UNIT 5 Evolution

Kingfisher male with courtship gift

Insect of the newly named order Mantophasmatodea

Poison dart frogs

DISCOVERIES IN SCIENCE

Evolution and Life on Earth

1753

Carolus Linnaeus publishes the first of two volumes containing the classification of all known species. In doing so, Linnaeus establishes a consistent system for naming and classifying species. The system is widely used thereafter.

1859

Charles Darwin suggests that natural selection is the mechanism of evolution. Within months, public debates regarding the truth and significance of his theory ensue.

Galápagos tortoises

1907

In his book, *Plant Breeding,* Hugo de Vries, Dutch botanist, joins Mendel's laws of heredity with the newer theory of mutation. De Vries asserts that inheritable mutations are the mechanism by which species change and new species form.

1960

Mary and Jonathan Leakey discover fossil bones of a human ancestor, *Homo habilis,* in Olduvai Gorge, Tanzania.

Mary Leakey, paleoanthropologist

1974

Donald Johansen discovers a fossilized skeleton of one of the first hominids, *Australopithecus afarensis*. This specimen was nicknamed "Lucy."

Skull of *A. afarensis*

1980

Walter and Luis Alvarez, Frank Asaro, and Helen Michel publish a paper providing evidence that 65 million years ago, an asteroid collided with Earth and caused severe environmental changes. The changes may have led to the extinction of the majority of species that lived during that time.

1994

Reinhardt Kristensen and Peter Funch discover a tiny animal living on the lips of lobsters. They name the new species *Symbion pandora*. This species is so different from other animals that scientists classify it within a new phylum, Cycliophora, within kingdom Animalia.

2006

A team of biologists announces a study of Camiguin Island, the smallest island of the Philippines. They find 54 species of birds and 24 of species of mammals.

As-yet-unnamed parrot species

Beetles—one of the most diverse groups of animals on Earth

BIOLOGY CAREER

Museum Curator

Rob DeSalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. He is an adjunct professor at Columbia University and City University of New York and is a Distinguished Research Professor at New York University. His current research focuses on molecular evolution in various organisms, including pathogenic bacteria and insects.

DeSalle enjoys being a scientist because he can investigate the diversity of life every day. He also enjoys the opportunity to serve as a mentor to students. Most of all, he enjoys the thrill of discovering something that no one else on the planet has found.

He considers his most significant accomplishment in science to be his work communicating scientific ideas through his writing and museum exhibitions.

Besides his work, DeSalle loves baseball and is a passionate fan of the Chicago Cubs.

Fossil and eggs of dinosaur called *oviraptor*

Chapter Planner 19

History of Life on Earth

		Standards	Teach Key Ideas
CHAPTER OPENER, pp. 444–445	15 min.	*National Science Education Standards*	
SECTION 1 How Did Life Begin?, pp. 447–449 › The Basic Chemicals of Life › Where Did Life Begin? › The First Cells	45 min.	LSCell 3, LSCell 6, LSMat 6, UCP3, UCP4, ESS3	**Bellinger Transparency** **Transparencies** D5 Miller-Urey Experiment **Visual Concepts** Spontaneous Origin
SECTION 2 The Age of Earth, pp. 450–453 › The Fossil Record › Analyzing Fossil Evidence › Describing Geological Time	90 min.	LSEvol 1, LSEvol 2, LSEvol 3, ESS3, HNS2	**Bellinger Transparency** **Transparencies** D4 Radioactive Decay **Visual Concepts** Radiometric Dating • Half-Life • Mass Extinction
SECTION 3 Evolution of Life, pp. 454–460 › Precambrian Time › Paleozoic Era › Mesozoic and Cenozoic Eras	45 min.	LSCell 5, LSCell 6, LSEvol 2, LSEvol 4, ESS3, SPSP3, SPSP5	**Bellinger Transparency** **Transparencies** D7 Ozone Shields the Earth • D8 Evolution of Eukaryotes **Visual Concepts** Comparing Prokaryotes and Eukaryotes • Origin of Eukaryotic Cells • Endosymbiosis • Comparing Organisms that Are Unicellular and Multicellular • Ozone and Ecosystems • Characteristics of Arthropods • Vertebrates • Characteristics of Fish
			See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 462
- SE Chapter Review, p. 463
- SE Standardized Test Prep, p. 465
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER FastTrack

To shorten instruction due to time limitations, eliminate the Skills Practice Lab.

Basic Learners

- TE First Cells, p. 448
- TE Rate of Decay, p. 452
- TE Evolution of Vertebrates, p. 458
- TE Pattern Puzzles, p. 458
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Burgess Shale, p. 451
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key

SE Student Edition
TE Teacher's Edition

Chapter Resource File
Workbook
Transparency

CD or CD-ROM
* Datasheet or blackline master available

■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Logical Order, p. 445*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 444 SE **Reading Toolbox,** p. 446	
TE **Demonstration** First Billion Years, p. 447 TE **Space Science,** p. 448		SE **Reading Toolbox** Process Chart, p. 449 TE **Reading Toolbox** Process Chart, p. 449	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
TE **Demonstration** Fossils, p. 450	SE **Quick Lab** Radioactive Decay, p. 452*■ SE **Skills Practice Lab** Model of Rock Strata, p. 461*■ **Skills Practice Lab** Determining the Age of Artifacts Using C-14*	SE **Reading Toolbox** Word Parts, p. 451 TE **Reading Toolbox** Word Parts, p. 451	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
TE **Demonstration** Earth's Timeline, p. 454 TE **Effects of UV Radiation,** p. 455 SE **Nearing the End,** p. 460	SE **Quick Lab** Timeline of Earth, p. 457*■ **Quick Lab** Analyzing Adaptations: Living on Land*	SE **Reading Toolbox** Describing Time, p. 455 TE **Reading Toolbox** Describing Time, p. 455 TE **Reading Toolbox** Visual Literacy, p. 460	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

TE Cellular Specialization, p. 457
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Multilingual Glossary

Struggling Readers

TE Key-Term Fold, p. 450
TE Endosymbiosis and Bacteria, p. 456
TE Pattern Puzzles, p. 458
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Special Education Students

Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Alternative Assessment

TE Timeline Interpretation, p. 452
Science Skills Worksheets*
Section Quizzes*■
Chapter Tests A, B, and C*■

Chapter 19

Overview

The purpose of this chapter is to explore how life may have begun and how scientists estimate the age of Earth. The chapter also discusses how life increased in complexity from its first forms on Earth.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:

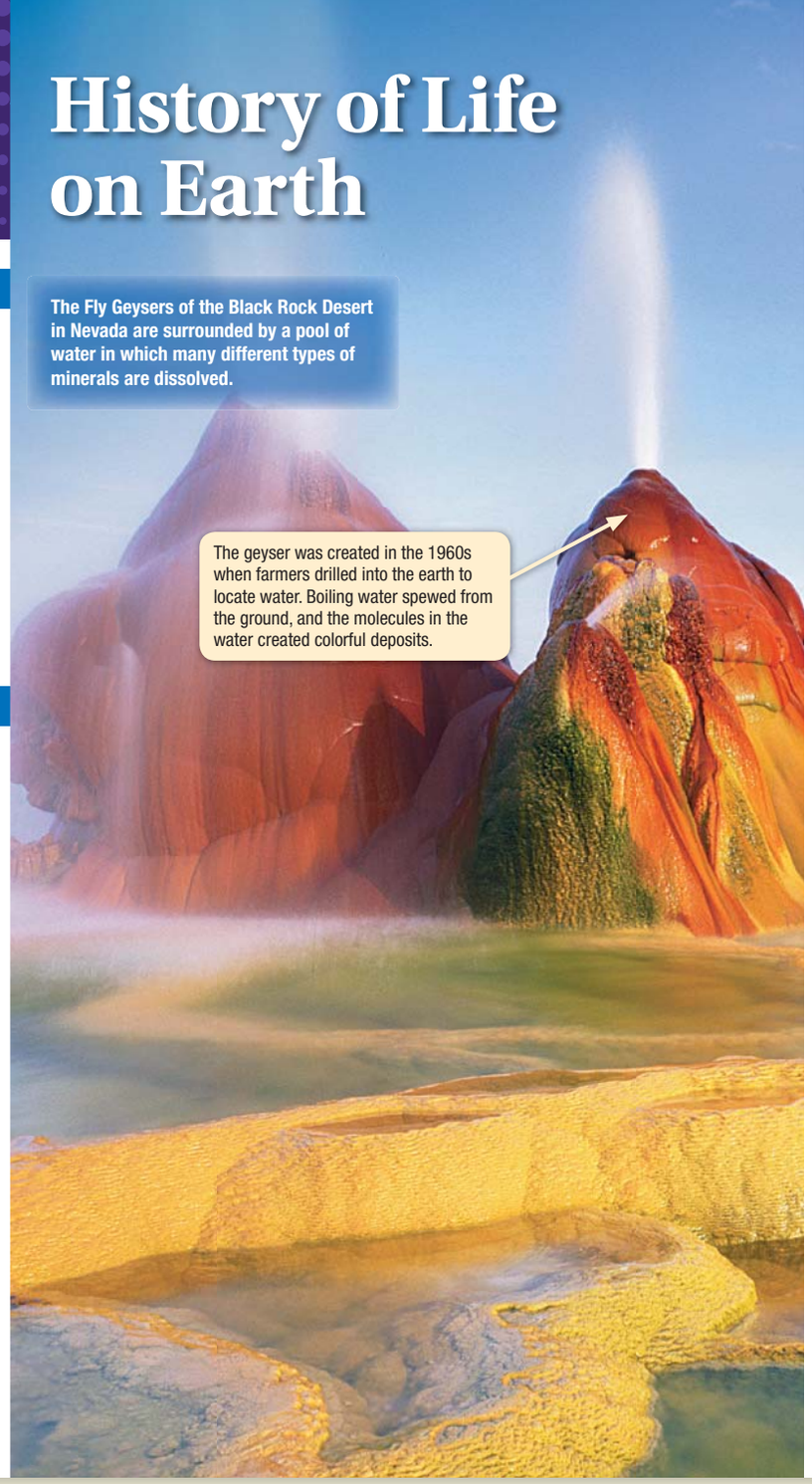
- cellular nature of life
- biodiversity
- evolution

Visual Literacy Tell students that the Black Rock Desert is one of the flattest surfaces on Earth. During the Ice Age, the area was covered by a large lake that at its peak was about 150 m deep.

