>
<td>65</td>
<td>1.8</td>
</tr>
</tbody>
</table>

1.8

The BioLab at the end of the chapter can be used at this point in the lesson.

Resources

For additional high interest activities, see the Forensics and Biotechnology Lab Manual.

Chalkboard Example

To illustrate the concept of geological time, reproduce on the chalkboard or an overhead transparency a page from a monthly calendar. Remind students that the total area of the page represents a unit of time equal to one month. Divide the calendar into four (or five) horizontal strips. Ask students what amount of time each strip represents. one week Cut one of the strips into seven pieces and ask students what each square represents. one day Then, ask students how minutes and seconds could be shown. Elicit from students how geologic time, like calendars, is also divided into units.

California Content Standards

Pages 374–375: Biology/Life Sciences 8e, 8g*
Inv. & Exp. 1i

PTELL
**MiniLab 14.2**

**Purpose**
Students will model the geologic time scale.

**Process Skills**
Use a table, sequence, measure in SI units.

**Teaching Strategies**
- Review how to make a scale model.
- Review the geologic time scale’s major divisions.

**Expected Results**
Students perform the calculations that establish their scales. They plot major events on the scale.

**Analysis**
1. The longest era—Paleozoic; the shortest era—Cenozoic
2. Mesozoic Era
3. Primates

**Modified Assessment**
Performance: Have student groups collect pictures of 15–20 organisms. Ask them to illustrate the geologic time scale on poster board, and glue each picture where the organism first appeared in the fossil record. Use the Performance Task Assessment List for Poster in PASC, p. 145.

**California Content Standards**
Pages 376–377: Biology/Life Sciences 8e
Inv. & Exp. 1i

---

---

**Extinct Animals** Ask students to research an extinct animal, such as a woolly mammoth, brachiosaur, pterodactyl, or saber-toothed cat. Have them describe in their journals what foods, environments, enclosures, or other factors might be required to keep the animal alive in a zoo.

**Life during the Precambrian**

In your hypothetical calendar year, the first day of January becomes the date on which Earth formed. The oldest fossils are found in Precambrian rocks that are about 3.4 billion years old—near the end of March on the hypothetical calendar. Scientists found these fossils, which are shown in Figure 14.5, in rocks found in the deserts of western Australia. They have found more examples of similar types of fossils on other continents. The fossils resemble the forms of modern species of photosynthetic cyanobacteria (sia noh bak THIR ee uh). You will read more about cyanobacteria in a later chapter.

Scientists have also found dome-shaped structures called stromatolites (stroh MAT ul ites) in Australia and on other continents. Stromatolites still form today in Australia from mats of cyanobacteria, Figure 14.6. Thus, the stromatolites are evidence of the existence of photosynthetic organisms on Earth during the Precambrian.

The Precambrian accounts for about 87 percent of Earth’s history—until about the middle of October in the hypothetical calendar year. Near the beginning of the Precambrian, unicellular prokaryotes—cells that do not have a membrane-bound nucleus—appear to have been the only life forms on Earth. About 2.1 billion years ago, the fossil record shows that more complex eukaryotic organisms, living things with membrane-bound nuclei in their cells, appeared. By the end of the Precambrian, about
543 million years ago, multicellular eukaryotes, such as sponges and jellyfishes, diversified and filled the oceans.

**Diversity during the Paleozoic**

In the Paleozoic Era, which lasted until 248 million years ago, many more types of animals and plants were present on Earth, and some were preserved in the fossil record. The earliest part of the Paleozoic Era is called the Cambrian Period. Paleontologists often refer to a “Cambrian explosion” of life because the fossil record shows an enormous increase in the diversity of life forms during this time. During the Cambrian Period, the oceans teemed with many types of animals, including worms, sea stars, and unusual arthropods, similar to the one shown in Figure 14.7.

During the first half of the Paleozoic, fishes, the oldest animals with backbones, appeared in Earth’s waters. There is also fossil evidence of ferns and early seed plants existing on land about 400 million years ago. Around the middle of the Paleozoic, four-legged animals such as amphibians appeared on Earth. During the last half of the era, the fossil record shows that reptiles appeared and began to flourish on land.

The largest mass extinction recorded in the fossil record marked the end of the Paleozoic. About 90 percent of Earth’s marine species and 70 percent of the land species disappeared at this time.