Today, Fly Geyser continuously sprays water onto the desert sand. The plumes can be seen for miles. As the water has spewed from the geyser over the years, mineral deposits left behind when the water evaporates have created the colorful mounds shown in the picture. The bright colors on the mounds and the surrounding area are due to thermophilic prokaryotes, which flourish in the hot, moist environment.

Chapter 19

History of Life on Earth



The Fly Geysers of the Black Rock Desert in Nevada are surrounded by a pool of water in which many different types of minerals are dissolved.

The geyser was created in the 1960s when farmers drilled into the earth to locate water. Boiling water spewed from the ground, and the molecules in the water created colorful deposits.

Preview

Why It Matters

The history of life on Earth is like a puzzle; scientists continue to search for evidence and to put it together into a cohesive theory.

Chapter Correlations

National Science Education Standards

LSCell 3 Cells store and use information to guide their functions.

LSCell 5 Plant cells contain chloroplasts, the site of photosynthesis.

LSCell 6 Cells can differentiate and form complete multicellular organisms.

LSEvol 1 Species evolve over time.

LSEvol 2 The great diversity of organisms is the result of more than 3.5 billion years of evolution.

LSEvol 3 Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms as well as for the striking molecular similarities observed among the diverse species of living organisms.

LSEvol 4 The millions of difference species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

LSMat 6 As matter and energy flows through different levels of organization of living systems-cells, organs, communities-and between living systems and the physical environment, chemical elements are recombined in different ways.

UCP3 Change, constancy, and measurement

UCP4 Evolution and equilibrium

ESS3 Origin and evolution of the earth system

SPSP3 Natural resources

SPSP5 Natural and human-induced hazards

HNS2 Nature of scientific knowledge

Some of the colors in the deposits are caused by prokaryotes. Certain species can thrive in extreme environments.

15 min

InquiryLab

Logical Order

By analyzing overlap in layers of sedimentary rock, scientists reassemble the relative order of much longer sequences of layers.

Procedure

1. Write the following sequence of letters on **six individual index cards** with a **marker:** WXQ, PNB, NBSF, RTK, SFVW, and TKLPN.
2. Look for overlaps in the sequences between individual cards. You can use this overlap to infer the order of the entire series.

Analysis

1. **Sequence** the most likely order of letters in the complete series.
2. **Debate** how the amount of overlap affected how you established this order.
3. **Estimate** how a newly discovered rock sample that had the sequence PNAPN would affect the assembled series.

InquiryLab

Teacher's Notes Have students work with a partner. Briefly introduce the law of superposition, which states that underlying layers of rock will be older if the rock layers have not been rearranged by tectonic processes. As new sedimentary rock forms atop older rock, it creates a permanent record of the strata's history. Older layers are formed first, and are therefore found deeper in a column of rock than younger layers. The relative age of the rocks and their fossils can be determined by examining the order of the layers. Scientists also compare the order of layers from columns of rock in different geologic locations in order to devise the most logical sequence of strata.

Materials

- index cards (6)
- marker

Answers to Analysis

1. RTKLPNBSFVWXQ
2. The more overlap there is, the more likely that the inferred sequence is correct.
3. The series would most likely be updated to RTKLPNAPNBSFVWXQ.

READING TOOLBOX

Using Words

Answers will vary.

1. A microsphere is a small, ball-shaped object.
2. The lithosphere is a ball of rock or stone.
3. Paleolithic refers to something made of ancient rock.

Using Language

1. 16th, Saturday, two weeks ago
2. 65 million years ago, end of the Cretaceous period

Using Science Graphics

1. RNA nucleotides
2. RNA molecules catalyze protein synthesis.
3. First, inorganic molecules are processed into RNA nucleotides. Then, they form RNA macro-nucleoles that self-replicate. Next, smaller RNA molecules catalyze protein synthesis. Finally, proteins form.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Word Parts You can tell a lot about a word by taking it apart and examining its prefix and root.

Your Turn Use the information in the table to write your own definition for the following terms.

1. *microsphere*
2. *lithosphere*
3. *paleolithic*

Word Parts

Word part	Type	Meaning
micro-	prefix	small
paleo-	prefix	ancient
lith	root	rock, stone
sphere	root	ball-shaped object

Using Language

Describing Time Certain words and phrases can help you get an idea of when something happened and for how long it happened. These phrases are called *specific time markers*. Specific time markers include phrases such as 1 hour, yesterday, the 20th century, and 30 years later.

Your Turn Read the sentences below, and write the specific time markers.

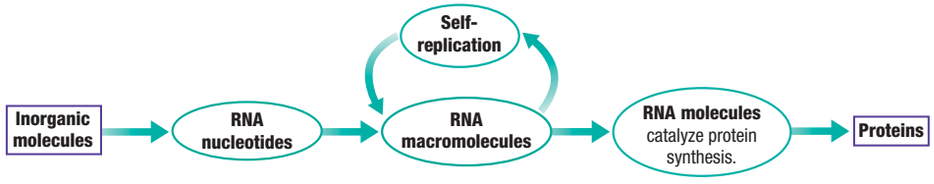
1. Jennifer celebrated her 16th birthday on Saturday two weeks ago.
2. Dinosaurs became extinct about 65 million years ago, at the end of the Cretaceous Period.

Using Science Graphics

Process Chart Process charts show the steps that a process takes to get from one point to another point. Events in a process happen in a certain order. There are many words that can be used to describe the order in which things happen. Some of these words include *first, next, then,* and *last.*

Your Turn Use the diagram to answer the following questions.

1. Which event happens second?
2. Which event follows RNA self-replication?
3. Describe the process illustrated in this chart in paragraph form. Use sequence words to indicate in what order things happen.



Section 1

How Did Life Begin?

Key Ideas	Key Terms	Why It Matters
❯ What did the Miller-Urey experiment show about the formation of the basic molecules of life? ❯ What are two theories that propose where the building blocks of life originated on early Earth? ❯ How could molecules have become packaged into cells that contain heritable cellular instructions?	microsphere ribozyme	Studying the origin of life on Earth allows scientists to discover key biological and chemical processes.

Most scientists think that life on Earth evolved through natural processes. The point when life started likely involved simple chemicals.

The Basic Chemicals of Life

In the 1920s, Russian scientist Aleksandr I. Oparin and British scientist John B. S. Haldane suggested that Earth's early oceans contained large amounts of organic molecules. They proposed that these molecules formed spontaneously in chemical reactions that were activated by energy from the sun, volcanic eruptions, and lightning.

Oparin and American scientist Harold Urey, along with other scientists, hypothesized that the early atmosphere was rich in hydrogen gas, H_2, and hydrogen-containing gases, such as water vapor, H_2O, ammonia, NH_3, and methane, CH_4. They thought that if the atmosphere lacked oxygen gas, a variety of organic compounds made up of the elements found in these gases could form. This hypothesis was tested in the 1950s by Urey and American scientist Stanley Miller.

The Miller-Urey Experiment Urey and Miller placed the gases into a device like the one in **Figure 1.** To simulate lightning, they used electrical sparks. After a few days, they found organic molecules in the device, which included some of life's basic building blocks: amino acids, fatty acids, and other hydrocarbons (molecules made of carbon and hydrogen). ❯ **The Miller-Urey experiment showed that, under certain conditions, organic compounds could form from inorganic molecules.**

We now know that the molecules used in the Miller-Urey experiment could not have existed in abundance on early Earth. Four billion years ago, shortly after Earth formed, it did not have a protective layer of ozone gas. Ultraviolet radiation from the sun would have destroyed any ammonia and methane in the atmosphere when the ozone layer did not exist. When ammonia and methane gases are absent from the Miller-Urey experiment, key biological molecules are not made. However, the Miller-Urey experiment clearly shows that complex biological compounds can form from simple building blocks.

❯ **Reading Check** *What compounds were formed in the Miller-Urey experiment? (See the Appendix for answers to the Reading Checks.)*

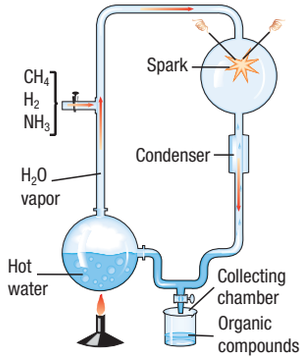


Figure 1 Urey and Miller simulated an atmosphere that Oparin and others incorrectly hypothesized as the atmosphere of early Earth. The experiment produced several organic compounds.

Key Resources

Transparencies
D5 Miller-Urey Experiment

Visual Concepts
Spontaneous Origin

Section 1

❯ Focus

This section explains models that scientists have developed to explain how life originated on Earth from the chemicals present at the time.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

First Billion Years Students may have difficulty understanding the enormity of time represented by Earth's history. To help them visualize the concept of 1 billion, ask if they think they could physically carry 1 million dollars. (Answers will vary.) Then, explain that 1 million dollars would be a stack of $100 bills approximately 1 m in height (10,000 bills). One billion dollars would be a stack of the same bills to a height of the Washington Monument (1 million bills). Now, relate this image to the first billion years of our planet's existence without any form of life. LS Visual

Teach, *continued*

Teaching Key Ideas

Pass the Salt Early oceans were probably similar in composition to modern freshwater lakes. The salt concentration in today's oceans is the result of million of years of water running over rocks and picking up mineral salts before flowing to the sea.

Teaching Key Ideas

Cell Structure Before students read the information about the first cells, review with them the parts of a cell and the types of molecules that make up these structures. Ask students why the cell membrane is important to the cell. (It controls what materials enter and leave the cell.) LS **Logical**

Answers to Caption Questions

Figure 2: Scientists study the conditions around hydrothermal vents because these conditions approximate those thought to have existed on Earth when life began. These conditions might provide clues to where the first building blocks of life were formed.

SCILINKS
www.scilinks.org
Topic: Origin of Life
Code: HX81083

Life's Building Blocks

Scientists agree that the building blocks of life formed under special conditions. They research environments that could have made these molecules. **Among the hypotheses that address the origin of life, one states that early biological molecules formed close to hydrothermal vents. Organic molecules may also have arrived on early Earth in meteorites.**

Hydrothermal Vents Some scientists think that the chemical reactions that produced the first biological molecules occurred in the oceans of early Earth. The heat from hydrothermal vents, shown in **Figure 2,** could have provided energy for chemical reactions. Within the sea, biological molecules also would have been protected from potentially harmful solar radiation.

Space Some scientists think that organic molecules could have arrived on Earth on meteorites or comets. For example, the meteorite shown in **Figure 2** contains amino acids. Organic molecules likely arrived on early Earth from outside of our atmosphere. It is unknown, however, whether these chemicals influenced the history of life on Earth. But we know that such impacts were more frequent in the early history of Earth than they are now.

ACADEMIC VOCABULARY
impact collision

The First Cells

Research continues that might provide clues to how biological molecules first began to group together and become packaged into cells. For example, how did amino acids link to form proteins? There are major differences between simple organic molecules and the large organic molecules found in living cells. Research has shown that amino acids can form proteins under certain conditions.

Forming a Cell How did molecules become packaged together inside a cell membrane? To answer this question, scientists have studied the behavior of organic molecules in water. Lipids, which make up cell membranes, tend to combine in water. Certain lipids, when combined with other molecules, can form a tiny droplet that has a surface that resembles a cell membrane.

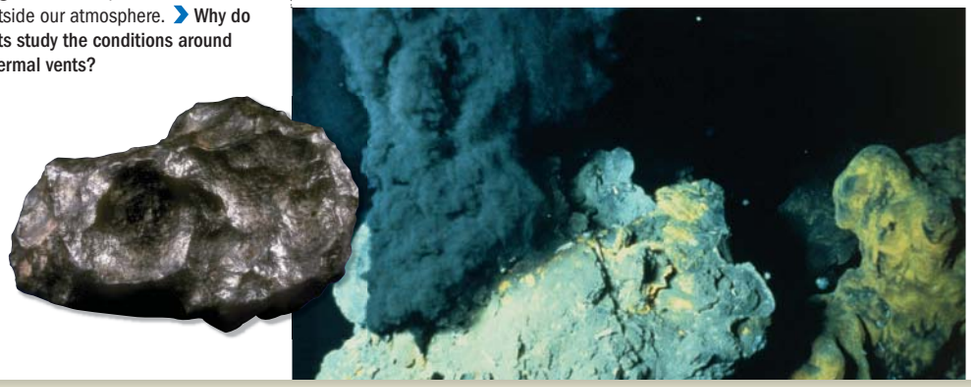


Figure 2 Scientists have suggested that the basic chemicals of life could have originated in deep-sea vents or from outside our atmosphere. **Why do scientists study the conditions around hydrothermal vents?**

Why It Matters

Space Science Investigators in the fields of biology, chemistry, physics, geology, and astrophysics are all working together to learn more about other planets in the quest to learn more about our own. Indeed, whole new fields of study, such as planetary geology, were unheard of until recently. In fact, the characteristics of a planet have been called into question with the reevaluation of Pluto. Ask students to discuss new fields of study that might arise from exploration of the planets in our solar system. (Answers will vary but might include planetary mining and refining and mass transit between planets.) LS **Verbal**

Differentiated Instruction

Basic Learners

First Cells Have students answer this question: Were the first cells that evolved on Earth prokaryotes or eukaryotes? Have students justify their answers. (The first cells were prokaryotes. At this point in the chapter, students should conclude that, because prokaryotes are single-cell organisms lacking a nucleus, they probably evolved earlier than more complex eukaryotes.) LS **Visual**

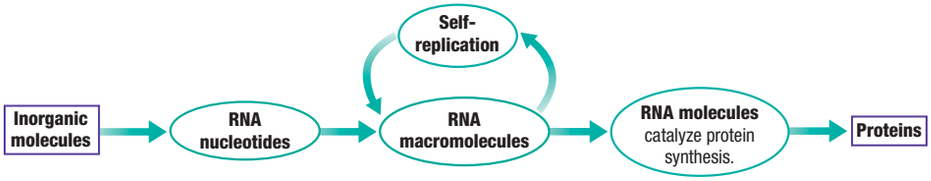


Figure 3 In this proposed model of protein formation, chemical reactions between inorganic molecules formed RNA nucleotides. The nucleotides assembled into large RNA molecules which were able to replicate and to catalyze the formation of proteins.

Further research has shown that, in water, lipids can form tiny spherical structures called **microspheres** that act like a membrane. **Many scientists think that the formation of microspheres may have been the first step toward cellular organization.** Microspheres could not be considered cells, however, unless they had characteristics of living things, including heredity.

Origin of Heredity How did heredity begin? Recall that our DNA contains instructions for making proteins. DNA is also passed on from one generation to the next. In the laboratory, scientists have not been able to make most proteins or DNA form spontaneously in water. However, scientists have been able to form short chains of RNA, the nucleic acid that helps carry out the instructions of DNA, in water.

Scientists now know that RNA molecules perform many tasks in a cell. There are several types of RNA that accomplish these tasks. Each type of RNA has a unique structure that relates to its function. In the 1980s, American scientists Thomas Cech and Sidney Altman found that a certain type of RNA molecule, called a **ribozyme,** can act like an enzyme. Also, they showed that RNA can form spontaneously in water, without DNA. Other scientists have hypothesized that RNA was the first self-replicating molecule that stored information and that catalyzed the formation of the first proteins. One idea of how RNA could have been involved in protein synthesis is shown in **Figure 3.** It was further hypothesized that RNA could have changed—evolved—from one generation to the next. Scientists hypothesize that DNA and proteins eventually took over these roles in the cell.

Reading Check *Explain how RNA could have existed before DNA.*

READING TOOLBOX

Process Chart Use the process chart in **Figure 3** to understand the hypothesis about how proteins were created. What is the significance of the loop at the self-replication step?

microsphere (MIE kroh SFIR) a hollow microscopic spherical structure that is usually composed of proteins or a synthetic polymer

ribozyme (RIE buh ZIEM) a type of RNA that can act as an enzyme

Section 1 Review

KEY IDEAS

1. **State** what the Miller-Urey experiment demonstrated.
2. **Describe** two theories that address where the building blocks of life evolved.
3. **Explain** a prevailing theory of how cells evolved.

CRITICAL THINKING

4. **Evaluating Conclusions** People once believed fish could form from the mud in a pond that sometimes dried up. How could you demonstrate that this conclusion is false?
5. **Inferring Conclusions** How might the hypothesis about the origin of heredity change if DNA could form spontaneously in water?

USING SCIENCE GRAPHICS

6. **Analyzing Models** Using **Figure 1,** determine what changes to the apparatus used by Miller and Urey would be necessary to model the production of amino acids and other organic compounds near hydrothermal vents.

Teaching Key Ideas

First Hereditary Molecule Some students may not understand how RNA, which in most cases relies on a template provided by DNA, could have developed before DNA. Explain that today certain viruses (called *retroviruses*), including HIV, contain only RNA as their genetic material. Their viral RNA, when released into a host cell, is used as a template to then make DNA. LS Verbal

READING TOOLBOX

Process Chart Self-replication provides a mechanism for passing genetic information to a new generation, and for the evolution of more complex life forms.

Close

Formative Assessment

What do some scientists think provided the energy for chemical reactions that produced the first biological molecules?

A. meteors (Incorrect. Meteors may have carried the first organic molecules to Earth.)
B. heat from hydrothermal vents (Correct!)
C. ribozymes (Incorrect. Ribozymes are a type of RNA molecule that can act like an enzyme.)
D. microspheres (Incorrect. These are tiny spherical structures composed of lipids.)

Answers to Section Review

1. The Miller-Urey experiment showed that under certain conditions organic compounds could form from inorganic molecules.
2. Some scientists think that the chemical reactions that produced the first organic molecules occurred deep in Earth's ocean. Others think that the molecules could have arrived on Earth with meteorites or comets.
3. Scientists think that the formation of microspheres might have been the first step toward cellular organization. Microspheres cannot be considered true cells, however, unless they have the characteristics of living things, including heredity.
4. Sample answer: Remove a sample of mud from a dry lake that sometimes has fish. Place the mud in an aquarium with water and see if fish develop. Use sterilized mud as a control.
5. Scientists might hypothesize that DNA was the first self-replicating information-storage molecule. However, RNA could remain part of the hypothesis if DNA was not found to be a necessary catalyst for the assembly of proteins.
6. Instead of gases, the model would use inorganic chemicals dissolved in sea water. Instead of generating a spark, the model would heat the sea water to an extremely high temperature.