**Life in the Mesozoic**

The Mesozoic Era began about 248 million years ago, which would be about December 10 on the hypothetical one-year calendar. Many changes, in both Earth’s organisms and its geology, occurred over the span of this era.

The Mesozoic Era is divided into three periods. Fossils from the Triassic Period, the oldest period, show that mammals appeared on Earth at this time. These fossils of mammals indicate that early mammals were small and mouselike. They probably scurried around in the shadows of huge fern forests, trying to avoid dinosaurs, reptiles that also appeared during this time.

The middle of the Mesozoic, called the Jurassic Period, began about 206 million years ago, or mid-December on the hypothetical calendar.

Recent fossil discoveries support the idea that modern birds evolved from one of the groups of dinosaurs toward the end of this period.

**Evidence** Students can research local geological history to determine what organisms previously might have lived in their area. Have students provide evidence, such as the type of climate or the type of food source, for the answers.

**Quick Demo**

**Microscopic Life** Set up a microscope with a living culture or prepared slide of *Oscillatoria*. Point out that early cyanobacteria are hypothesized to have produced much of the oxygen that changed the initial composition of Earth’s atmosphere.

**Enrichment**

Some students may comment on the smooth, gliding movement of *Oscillatoria*. Explain that these organisms expel jets of slime through holes in their cell walls. This pushes the organism through their environment.

**Visual Learning**

Ask students what living group of animals most resembles the trilobite in Figure 14.7. **arthropods or insects**

**Inquiry**

**Discussion** Lead students in a discussion about the Cambrian Explosion. Make certain that they understand the significance of this event in geologic history. Although shelly fauna existed in the late Precambrian, they became abundant after the Cambrian Explosion. Many of the major groups of marine invertebrates appeared at about this time.
Visual Learning

Figure 14.8 Have students compare the *Archaeopteryx* and hoatzin. Discuss the characteristics that the animals share and do not share. Both have scaled legs, claws on wings, and feathers. The hoatzin loses the claws on its wings a few days or weeks after hatching, and is a better flyer.  

Reinforcement

Assess the students’ understanding of geologic time by having them sequence some of the major events of the geologic time scale with the era in which they occurred.

Inquiry

Activity Have students do research to find out the significance of fern spikes in the geologic record. Fern spikes refer to layers in sediment that contain abundant fern spores. Ferns are one of the first plant types to recover after a catastrophic occurrence. Sediment layers that contain mostly fern spores as microfossils suggest that vegetation was destroyed and then began to recover after such a catastrophe, such as a meteorite impact.

For example, in Figure 14.8A, you see the fossil of *Archaeopteryx*, a small bird discovered in Germany. The fossil reveals that *Archaeopteryx* had feathers, a birdlike feature. You also see a present-day bird, the hoatzin, in Figure 14.8B. This bird has a reptilian feature, claws on its wings, for its first few weeks of life. It also flies poorly, as the earliest birds probably did. Scientists suggest that such evidence supports the idea that modern birds evolved from dinosaurs.

A mass extinction

The last period in the Mesozoic, the Cretaceous, began about 144 million years ago. During this period, many new types of mammals appeared and flowering plants flourished on Earth. The mass extinction of the dinosaurs marked the end of the Cretaceous Period about 65 million years ago. Scientists estimate that not only dinosaurs, but more than two-thirds of all living species at the time became extinct. Some scientists propose that a large meteorite collision caused this mass extinction. Such a collision could have filled the atmosphere with thick, possibly toxic dust that, in turn, changed the climate to one in which many species could no longer survive. Based on geological evidence of a large crater of Cretaceous age in the waters off eastern Mexico, scientists theorize that this was the impact site.

Changes during the Mesozoic

Geological events during the Mesozoic changed the places in which species lived and affected their distribution on Earth. The theory of continental drift, which is illustrated in Figure 14.9, suggests that Earth's continents have moved during Earth's history and are still moving today at a rate of about six centimeters per year. This is about the same rate at which your hair grows. Early in the Mesozoic, the continents were merged into one large landmass. During the era, this supercontinent broke up and the pieces drifted apart.

**Word Origin**

**tectonics** from the Greek word tecton, meaning “builder”; Plate tectonics is a theory that explains mountain building.

**Evidence of Pangaea** Have student groups report about a type of fossil animal that has modern descendants distributed in a way that supports the existence of Pangaea. Ask students to use maps and drawings to show how plate tectonics affected the animal.
The theory that explains how the continents move is called **plate tectonics** (tek TNuh nikz). According to this idea, Earth's surface consists of several rigid plates that drift on top of a plastic (capable of flow), partially molten layer of rock. These plates are continually moving—spreading apart, sliding by, or pushing against each other. The movements affect organisms. For example, after a long time, the descendants of organisms living on plates that are moving apart may be living in areas with very different climates.

**The Cenozoic Era**

The Cenozoic began about 65 million years ago—around December 26 on the hypothetical calendar of Earth's history. It is the era in which you now live. Mammals began to flourish during the early part of this era. Among the mammals that appeared was a group of animals to which you belong, the primates. Primates first appeared approximately more than 65 million years ago and have diversified greatly. The modern human species appeared perhaps as recently as 200,000 years ago. On the hypothetical calendar of Earth's history, 200,000 years ago is late in the evening of December 31.

---

**Understanding Main Ideas**

1. Describe what some scientists propose Earth was like before life arose.
2. Why are most fossils found in sedimentary rocks?
3. Using fossils, identify evidence showing that species have changed over geologic time.
4. Explain the difference between relative dating and radiometric dating.

**Thinking Critically**

5. Suppose you are examining layers of sedimentary rock. In one layer, you discover the remains of an extinct relative of the polar bear. In a deeper layer, you discover the fossil of an extinct alligator. What can you hypothesize about changes over time in this area's environment?

**Skill Review**

6. Make and Use Tables Make a table listing the four major divisions of the geologic time scale, their time spans, and the major life forms that appeared during each interval. Use the information to construct a time line based on a clock face. For more help, refer to Make and Use Tables in the Skill Handbook.

---

The climate of the region may have changed from a warmer one to a colder one.

5. The climate of the region may have changed from a warmer one to a colder one.

6. Tables should be constructed from the information in Figure 14.4 and under the heading "A Trip Through Geologic Time" in the text. Check tables and time lines for accuracy.

---

**Figure 14.9** The theory of continental drift describes the movement of the landmasses over geological time. Describe How has Africa moved over time?
Using Prior Knowledge

**Experiment** The cooked hot dog should change more slowly than the uncooked hot dog. The reason is that more bacteria were present in the uncooked meat and began to decompose the hot dog faster.

**Figure 14.10** Francesco Redi's controlled experiment tested the spontaneous generation of maggots from decaying meat.

**A** Redi placed decaying meat in several uncovered control jars and in covered experimental jars. The covers prevented flies from landing on the meat.

**B** In time, maggots and flies filled the open jars, but not the covered jars, showing that only flies produce flies.

**The Origin of Life**

**Mold and Mudskippers**

**Using Prior Knowledge** You've probably opened your refrigerator and found some leftovers with an unpleasant surprise—mold. Where did the mold come from? Was it in the air or in the food originally? Did these mudskippers come from the mud or from the air?

**Experiment** Cut a hot dog in half. Cook one half and place it in an airtight, sealable plastic bag. Place the uncooked half in another airtight, sealable plastic bag. Leave both bags out at room temperature until a change is observed. How did each hot dog sample change? Which sample changed faster? Hypothesize why the changes you observed occurred.

**Origins: The Early Ideas**

In the past, the ideas that decaying meat produced maggots, mud produced fishes, and grain produced mice were reasonable explanations for what people observed occurring in their environment. After all, they saw maggots appear on meat and young mice appear in sacks of grain. Such observations led people to believe in **spontaneous generation**—the idea that nonliving material can produce life.
Spontaneous generation is disproved

In 1668, an Italian physician, Francesco Redi, disproved a commonly held belief at the time—the idea that decaying meat produced maggots, which are immature flies. You can follow the steps of Redi’s experiment in Figure 14.10. Redi’s well-designed, controlled experiment successfully convinced many scientists that maggots, and probably most large organisms, did not arise by spontaneous generation.

However, during Redi’s time, scientists began to use the latest tool in biology—the microscope. With the microscope, they saw that microorganisms live everywhere. Although Redi had disproved the spontaneous generation of large organisms, many scientists thought that microorganisms were so numerous and widespread that they must arise spontaneously—probably from a vital force in the air.