Section 2

The Age of Earth

Key Ideas	Key Terms	Why It Matters
How is the fossil record used to chronicle the history of life? How do paleontologists date fossils? What evidence was used to make the geologic time scale?	fossil record relative dating radiometric dating half-life geologic time scale mass extinction	The fossil record is used to understand the diversity of life on Earth.

Focus

The purpose of this section is to explain how scientists estimate the age of Earth. It also discusses the geologic time scale and how mass extinctions have played an important role in the diversity of life on Earth.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Fossils Bring to class a variety of fossils. Petrified wood, diatomaceous earth, trilobites, casts and molds of small fish, mollusks, and coprolites (petrified feces) are usually inexpensive and easy to obtain. Ask students to bring in any fossil collections they may have at home. Display the materials, and have students observe the fossils. Tell them how the organisms that made the fossils were similar to modern organisms. Then ask students how they think each fossil formed. LS Visual

Answers to Caption Questions

Figure 4: The organism gradually dissolves and leaves a hollow impression in the sediment.

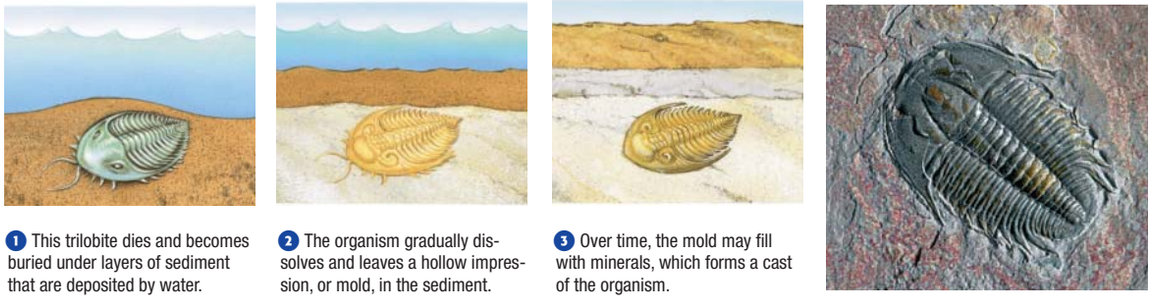
Scientists think Earth formed more than 4.5 billion years ago. Fossil evidence indicates that for much of that long history, Earth has been the home of living things.

The Fossil Record

The **fossil record** includes all fossil remains of living things on Earth. **Both the geographical distribution of organisms and when they lived on Earth can be inferred from the fossil record. It chronicles the diversity of life on Earth.** The fossil record also provides evidence of intermediate forms of life and suggests how organisms are related to each other. Although our examination of the fossil record will never be complete, it presents strong evidence that evolution has taken place.

How Fossils Form Most fossils are found in sedimentary rock. These fossils form when organisms and traces of organisms are rapidly buried in fine sediments that are deposited by water, wind, or volcanic eruptions. The formation of one kind of fossil from a marine animal is shown in **Figure 4.** Environments that often cause fossil formation are wet lowlands, slow-moving streams, lakes, shallow seas, and areas near volcanoes that spew volcanic ash. However, many species have lived in environments where fossils do not form. Even if an organism lives in an environment where fossils can form, its dead body might not be buried in sediment before it decays or is eaten.

Figure 4 Fossils can form in several ways. The most common way is when an organism dies and is buried in sediment. **What happens when an organism is covered by sediment?**



1 This trilobite dies and becomes buried under layers of sediment that are deposited by water.

2 The organism gradually dissolves and leaves a hollow impression, or mold, in the sediment.

3 Over time, the mold may fill with minerals, which forms a cast of the organism.

Key Resources

Transparencies
D4 Radioactive Decay

Visual Concepts
Radiometric Dating
Half-life
Mass Extinction

Differentiated Instruction

Struggling Readers

Key-Term Fold Have students create a Key-Term Fold using the unfamiliar terms in this lesson. Instructions for the Key-Term Fold can be found in the Reading and Study Skills section of the Appendix. Students should include the following terms and their definitions: *absolute age, absolute dating, index fossil, relative age, relative dating, strata,* and *superposition.* Encourage students to use the Key-Term Fold while reading this section and note any sentences that they do not understand. LS Verbal

Analyzing Fossil Evidence

Earth's surface changes constantly. Rocks are eroding and are laid down as sediment. This sediment forms layers of sedimentary rock called *strata,* shown in **Figure 5.** According to the *principle of superposition,* older strata are covered by younger strata. However, geologic events such as earthquakes can affect how the strata are arranged. **In order to analyze fossil evidence, paleontologists use both relative and absolute dating methods to date fossils.**

fossil record the history of life in the geologic past as indicated by the traces or remains of living things

relative dating a method of determining whether an event or object, such as a fossil, is older or younger than other events or objects

Types of Fossils The most common types of fossils are little-altered mineral shells of animals. In some cases, as shown in **Figure 4,** an organism breaks down, leaving a hollow space. This mold may fill with minerals. In other cases, the pores of the organism are filled with minerals, preserving the shape of the organism. An example of a mineralized fossil is shown in **Figure 5.** In rare cases, fossils are preserved in hardened plant sap, or amber. In these fossils, soft parts of the tissue are preserved in detail.

Relative Age A process called **relative dating** is used to estimate ages of fossils found within strata. Relative dating cannot reveal a fossil's age, in years. But it can reveal the order that strata and the fossils within them were laid down over time. Paleontologists organize fossils into a sequence based on the relative age of the strata in which the fossil was found.

Index Fossils An *index fossil* is a fossil of an organism that was common and had widespread geographical distribution during a certain time in Earth's history. Index fossils are used to estimate the age of other strata that contain the same type of fossil. Scientists have compared patterns of strata and the index fossils within them to make the geologic time scale.

Reading Check ***What is the principle of superposition?***

READING TOOLBOX

Word Parts The suffix *-ologist* means "one who studies." What do you think a paleontologist does?

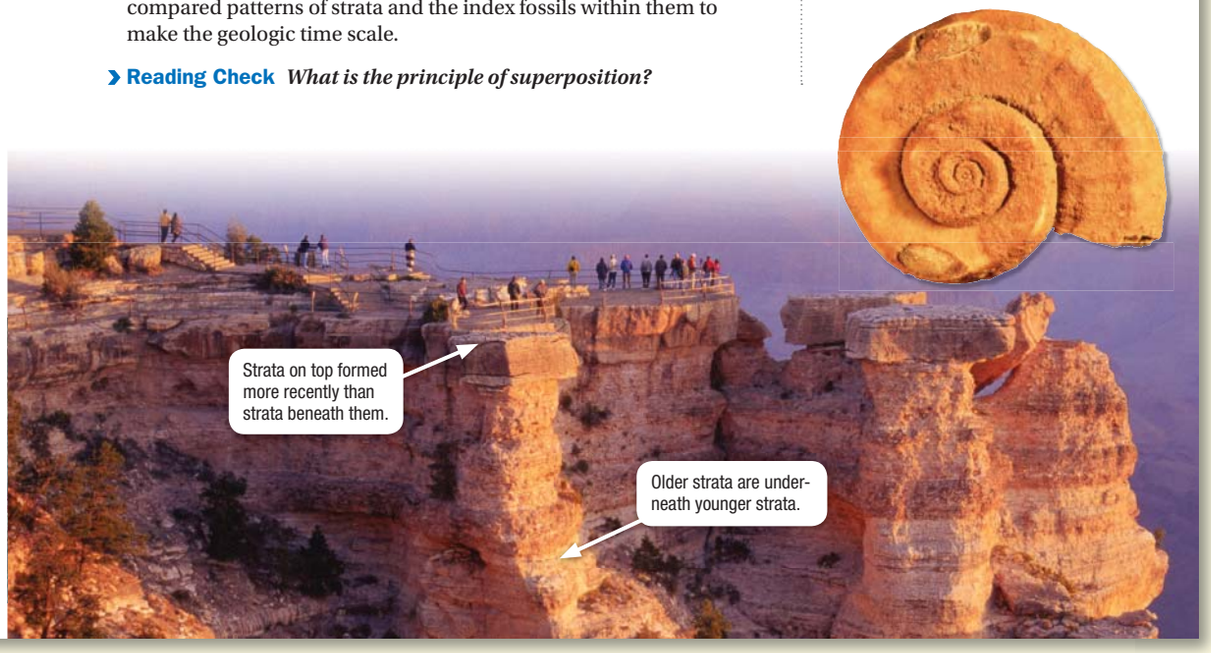


Figure 5 Rock strata are easily visible in the Grand Canyon. Gastropod fossils like this one have been found in the region.

Teaching Tip

Not Always Simple to Complex Tell students that the idea that evolution results in progress or improvement is a misconception. Evolution does not have directionality. The idea that life has steadily evolved from simple to complex also does not hold true. For example, the diverse Burgess Shale fauna discovered in the Canadian Rocky Mountains by Charles D. Walcott in 1909 lived over 540 million years ago. Some of the organisms found in this fauna, such as *Anomalocaris* and *Opabinia,* were very complex organisms. Examples of almost all major groups of modern animals have been found in this fossil deposit as well as several organisms that have not been assigned to any modern group.

Trends in Paleontology

Behavioral Evidence for Evolution Paleontologists have discovered a fossil of a dinosaur sitting on a nest of eggs. This finding of brooding behavior, characteristic of birds, supports the hypothesis that birds share a common ancestor with dinosaurs.

READING TOOLBOX

Word Parts Students learned from the beginning of the chapter that *paleo-* meant "ancient." Thus, accept any answers similar to "one who studies ancient times."