Pasteur’s experiments

Disproving the existence of a vital force in air proved difficult. Finally, in the mid-1800s, Louis Pasteur designed an experiment that disproved the spontaneous generation of microorganisms. Pasteur set up an experiment in which air, but no microorganisms, was allowed to contact a broth that contained nutrients. You can see how Pasteur carried out his experiment in Figure 14.11.

Pasteur’s experiment showed that microorganisms do not simply arise in broth, even in the presence of air. From that time on, biogenesis (bi oh JEN uh sus), the idea that living organisms come only from other living organisms, became a cornerstone of biology.

Origins: The Modern Ideas

Biologists have accepted the concept of biogenesis for more than 100 years. However, biogenesis does not answer the question: How did life begin on Earth? No one has yet proven scientifically how life on Earth began. However, scientists have developed theories about the origin of life

---

**Learning Disabled** Have students use block diagrams on paper to model how the experiments of Redi or Pasteur demonstrate scientific methods. Have students record their procedures and observations. **ELL**

**Using Models** Disproving Spontaneous Generation Make a model of Redi’s controlled experiment shown in Figure 14.10 using a *Drosophila* culture medium. Use this model to explain the idea of spontaneous generation and how Pasteur disproved the idea. **L2**
**Tying to Prior Knowledge**

Review the chemistry concepts that students studied previously, particularly the role of carbon in organic molecules. Review the general structure of proteins and nucleic acids. Relate this information to the hypotheses about the origin of life.

**Word Origin**

Have the students research to find other words using “primo” as part of the root, such as _primogenitor_ and _primordial meristem_.

**Tying to Prior Knowledge**

Review the basic structure and function of cells. Emphasize the substances cells need to live and the different ways cells release energy. Relate this information to the evolution of cells.

---

### California Content Standards

Pages 382–383: 
Inv. & Exp. 1k

---

### Additional Lab

**Making Coacervates**

**Purpose**

Students will investigate the conditions under which the first cells may have evolved.

**Materials**

- 1% gelatin solution, droppers (3)
- 1% gum arabic solution
- pH papers, microscopes, microscope slides, coverslips
- 0.1M hydrochloric acid (HCl), test tubes, stirring rods
- For preparation instructions, see page 17T of the Teacher Guide.

**Safety Precautions**

Remind students to wear safety goggles, a lab apron, and disposable gloves. Remind them to use care when working with a microscope and glass slides, and to wash hands thoroughly when finished.

**Procedure**

Give the following directions.

1. Measure 5 mL of 1% gelatin solution. Pour it into the test tube. Add 3 mL of 1% gum arabic solution. Mix gently.
2. Record the pH of the mixture.
3. Make a wet mount of the mixture. Observe under high power, and record

---

**Figure 14.12**

Miller and Urey’s experiments showed that under the proposed conditions on early Earth, small organic molecules, such as amino acids, could form.

**Word Origin**

*primordial* from the Latin word _primum_, meaning “origin”; The origin of life may have been in the primordial soup.

---

**Simple organic molecules formed**

Scientists hypothesize that two developments must have preceded the appearance of life on Earth. First, simple organic molecules, or molecules that contain carbon, must have formed. Then these molecules must have become organized into complex organic molecules such as proteins, carbohydrates, and nucleic acids that are essential to life.

Remember that Earth’s early atmosphere probably contained no free oxygen. Instead, the atmosphere was probably composed of water vapor, carbon dioxide, nitrogen, and perhaps methane and ammonia. Many scientists have tried to explain how these substances could have joined together and formed the simple organic molecules that are found in all organisms today.

In the 1930s, a Russian scientist, Alexander Oparin, hypothesized that life began in the oceans that formed on early Earth. He suggested that energy from the sun, lightning, and Earth’s heat triggered chemical reactions to produce small organic molecules from the substances present in the atmosphere. Then, rain probably washed the molecules into the oceans to form what is often called a primordial soup.