Differentiated Instruction

Advanced Learners/GATE

Burgess Shale Have students use library or Internet resources to research the Burgess Shale. Fossil evidence from the shale suggests that animals with a wide variety of body plans existed very early in evolutionary history. Have students search for organisms that would be considered unusual (even bizarre) today. Tell them to make simple sketches of the organisms. Have students make a diagram that shows the relative age of the unusual fossils.

LS Visual

Teach, *continued*

QuickLab

Teacher's Notes Have pennies counted and placed in paper or plastic cups. If time allows, multiple trials (two or three) would provide a better set of data. Make sure all pennies are accounted for at the end of the lab.

Materials
- pennies (100)
- box-like container, with lid

Answers to Analysis

1. It represents the amount of radioisotope remaining after some decay has occurred.
2. When only 25 coins remain, two half-lives have passed. Therefore, the age of the sample is 11,460 years.
3. Answers will vary. Accept all reasonable answers that demonstrate knowledge of what the variables represent in the model and that are supported by data.

MISCONCEPTION ALERT

Dating Fossils It is commonly stated that fossils can be dated using radiometric dating techniques. However, radiometric dating indicates the time when the particles in rock were originally formed. Because most fossils are formed from sedimentary rock, dating the particles within them does not indicate when the fossil was formed. So, most fossils are dated indirectly, by inference from surrounding igneous or metamorphic rock that has been directly dated.

Hands-On

QuickLab

15 min

Radioactive Decay

You can use pennies to model radioactive decay.

Procedure

1. Work in pairs. Make a data table like the one shown.
2. Place **100 pennies** into a **box that has a lid.**
3. Shake the box gently. Remove the pennies showing heads. This process models one half-life. Record the number of coins remaining in the box.
4. Repeat step 3 until every coin has been removed.
5. Make a line graph of your data. Label "Half-life" on the *x*-axis and "Coins remaining" on the *y*-axis.

Half-life	Number of coins remaining
1	
2	
3	

Analysis

1. **Identify** what "Number of coins remaining" represents.
2. **Calculate** the age of your sample if 25 coins remained. Assume that each half-life equals 5,730 years.
3. CRITICAL THINKING **Evaluating Models** Describe how this model illustrates radioactive decay.

radiometric dating a method of determining the absolute age of an object, often by comparing the relative percentages of a radioactive (parent) isotope and a stable (daughter) isotope

half-life the time required for half of a sample of a radioactive substance to decay

geologic time scale the standard method used to divide Earth's long natural history into manageable parts

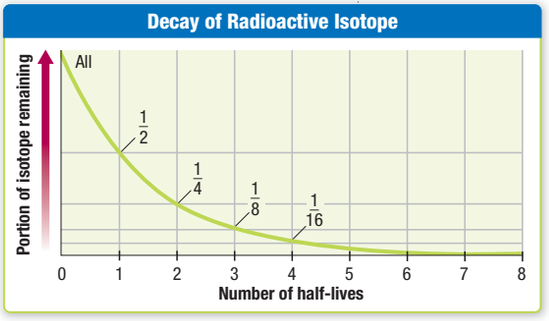
mass extinction an episode during which large numbers of species become extinct

Absolute Age

Relative dating can show only whether an object is older or younger than another object. **Radiometric dating** estimates the age in years of an object by measuring certain radioactive isotopes that the igneous rock that surrounds the object contains. An *isotope* is a form of an element whose atomic mass differs from that of other atoms of the same element. Radioactive isotopes, or *radioisotopes,* are unstable isotopes that break down and give off energy in the form of charged particles, or radiation. This breakdown is called *radioactive decay.*

When the radioactive isotope, called a "parent," decays, it produces new isotopes—*daughter* isotopes—that are smaller and more stable. The time required for half of a sample of parent radioisotope to decay into a daughter isotope is the isotope's **half-life.** **Figure 6** shows this concept. Each radioisotope has a specific half-life, and the rate at which a radioisotope decays is not affected by external factors.

Figure 6 This graph shows the rate of decay of a radioactive isotope.



Measuring Age

As the parent radioisotope decays, the amount of the daughter radioisotope increases. By comparing the amounts of certain radioisotopes and their daughter isotopes, scientists can calculate how many half-lives have passed since a material formed. One radioisotope that is widely used to date organic materials, such as mummified remains, is carbon-14. The half-life of carbon-14 is relatively short—5,730 years. Carbon-14 is used to measure the age of carbon-containing materials that are younger than 75,000 years old. Older materials have too little isotope remaining for scientists to accurately measure the age of the materials. To find the age of the older materials, scientists have to measure other radioisotopes.

Differentiated Instruction

Basic Learners

Rate of Decay Ask students to explain why the graph of the rate of decay shown in **Figure 6** is not a straight line. (The rate of radioactive decay is based on the half-life of a radioactive isotope. The amount of material that decays in one half-life is half of the undecayed portion of the sample present at the beginning of the time period. With each successive half-life, the total amount of remaining radioactive isotope decreases.) LS Visual

Alternative Assessment

Timeline Interpretation Ask students the following to determine whether they understand the relationships shown in **Figure 7.** What is the most recent era? (Cenozoic) What was the longest era? (Precambrian) In what period would a 356 million year old fossil have lived? (Carboniferous) Which dinosaurs' remains are older, Jurassic or Triassic? (Triassic) Which period was the shortest in history? (Silurian)

Describing Geologic Time

The **geologic time scale** organizes geologic and evolutionary events. **The geologic time scale is based on evidence in the fossil record and has been shaped by mass extinctions.** A shortened geologic time scale is shown in **Figure 7.**

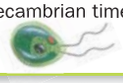
Divisions of Geologic Time Earth has existed for more than 4 billion years. From the beginning of Earth to about 542 million years ago is often referred to as Precambrian time. From the end of Precambrian time to the present, Earth's history is divided into three *eras*—the Paleozoic Era, the Mesozoic Era, and the Cenozoic Era. These three eras are further divided into periods. Humans appeared during the Quaternary Period.

Mass Extinction Recall that the extinction of a species is the death of all members of that species. When large numbers of species become extinct, the event is called a **mass extinction.** The fossil record indicates that many mass extinctions have occurred during Earth's history. Evidence indicates that worldwide geologic and climate changes are common factors that contribute to mass extinctions. Mass extinctions may have contributed to overall biodiversity on Earth. After a mass extinction, opportunities open for new life-forms to emerge.

Mass extinctions have been used to mark the divisions of geologic time. Large mass extinctions mark the boundaries between eras, as shown on **Figure 7.** For example, mass extinctions occurred at the end of Precambrian time, at the end of the Paleozoic Era, and at the boundary between the Mesozoic Era and Cenozoic Era. Smaller mass extinctions mark the divisions between periods.

Reading Check *What evidence shows that mass extinctions occur?*

Geologic Time Scale

Era	Period	Time*
Cenozoic 	Quaternary	1.8
	Tertiary	65.5
MASS EXTINCTION		
Mesozoic 	Cretaceous	146
	Jurassic	200
	Triassic	251
MASS EXTINCTION		
Paleozoic 	Permian	299
	Carboniferous	359
	Devonian	416
	Silurian	444
	Ordovician	488
	Cambrian	542
MASS EXTINCTION		
Precambrian time  		>4,500

*indicates how many millions of years ago the period began

Figure 7 The geologic time scale is based on fossil evidence. The time in the scale refers to the number of years ago that the time period started. **How long did the Permian period last?**

Section 2 Review

KEY IDEAS

1. **Describe** how the fossil record chronicles the history of life.
2. **Explain** how dating methods are used to analyze fossil evidence.
3. **State** the evidence that scientists have used to create the geologic time scale.

CRITICAL THINKING

4. **Constructing Explanations** Why might the fossil record give an inaccurate picture of the history of biodiversity? Explain your answer.
5. **Explaining Relationships** How could index fossils in two different rock strata in a series help a paleontologist to estimate the absolute age of fossils in a layer of rock between them? Explain your reasoning.

METHODS OF SCIENCE

6. **Describing Methods** You are a paleontologist who is digging for fossils in a remote area. Describe the methods you would use on the dig to make sure that you could estimate the age of the fossils.

Answers to Section Review

1. Both the geographic and chronologic distribution of organisms can be inferred by examining the fossil record. The fossil record also chronicles the diversity of life on Earth.
2. Paleontologists organize fossils into a sequence based on the relative age of the strata in which the fossils were found. They also use radiometric dating to estimate the age of an object by measuring certain radioisotopes that the object contains.
3. The geologic time scale is based on evidence in the fossil record.
4. Organisms with hard parts have more representation in the fossil record than organisms with only soft parts. Organisms that lived in certain places, such as shallow seas, also get more representation. Therefore, the fossil record would not represent the correct relative abundance or total number of species.
5. The paleontologist could use the age of each index fossil to estimate an age range for the fossils in between. For example, if the index fossil in the higher strata formed around 350 million years ago and the index fossil in the lower strata formed around 420 million years ago, the fossil in between would have formed between 350 and 420 million years ago.
6. Sample answer: I would record the rock layer in which each fossil was found so that I could use relative dating to estimate the age of the fossils.

Answers to Caption Questions

Figure 7: The Permian period lasted approximately 48 million years.

Teaching Key Ideas

Geologic Time Scale Help students understand that the geologic time scale is a scientific model. This organizational scheme has been and will continue to be revised based on new discoveries. Intervals for each era and period can change based on documented discoveries. This is one reason why you can find conflicting dates in reference materials depending on the timeliness of that reference. Be sure students recognize that Precambrian time covers the longest interval on the scale. Periods and Epochs are smaller divisions in more recent history signifying major changes in the fossil record.

Close

Formative Assessment

What process is used to estimate the ages of fossils within strata?

A. half-life (Incorrect. This is the time required for half of a radioactive substance to decay.)

B. radioactive decay (Incorrect. This is the breakdown of radioisotopes.)

C. radiometric dating. (Incorrect. This process estimates absolute age.)

D. relative dating (Correct! This process can reveal the sequence in which the fossils and strata were laid.)

Section 3

Section 3 Evolution of Life

Key Ideas	Key Terms	Why It Matters
What major evolutionary developments occurred during Precambrian time? What dominant organisms evolved during the Paleozoic Era? What dominant organisms evolved during the Mesozoic Era and the Cenozoic Era?	cyanobacteria endosymbiosis	Knowing the order in which life-forms evolved helps scientists form new hypotheses of how life forms are related.

Focus

This section explains how the first eukaryotic cells and their organelles might have evolved and how multicellular organisms likely evolved. The section also explains the challenges of living on land and discusses the succession of organisms that moved from the oceans onto land.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Earth's Timeline Some students may have difficulty understanding the timeline of Earth's history. Draw a large circle on the board to represent a clock. Place an arrow at 12:01 to indicate when Earth was formed. Place additional arrows on the clock as follows:
1:15 (the first bacteria appeared),
8:00 (the first eukaryotes appeared),
11:00 (the first life on land appeared),
11:50 (dinosaurs became extinct),
and 11:59 (first humans appeared).
LS Visual

When did life first evolve on Earth? To find out, scientists study fossils and other evidence of early life, such as "signatures" of certain isotopes in rock. These isotopes are associated with living things.

Precambrian Time

Precambrian time spanned between about 4.5 billion and 542 million years ago. Many critical events occurred during this long period of Earth's history. **Single-celled prokaryotes and later, eukaryotes, evolved and flourished in Precambrian time. The evolution of multicellular organisms set the stage for the evolution of modern organisms. The accumulation of atmospheric oxygen allowed organisms to become larger and live on land.**

Early Earth was a dangerous place. Meteors bombarded the planet in large numbers. This activity heated Earth's surface repeatedly and made our planet a hostile place for living things. Eventually, fewer meteor impacts occurred, which allowed early cells to evolve.

Prokaryotic Life Recall that organisms on Earth are divided into three groups: eukaryotes and Archaea and bacteria, the prokaryotes. Living examples from these two groups are shown in **Figure 8.** The close relationship of some eukaryotic genes to those of archaeans suggests that archaea played a role in eukaryote evolution.

cyanobacteria
(SIE uh noh bak TIR ee uh) bacteria that carry out photosynthesis; blue-green algae

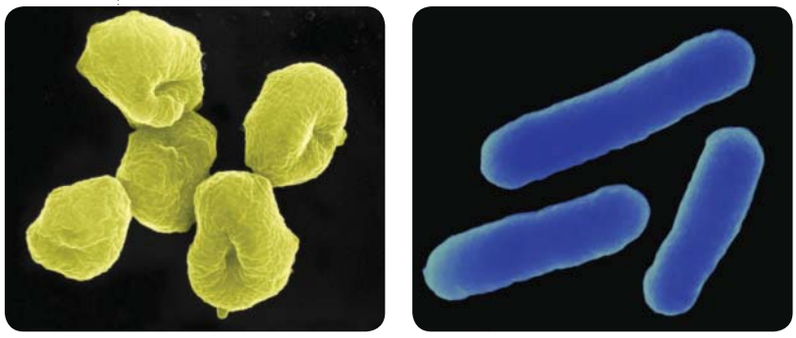


Figure 8 *Sulfolobus* (left) is a living example of archaea. *Escherichia coli* (right) is a living example of bacteria. Both archaea and bacteria are groups of organisms that have existed since ancient times.

Key Resources

Transparencies
D7 Ozone Shields the Earth
D8 Evolution of Eukaryotes

Visual Concepts
Comparing Prokaryotes and Eukaryotes
Origin of Eukaryotic Cells
Endosymbiosis
Comparing Organisms that Are Unicellular and Multicellular
Ozone and Ecosystems
Vertebrates

Figure 9 Fossilized mats of cyanobacteria, called *stromatolites,* are the most common Precambrian fossils. These modern stromatolites are similar to stromatolites that existed during Precambrian time.

Recall that most prokaryotes are single-celled organisms that lack membrane-bound organelles. The oldest presumed fossils, which are microscopic fossils of prokaryotes, come from rock that is about 3.5 billion years old. The earliest common fossils are those of marine cyanobacteria. **Cyanobacteria** are photosynthetic prokaryotes. Modern cyanobacteria, clustered in layered structures called *stromatolites* are shown in **Figure 9.**

Formation of Oxygen About 2.4 billion years ago, the chemistry of rock layers changed markedly. Because of this, scientists think that cyanbacteria began adding oxygen to the atmosphere at this time. Before cyanobacteria appeared, oxygen gas was scarce on Earth. But as ancient cyanobacteria carried out photosynthesis, they released oxygen gas into Earth's oceans. This oxygen eventually escaped into the air. The increase of oxygen in the ocean destroyed many marine prokaryotes. These organisms had evolved to live without oxygen, which was a poison to them.

As oxygen reached Earth's upper atmosphere, the sun's rays caused some of the oxygen gas, O_2, to chemically react and form molecules of ozone, O_3. In the upper atmosphere, the ozone layer blocks some of the ultraviolet radiation of the sun. The sun provides life-giving light, but overexposure to ultraviolet radiation is dangerous to living things. Organisms on the very early Earth could not survive on land because ultraviolet radiation damaged their DNA. After millions of years however, enough ozone had accumulated to make land a safe place for organisms to live. The first organisms to live on land were prokaryotes.

Eukaryotic Life Later in Precambrian time, the first eukaryotes appeared. Most eukaryotic cells are much larger than prokaryotic cells are. Eukaryotes have a complex system of internal membranes, and their DNA is enclosed within a nucleus. Most eukaryotes have mitochondria. Plants and some protists also have chloroplasts, which carry out photosynthesis. Mitochondria and chloroplasts are the size of prokaryotes, and they contain their own DNA, which is similar to that of prokaryotes.

READING TOOLBOX

Describing Time Scientists describe events in Earth's history in terms of geologic time. Look for references to time in this section, and construct a table of their meanings.

ACADEMIC VOCABULARY

accumulate to collect, especially over a period of time

Why It Matters

Effects of UV Radiation Remind students that ultraviolet (UV) radiation can be very damaging to their health. Sunburn indicates that skin has been damaged by UV radiation. The American Cancer Society reminds us that people who have been seriously sunburned, even once, have an increased risk of developing skin cancer. LS Visual

Teach Key Ideas

Earth's Changing Atmosphere Have students compare the changes in the early atmosphere of Earth with the changes that are occurring in the atmosphere today. Begin by describing how oxygen levels steadily increased in the ancient atmosphere due to the activity of photosynthetic bacteria. Then ask students what kind of gaseous products human activity is producing today. (Carbon dioxide, methane, sulfur dioxide, nitrous oxide, and others) Ask which gas of particular importance is increasing worldwide and which is decreasing. (Carbon dioxide is increasing, and upper atmospheric ozone is decreasing.) Ask students if ozone is a desirable part of our atmosphere. (Most will answer yes.) Then ask if ozone is always a desirable part of our atmosphere. (At lower elevations, ozone contributes to pollution; at higher elevations, however, ozone absorbs much of the damaging ultraviolet radiation that would otherwise reach Earth and harm living things.) LS Verbal

READING TOOLBOX

Describing Time Students should include the following "time" words and phrases in their tables: *between, about, years ago, evolved early, eventually, oldest known, among the first, first, later, descendants,* and *descended from.*

Teach, *continued*

Teaching Key Ideas

Endosymbiosis The term *endosymbiosis* refers to any symbiotic relationship in which one organism lives inside another. Help students understand the hypothesis for the endosymbiotic origin of mitochondria and chloroplasts by reviewing other examples of endosymbiosis. Examples include wood-digesting bacteria that live within the digestive tracts of termites, bacteria that break down plant cell walls within the digestive tract of cows, and bacteria in the human digestive tract that break down otherwise undigested materials and synthesize vitamin K as a by-product. LS **Verbal**

go.hrw.com
interact online

Students can interact with "Endosymbiotic Theory" by going to go.hrw.com and typing in the keyword HX8LIFF10.

Answers to Caption Questions

Figure 10: Mitochondria and chloroplasts both have DNA that is similar to that found in bacteria, which suggests that they descended from a common bacterial ancestor.

endosymbiosis (EN doh SIM bie OH ses) a mutually beneficial relationship in which one organism lives within another

SCILINKS
www.scilinks.org
Topic: Endosymbiosis
Code: HX80506

Origin of Energy-Releasing Organelles Mitochondria and chloroplasts likely originated as described by the endosymbiotic theory proposed by Lynn Margulis, which is illustrated in **Figure 10.** **Endosymbiosis** is a mutually beneficial relationship in which one organism lives within another. Endosymbiotic theory proposes that larger cells engulfed smaller cells, which then began to live inside larger cells. According to this theory, mitochondria are the descendants of symbiotic, aerobic (oxygen-requiring) bacteria. Likewise, scientists think that chloroplasts are thought to be the descendants of symbiotic, photosynthetic bacteria. The following observations support the theory that mitochondria and chloroplasts descended from bacteria:

- **Size and Structure** Mitochondria are the same size as most bacteria. Chloroplasts are the same size as some cyanobacteria.
- **Genetic Material** Both chloroplasts and mitochondria contain genes that are different from those found in the nucleus of the host cell and that are closely related to bacterial genes.
- **Ribosomes** Mitochondrial and chloroplast ribosomes are similar in size and structure to bacterial ribosomes.
- **Reproduction** Like bacteria, chloroplasts and mitochondria reproduce by simple fission. This replication takes place independently of the cell cycle of the host cell.