In 1953, two American scientists, Stanley Miller and Harold Urey, tested Oparin’s hypothesis by simulating the conditions of early Earth in the laboratory. In an experiment similar to the one shown in _Figure 14.12_, Miller and Urey mixed water vapor (steam) with ammonia, methane, and hydrogen gases. They then sent an electric current that simulated lightning through the mixture. Then, they cooled the mixture of gases, produced a liquid that simulated rain, and collected the liquid in a flask. After a week, they analyzed the chemicals in the flask and found several kinds of amino acids, sugars, and other small organic molecules, providing evidence that supported Oparin’s hypothesis.
The formation of protocells

The next step in the origin of life, as proposed by some scientists, was the formation of complex organic compounds. In the 1950s, various experiments were performed and showed that if the amino acids are heated without oxygen, they link and form complex molecules called proteins. A similar process produces ATP and nucleic acids from small molecules. These experiments convinced many scientists that complex organic molecules might have originated in pools of water where small molecules had concentrated and been warmed.

How did these complex chemicals combine to form the first cells? The work of American biochemist Sidney Fox in 1992 showed how the first cells may have occurred. As you can see in Figure 14.13, Fox produced protocells by heating solutions of amino acids. A protocell is a large, ordered structure, enclosed by a membrane, that carries out some life activities, such as growth and division.

**Reading Check** Summarize the theories for how organic molecules were first formed on Earth.

**Figure 14.13** Sidney Fox showed how short chains of amino acids could cluster to form protocells.

---

The Evolution of Cells

Fossils indicate that by about 3.4 billion years ago, photosynthetic prokaryotic cells existed on Earth. But these were probably not the earliest cells. What were the earliest cells like, and how did they evolve?

The first true cells

The first forms of life may have been prokaryotic forms that evolved from a protocell. Because Earth's atmosphere lacked oxygen, scientists have proposed that these organisms were most likely anaerobic. For food, the first prokaryotes probably used some of the organic molecules that were abundant in Earth's early oceans. Because they obtained food rather than making it themselves, they would have been heterotrophs.

Over time, these heterotrophs would have used up the food supply. However, organisms that could make food had probably evolved by the time the food was gone. These first autotrophs were probably similar to present-day archaebacteria.

**Analysis**

1. What living things do coacervates resemble? cells
2. Around what pH did you observe coacervates? pH 5
3. What conditions of early Earth does the mixture of gelatin (a protein) and gum arabic (a carbohydrate) simulate? the amino acids and simple sugars in the "primordial soup"

---

Assessment

**Knowledge** Have students present an oral report of the investigation. Ask: “What was the role of hydrochloric acid? How does this investigation relate to hypotheses about the origin of life?” Use the Performance Task Assessment List for Oral Presentation in PASC, p. 143.

---

Visual Learning

**Figure 14.13** Have students study the illustration of Fox's experiment. Discuss how Fox's experiment relates to Oparin's hypothesis and the Miller-Urey experiment.

**Discussion**

Ask students why studying modern archaeabacteria and cyanobacteria is important for determining the origin of life. Such bacteria resemble the earliest known living things and indicate the conditions required to support life then.

**Reading Check** The first organic molecules were formed when energy from the sun or lightning combined with a mixture of water vapor, ammonia, methane, and hydrogen gas. Miller and Urey lent support to Oparin by showing that simple molecules could form complex organic compounds in a watery environment. Sidney Fox’s experiments produced ordered structures called protocells from amino acids.
Purpose
Students will use a model to show events on the geologic time scale.

Process Skills
observe and infer, sequence, use an illustration

Teaching Strategies
- Question students about the history of life to assess their knowledge before they start.
- Students could also model the geologic time scale using a 24-hour clock.

Thinking Critically
Prokaryotes appeared around 4:00 to 4:30 A.M. and eukaryotes around 10:00 A.M.

Assessment
Knowledge Have students approximate the time of evolution of three other groups of organisms by finding out when they appear in the fossil record. L2

Caption Question Answer
Figure 14.14 In this environment, an organism would need to be able to survive high temperatures, possibly acidic conditions, and the presence of minerals, such as sulfur.

Inquiry
Discussion Ask students to evaluate the strengths and weaknesses of the endosymbiont theory. Be sure that students understand that Margulis’s theory does not suggest how the original cells evolved. L2

Archaebacteria (ar kee bac TEER ee uh) are prokaryotic and live in harsh environments, such as deep-sea vents and hot springs like the one shown in Figure 14.14. Some early autotrophs may have made glucose by chemosynthesis rather than by photosynthesis, which requires light-trapping pigments. These autotrophs released the energy of inorganic compounds, such as sulfur compounds, in their environment to make their food.

Photosynthesizing prokaryotes
Eventually, photosynthesizing prokaryotes capable of releasing oxygen from water evolve. Recall that the process of photosynthesis produces oxygen. As the first photosynthetic organisms increased in number, the concentration of oxygen in Earth’s atmosphere began to increase. Organisms that could respire aerobically would have evolved and thrived. In fact, the fossil record indicates that there was a large increase in the diversity of prokaryotic life about 2.8 billion years ago.

The presence of oxygen in Earth’s atmosphere probably affected life on Earth in another important way. The sun’s rays would have converted much of the oxygen into ozone molecules that would then have formed a layer that contained more ozone than the rest of the atmosphere. The ozone layer, that now exists 10 to 15 miles (16–24 km) above Earth’s surface, probably shielded organisms from the harmful effects of ultraviolet radiation and enabled the evolution of more complex organisms, the eukaryotes.

The endosymbiont theory
Complex eukaryotic cells probably evolved from prokaryotic cells. Use the Problem-Solving Lab on this page to determine how long the event might have taken. The endosymbiont theory,
1. Life did not appear in sterile broth. Life did appear in broth where there were previously existing organisms. Miller and Urey tested the hypothesis.

2. Life began in Earth’s oceans after organic molecules formed from ocean substances. Protocells evolved into anaerobic prokaryotes, which eventually became oxygen-rich atmospheres. Organisms evolved that could use the oxygen.

3. There was no oxygen in the atmosphere, and there were food molecules in the “organic soup” of the ocean. They eventually created an oxygen-rich atmosphere. Organisms evolved that could use the oxygen.

4. Possible answers include sunlight, radioactivity, or heat from volcanoes. Protocells ⇒ anaerobic prokaryotes ⇒ photosynthetic prokaryotes ⇒ eukaryotes

5. The cyanobacteria became chloroplasts, no longer able to live on their own.

6. The eukaryotic cells of plants and animals probably evolved by endosymbiosis.

A prokaryote ingested some aerobic bacteria. The aerobes were protected and produced energy for the prokaryote.

Over a long time, the aerobes become mitochondria, no longer able to live on their own.

Some primitive prokaryotes also ingested cyanobacteria, which contain photosynthetic pigments.

The cyanobacteria became chloroplasts, no longer able to live on their own.

Figure 14.15
The eukaryotic cells of plants and animals probably evolved by endosymbiosis.

Understanding Main Ideas
1. How did Pasteur’s experiment finally disprove spontaneous generation?
2. Review Oparin’s hypothesis and explain how it was tested experimentally.
3. Why do scientists think the first living cells to appear on Earth were probably anaerobic heterotrophs?
4. How would the increasing number of photosynthesizing organisms on Earth have affected both Earth and its other organisms?

Thinking Critically
5. Some scientists speculate that lightning was not present on early Earth. How could you modify the Miller-Urey experiment to reflect this new idea? What energy source would you use to replace lightning?

Sequence
Make a flowchart sequencing the evolution of life from protocells to eukaryotes. For more help, refer to Sequence in the Skill Handbook.

Extension
Intrapersonal Ask students who have mastered this section to find out how scientists think that nucleic acids may have developed from elements already present on Earth.

Resources
For more practice, use Reading Essentials for Biology, Section 14.2.
Make sure students wash their hands thoroughly after handling the coins.

Encourage students to make wise choices concerning disposal and recycling of lab materials.
**Data Table**

<table>
<thead>
<tr>
<th>Number of Shakes (half-lives)</th>
<th>Number of Heads (K-40 atoms left)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

9. Draw a full-page graph. Plot your average values on the graph. Plot the number of half-lives for K-40 on the x axis and the number of “heads” on the y axis. Connect the points with a line. Remember, each half-life mark on the graph axis for K-40 represents 1.3 billion years.

10. **Cleanup and Disposal** Return everything to its proper place for reuse. Wash hands thoroughly.

---

**Apply Your Skill**

Suppose you had calculated the same data for an element with a half-life of 5000 years rather than 1.3 billion years. Plot a graph for the hypothetical isotope. How do the graphs compare?