Multicellularity *Volvox,* a colonial protist, is shown in **Figure 11.** Colonies differ from true multicellular organisms. In true multicellularity, cells communicate with one another and differentiate to form different cell types. The development of multicellular organisms marked an important step in the evolution of life-forms that are familiar to us. Multicellularity first developed in protists in Precambrian time. Scientists think that the first multicellular organisms began as clusters of single-celled organisms. Eventually these cells took on specialized functions.

Figure 10 The theory of endosymbiosis states that energy-releasing organelles evolved from ancestors of bacteria.
What genetic evidence supports the theory of endosymbiosis?

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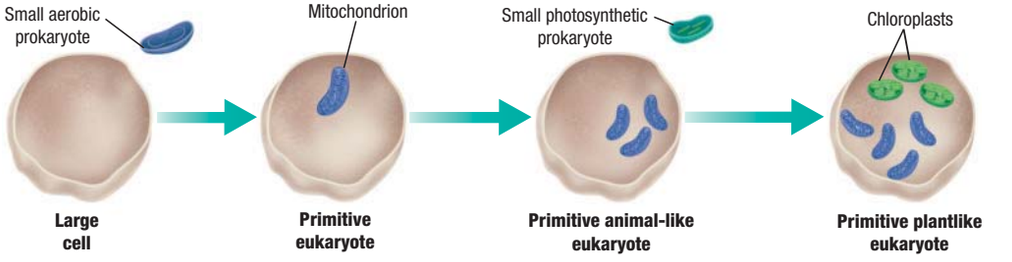
interact online
Keyword: HX8LIFF10

Endosymbiotic Theory



1 Large prokaryotes and small aerobic or photosynthetic prokaryotes exist as separate cells.

2 Aerobic prokaryotes enter the large prokaryotic cell either as parasites or as undigested prey.

3 Instead of being digested, the small prokaryotes survived and began to live inside the host cell.

4 The internalized prokaryotes eventually performed either cellular respiration (mitochondria) or photosynthesis (chloroplasts).

Differentiated Instruction

Struggling Readers

Endosymbiosis and Bacteria Have students work in small groups to create posters of chloroplasts, mitochondria, and both non-photosynthetic and photosynthetic bacterial cells. Their projects should have clearly labeled internal structures and realistic colors (i.e., green for chloroplasts or photosynthetic bacteria). They should also identify the names of the bacteria used for these models or pictures. LS **Visual**

Hands-On

QuickLab

15 min

Timeline of Earth

Using some calculations, you can create your own timeline of Earth's history.

Procedure

1. Copy the table shown onto a **piece of paper.**
2. Complete the table by using this scale: 1 cm is equal to 10 million years.
3. Lay a **5 m strip of adding-machine paper** flat on a hard surface. Use a **meterstick,** a **metric ruler,** and a **pencil** to mark off the beginning and end of Precambrian time according to the time scale that you calculated. Do the same for the three eras. Label each division of time, and make each a different color with **colored pencils.**

Era	Length of time (years)	Scale length
Precambrian	4,058,000,000	
Palezoic	291,000,000	
Mesozoic	185,500,000	
Cenozoic	65,500,000 (to present)	

4. Refer to the geologic time scale shown in **Figure 7.** Using the same scale as in step 2, calculate the scale length for each period listed. Mark the boundaries of each period on the paper strip, and label them.
5. Decorate your strip by adding names or drawings of the organisms that lived in each division of time.

Analysis

1. **Identify** in which period humans appeared.
2. **Calculate** the length from the period in which humans appeared to the present.
3. CRITICAL THINKING **Interpreting Graphics** What percentage of the geologic time scale do these eras combined represent? What percentage of the geologic time scale does Precambrian time represent?

Dominant Life For most of Precambrian time, life probably was limited to prokaryotes and protists, which are eukaryotes. Recent evidence suggests that the oldest known fossils of multicellular eukaryotes have been found in rock that is about 1 billion years old. The first known fossils of true multicellular animals are about 632 million years old. Very early animal fossils are scarce because most animals at that time had soft body parts that did not fossilize well. Fossils of marine animals similar to modern sea anemones and snail-like animals are dated to late Precambrian time.

Mass Extinctions The first known mass extinction in Precambrian time killed many microorganisms, including cyanobacteria and other types of bacteria. A second mass extinction, late in Precambrian time, killed off many animals that had recently evolved. This mass extinction opened up new ecological niches, and preceded a burst of diversification in animals. The animals, with their hard exoskeletons and shells, that evolved after this extinction have left a rich fossil record as evidence of evolution.

Reading Check ***Why is the evolution of colonial organisms an important step in evolution?***

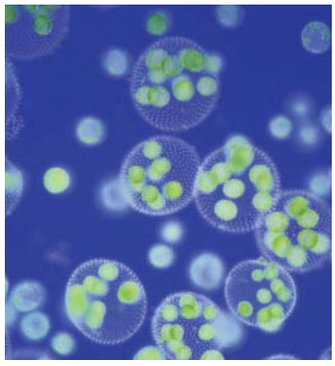


Figure 11 *Volvox* is a colonial protist. Cells in a colony remain attached after dividing. But they are not truly multicellular.

Differentiated Instruction

English Learners

Cellular Specialization To help students recognize the relationship between multicellularity and the division of labor among different types of cells, use the following analogy. Modern industry uses the skills and abilities of individual workers to perform different tasks that contribute to the production of a single product. Use an example from a local industry to show how more is produced, both in quantity and complexity, by breaking the total task into smaller tasks that are accomplished by workers trained to do each specific task. Point out that cells exhibit the same type of departmentalization. LS Logical

QuickLab

Teacher's Notes This lab activity may be easier to do in the hallway. As students study this section, have them add details about each time interval to their timelines.

Materials
- adding machine paper (5-m strip)
- meterstick
- metric ruler

Answers to Analysis

1. Humans appeared in the Quaternary period.
2. 1 mm
3. Twelve percent of the geologic time scale is represented by Paleozoic, Mesozoic, and Cenozoic eras combined. Precambrian time represents 88 percent of the geologic time scale.

Teaching Key Ideas

Extinct Organisms Tell students that scientists estimate that more than 99 percent of all species that ever existed are now extinct. LS Verbal

Trends in Paleontology

Oldest Multicellular Fossils? Scientists have discovered fossilized organisms that resemble brown algae in 1.7-billion-year-old rocks. These organisms seem to have been multicellular, but the fossils are 800 million years older than other known fossils of multicellular organisms. The first multicellular organisms were probably protists that developed cell specialization. Some modern algae show a degree of cell specialization—reproductive cells differ from other cell types.

Teach, *continued*

Teaching Key Ideas

Cambrian Explosion Point out to students that the diversity of multicellular organisms expanded rapidly during the period known as the "Cambrian explosion." Changing geologic and atmospheric conditions during this period are thought to have increased the number of available habitats for animals. Primitive multicellular organisms could then specialize differently, become more complex, and take advantage of the newly available resources. This first explosion of biological diversity was the foundation from which most complex life evolved.

Teaching Key ideas

Hard As a Rock Ask students what kinds of organisms could survive on bare rock. What would it take to be successful? (Students may suggest an association similar to lichen, in which a fungus and a cyanobacterium or alga coexist in a symbiotic relationship.) Remind students that as life emerged from the oceans, living things were confronted with this kind of problem. LS Logical

Paleozoic Era

The Cambrian Period, the first period in the Paleozoic Era, was a time of great evolutionary expansion. The rapid diversification of animals that appeared in the fossil record is sometimes referred to as the "Cambrian explosion," though it occurred over several million years.

Dominant Life The Paleozoic Era was a time of great evolutionary expansion. **During the Paleozoic Era, marine invertebrates diversified, and marine vertebrates evolved. The first land plants evolved. Some arthropods, and then some vertebrates, left the oceans to colonize land.**

Plants and Fungi on Land The first multicellular organisms to live on land may have been fungi living together with plants or algae. Plants and fungi began living together on the surface of the land about 475 million years ago. Eventually, great forests, illustrated in **Figure 12,** covered much of Earth's landscape.

Plant life from the Paleozoic Era still has an impact on our lives. In the great coal swamps of the Carboniferous Period, organic materials were subjected to pressure from overlying earth. Over millions of years this produced fossil fuels—beds of coal and reservoirs of oil. Humans now burn both oil and coal to release stored energy.

Arthropods An arthropod is an animal that has a hard outer skeleton, a segmented body, and paired, jointed limbs. Although many arthropods continued to live in the oceans, the first animals to successfully live on land were also arthropods. An important terrestrial arthropod—the insect—evolved in the late Devonian.

Vertebrates A vertebrate is an animal with a backbone. According to the fossil record, the first vertebrates were small, jawless fishes that evolved in the oceans about 530 million years ago. Fishes that have jaws appeared about 430 million years ago. For over one hundred million years, vertebrates lived only in the sea. The first land vertebrates, amphibians, came out of the sea about 370 million years ago. Reptiles evolved from amphibian ancestors about 340 million years ago.

Figure 12 The Devonian Period, which began about 416 million years ago, was dominated by large forests, such as the one shown in this illustration.