Web Links To find out more about radioactive dating, visit [ca.bdel.glencoe.com/radioactive_dating](http://ca.bdel.glencoe.com/radioactive_dating)

---

**Data and Observations**

<table>
<thead>
<tr>
<th>Half-life</th>
<th>Average number of K40</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

---

**Analyze and Conclude**

1. **Apply Concepts** What symbol represented an atom of K-40 in this experiment? What symbol represented an atom of Ar-40?

2. **Think Critically** Compare the numbers of protons and neutrons of K-40 and Ar-40. (Consult the Periodic Table on page 1112 for help.) Can Ar-40 change back to K-40? Explain your answer, pointing out what procedural part of the experiment supports your answer.

3. **Define Operationally** Define the term half-life. What procedural part of the simulation represented a half-life period of time in the experiment?

4. **Communicate** Explain how scientists use radioactive dating to approximate a rock’s age.

5. **Make and Use Graphs** You are attempting to determine the age of a rock sample. Use your graph to read the rock’s age if it has:
   a. 70% of its original K-40 amount.
   b. 35% of its original K-40 amount.
   c. 10% of its original K-40 amount.

6. **Error Analysis** Could the size of the box and how vigorously the box was shaken introduce errors into the data? Explain.

---

**ERROR ANALYSIS**

Suppose you had calculated the same data for an element with a half-life of 5000 years rather than 1.3 billion years. Plot a graph for the hypothetical isotope. How do the graphs compare?

---

**Graph**

The graphs will appear the same. Ask students to research how a radioactive element decays to form a different element.

**Assessment**

**Portfolio** Have students write a summary of this experiment in their portfolios that emphasizes the value of using the simulation to illustrate the concept of radioactive decay. Use the Performance Task Assessment List for Lab Report in PASC, p. 119.
Purpose
Students will explore a variety of ideas about the origin of life.

Teaching Strategies
- Organize students into teams for a debate on the origins of life. Have each team defend one point of view. Ask students to research the strengths of their viewpoint and the weaknesses of the opposing viewpoints. **COOP LEARN**
- Review the chemical composition of nucleic acids, amino acids, lipids, carbohydrates, and other organic molecules in cells.

**Forming Your Opinion**
Student reviews should compare and contrast the different viewpoints based on scientific evidence and information. Critiques should be presented in a constructive way.

**Linguistic** Have students research and report to the class about organic molecules on planets, meteors, and comets. Students may also research current technology in SETI (search for extraterrestrial intelligence) projects. Have students prepare models, videos, or posters for a class presentation. **ELL**

How life originated on Earth is a fascinating and challenging question. Many have proposed answers, but the mystery remains unsolved. Because it is impossible to travel in time, the question of how life originated on Earth might never be answered. However, a number of beliefs and hypotheses exist. Some of these are described below.

**Divine origins** Common to human cultures throughout history is the belief that life on Earth did not arise spontaneously. Many of the world’s major religions teach that life was created on Earth by a supreme being. The followers of these religions believe that life could only have arisen through the direct action of a divine force.

A variation of this belief is that organisms are too complex to have developed only by evolution. Instead, some people believe that the complex structures and processes of life could not have formed without some guiding intelligence.

**Meteorites** One scientific hypothesis about the origin of life on Earth is that the molecules necessary for life arrived here on meteorites, rocks from space that collide with Earth’s surface. Many meteorites contain some organic matter. These organic molecules, which are necessary for the formation of cells, might have arrived on Earth and entered its oceans.

**Primordial soup** Another hypothesis was proposed by A. I. Oparin. It states that Earth’s ancient atmosphere contained the gases nitrogen, methane, and ammonia, but no free oxygen. Energy from the sun, volcanoes, and lightning caused chemical reactions among these gases, which eventually combined into small organic molecules such as amino acids. Rain trapped and then carried these molecules into the oceans, making a primordial soup of organic molecules. In this soup, proteins, lipids, and the other complex organic molecules found in present-day cells formed. Harold Urey and Stanley Miller provided the first experimental evidence to support this idea. They produced organic molecules in the laboratory by creating a spark in a gas mixture similar to Earth’s early atmosphere.

**An RNA world** Some scientists hypothesize that the formation of self-replicating molecules preceded the formation of cells. Today’s self-replicating molecules, DNA and RNA, provide clues about the earliest self-replicating molecules. Scientists hypothesize that RNA, which is central to the functioning of a cell, probably predated DNA on Earth. However, because RNA is a more complex molecule than protein, it is not easy to obtain data that supports the idea that RNA was formed on early Earth.

**Research** Students who need an additional challenge can research the proposal made by Louis Lerman, and write a paper that compares Lerman’s proposal to that made by Oparin and supported by Miller and Urey. Advanced students could extend those ideas to the formation of protocells and the endosymbiont theory. **ELL**
**Key Concepts**

- Fossils provide a record of life on Earth. Fossils come in many forms, such as a leaf imprint, a worm burrow, or a bone.
- By studying fossils, scientists learn about the diversity of life and about the behavior of ancient organisms.
- Fossils can provide information on ancient environments. For example, fossils can help to predict whether an area had been a river environment, terrestrial environment, or a marine environment. In addition, fossils may provide information on ancient climates.
- Earth’s history is divided into the geologic time scale, based on evidence in rocks and fossils.
- The four major divisions in the geologic time scale are the Precambrian, Paleozoic Era, Mesozoic Era, and Cenozoic Era. The eras are further divided into periods.

**Vocabulary**

fossil (p. 370)
plate tectonics (p. 379)

---

**Section 14.2**

**The Origin of Life**

- Francesco Redi and Louis Pasteur designed controlled experiments to disprove spontaneous generation. Their experiments and others like them convinced scientists to accept biogenesis.
- Small organic molecules might have formed from substances present in Earth’s early atmosphere and oceans. Small organic molecules can form complex organic molecules.
- The earliest organisms were probably anaerobic, heterotrophic prokaryotes. Over time, chemosynthetic prokaryotes evolved and then photosynthetic prokaryotes that produced oxygen evolved, changing the atmosphere and triggering the evolution of aerobic cells and eukaryotes.

**Foldables™**

Have students use their Foldables to review the content of Section 14.1. On the back of the paper, write a paragraph to describe the major event that ended each era.

---

**Use the ExamView®Pro Test Bank CD-ROM to:**

- Create multiple versions of tests
- Create modified tests with one mouse click for inclusion students
- Edit existing questions and add your own questions
- Build tests aligned with state standards using built-in State Curriculum Tags
- Change English tests to Spanish with one mouse click and vice versa
11. Open Ended Why do scientists propose that the 3.4 billion-year-old fossils of cyanobacteria-like prokaryotic cells found in Australia were not the first species to have evolved on Earth?

12. Open Ended Explain how fossils might help paleontologists to learn about the important behaviors of different types of animals. Which social behaviors might they provide information about?

13. Interpret Scientific Illustrations Use the illustration above to explain the endosymbiont hypothesis.

14. REAL WORLD BIOCHALLENGE Recent scientific evidence from fossils indicates that feathered dinosaurs may have been a direct ancestor of birds. Visit ca.bdol.glencoe.com to investigate these finds. How do such finds impact our understanding of evolution?

15. Infer Why might the way organisms obtain energy have evolved over time?

16. Writing About Biology Why is knowledge of geology important to paleontologists?

17. Writing About Biology Explain why Francesco Redi’s experiment with flies did not completely disprove spontaneous generation.

14. Constructed Response Why are fossils important to geologists and paleontologists? What can fossils tell scientists about the past?

15. Constructed Response Explain how fossils might help paleontologists to learn about the important behaviors of different types of animals. Which social behaviors might they provide information about?

16. Infer Why might the way organisms obtain energy have evolved over time?

17. Writing About Biology Why is knowledge of geology important to paleontologists?

18. Writing About Biology Explain why Francesco Redi’s experiment with flies did not completely disprove spontaneous generation.
20. Which of the following rock types would most likely contain fossils?
A. sedimentary rock composed of limestone
B. igneous rock ejected from a volcano
C. metamorphic rock
D. hardened lava

21. How long does it take for half of the element to decay?
A. 1 billion years
B. 2 billion years
C. 3 billion years
D. 4 billion years

22. How much of the original material is left after 4 billion years?
A. 50%
B. 25%
C. 12.5%
D. less than 10%

23. This element would best be used to date fossils that are ________ years old.
A. a few thousand
B. less than a million
C. a few million
D. a billion

24. Open Ended The element in the graph above would best be used to date rocks from what era? Explain why.

25. Open Ended What kinds of clues can fossils provide about the past, including climate, what organisms ate, and the environment in which they lived?