Differentiated Instruction

Basic Learners

Evolution of Vertebrates Have students work in small groups. Distribute soft gelatin-based candy, such as "gummy worms," toothpicks, glue, and tape to each group. Challenge them to create an internal skeleton for some worms and an external skeleton for others. Caution students not to eat the candy. After groups complete their skeletons, ask whether internal or external skeletons require less material and which weigh less. (Internal skeletons should be smaller and lighter.) Help students list other adaptive advantages of internal skeletons. LS Kinesthetic

Struggling Readers/Basic Learners

Pattern Puzzles To help students sequence events correctly, have them put each of the following events on index cards: *prokaryotes and protists; plants and fungi on land; arthropods and vertebrates; reptiles and birds; mammals; modern humans; Precambrian; Paleozoic; Mesozoic; Cenozoic.* Then have students match the event to the era and arrange the cards in the correct sequence. LS Verbal/Visual

Mass Extinctions The fossil record indicates that mass extinctions occurred both at the end of the Ordovician Period (440 million years ago) and just before the end of the Devonian Period (375 million years ago). These events eliminated about 70% of all of the species on Earth. The most devastating of all mass extinctions occurred at the end of the Permian Period, about 252 million years ago. More than 90% of all animals species living at the time became extinct.

Mesozoic and Cenozoic Eras

Many of the dominant life-forms on our planet diverged during the Mesozoic and Cenozoic Eras. **› Reptiles, dinosaurs, and birds were the dominant animals during the Mesozoic Era, and mammalian animals dominated the Cenozoic Era.**

Dominant Life During the Mesozoic Era, dinosaurs and other reptiles evolved to be the dominant life-forms. Therapsids, which were mammal-like reptiles, gave rise to modern mammals at about the same time that dinosaurs evolved, during the Triassic Period. Scientists think that birds evolved from feathered dinosaurs during the Jurassic Period. Flowering plants evolved during the Cretaceous Period of the Mesozoic Era. The Cenozoic Era is the current era. During this era, mammals, such as the woolly mammoth shown in **Figure 13,** became the dominant life-form on land. The first hominids (early human ancestors) evolved during the Tertiary Period. Modern humans did not appear until the Quaternary Period.

Mass Extinction A mass extinction 65 million years ago included about two-thirds of all land species, including the dinosaurs. This mass extinction is often called the K-T extinction, because it marks the boundary between the Cretaceous Period (K) of the Mesozoic Era and the Tertiary Period (T) of the Cenozoic Era. Scientists think that this mass extinction was caused by a catastrophic event that had widespread effects.

Figure 13 This woolly mammoth is an example of an animal that lived during the Quaternary Period. **› Did woolly mammoths live before or after the K-T extinction?**

Section 3 Review

› KEY IDEAS

1. **Describe** the major events that occurred during Precambrian time.
2. **Name** the types of life-forms that evolved during the Paleozoic Era.
3. **Describe** the dominant life-forms that evolved during the Mesozoic and Cenozoic eras.

CRITICAL THINKING

4. **Justifying Conclusions** A classmate states that mitochondria and chloroplasts descended from the same type of bacteria. Does the evidence support this? Explain your reasoning.
5. **Evaluating an Argument** Defend the argument that fossil fuels are *not* a renewable resource.

CONNECTING KEY IDEAS

6. **Evaluating Viewpoints** Several scientists have said that if a large asteroid struck Earth, the impact could result in a mass extinction. If an asteroid impact did not kill all organisms, would evolution continue or stop? Explain your reasoning.

Teaching Key Ideas

Dinosaur Success Review with students that most of the dinosaurs became extinct with the mass extinction 65 million years ago. Ask students if they think dinosaurs were successful in evolutionary terms. Tell students to give reasons for their opinions. Then point out that dinosaurs were the dominant animals for about 150 million years. Compare that to the 10 million years the human family has lived on Earth. Ask students if any would like to change their opinion of the dinosaurs' success. LS Logical

Answers to Caption Questions

Figure 13: Woolly mammoths lived after the K-T extinction.

› Close

Formative Assessment

Which vertebrate animals were the first to evolve and successfully live on land?

A. arthropods (Incorrect. Arthropods are not vertebrates, however they were the first animals to live on land.)
B. reptiles (Incorrect. Reptiles appeared after amphibians.)
C. amphibians (Correct!)
D. mycorrhizae (Incorrect. Mycorrhizae are symbiotic relationships between fungi and plants.)

Answers to Section Review

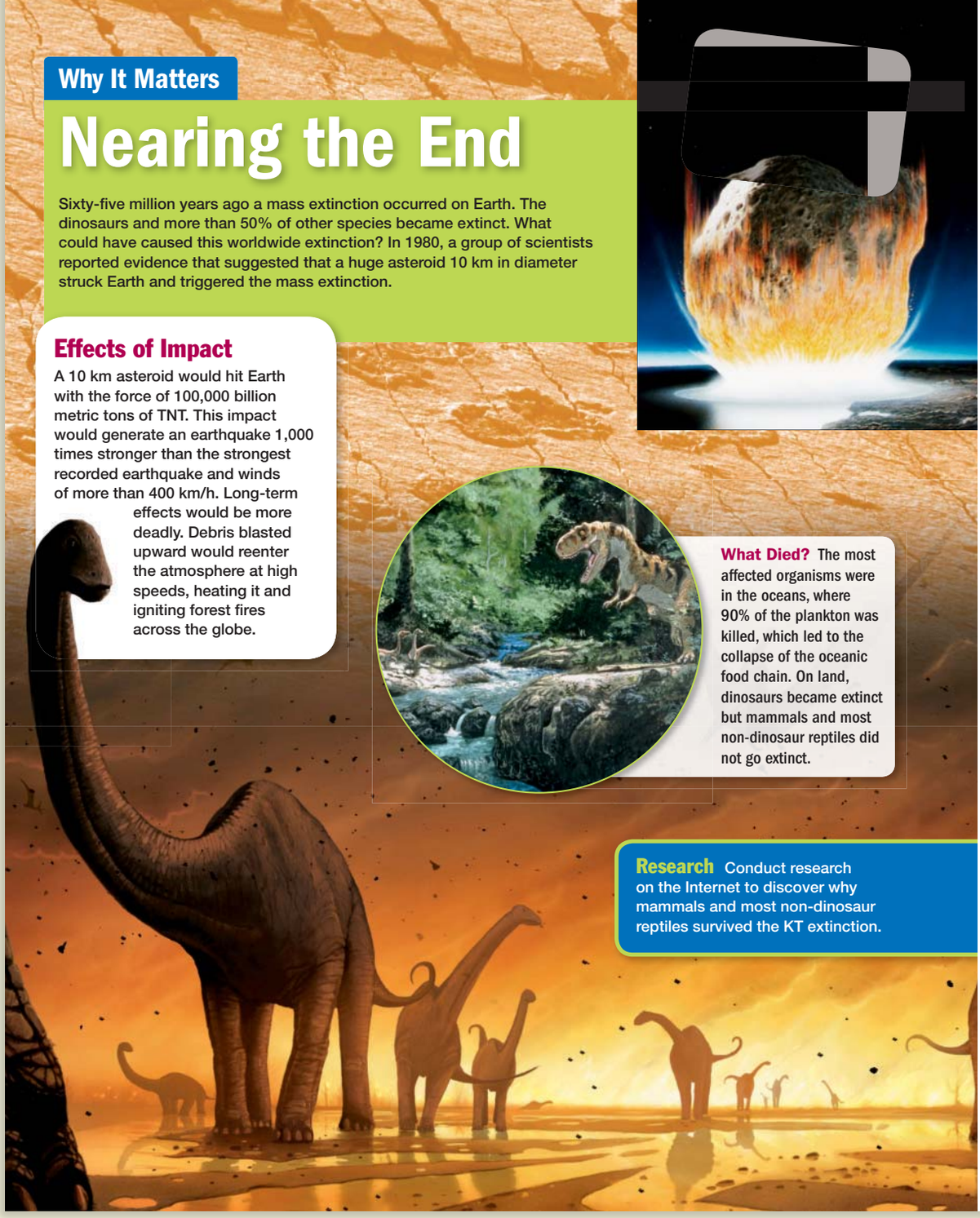
1. The evolution of multicellular organisms set the stage for the evolution of modern organisms. The accumulation of atmospheric oxygen allowed organisms to live on land.
2. Land plants, arthropods, aquatic vertebrates, and some land vertebrates evolved during the Paleozoic era.
3. Reptiles, dinosaurs, and birds were the dominant life forms during the Mesozoic era, and mammals dominated the Cenozoic era.
4. No, chloroplasts are needed for photosynthesis, but mitochondria are not. Therefore, scientists theorize that chloroplasts are descended from photosynthetic bacteria, and mitochondria are descended from aerobic bacteria.
5. The extremely long time required to produce fossil fuels from organic materials means that fossil fuels are not renewable.
6. Evolution continues after a mass extinction. Some traits in the remaining organisms could help a few survive and reproduce in the ecological niches that would have opened up. These traits would be amplified through their descendents. New species would then evolve.

Why It Matters

Teacher's Notes There are many different theories concerning why the dinosaurs and other organisms became extinct. Most groups agree that a brief but pronounced change occurred around 65 million years ago. Some theorists state that the cause of the K-T extinction was due to forces here on Earth (intrinsic) and that the extinction occurred gradually, over several million years. These theorists cite the most probable causes as huge volcanic eruptions and movement of the continental plates. Others hypothesize that the ultimate cause of the K-T extinction was due to forces created outside Earth (extrinsic) and that the event was fairly sudden and punctuated. These theorists cite the most probable cause as an asteroid colliding with Earth, precipitating global climatic change. Another theory hypothesizes that shock waves from the impact of a large asteroid moved through Earth and triggered intense volcanic eruptions. Although different hypotheses exist, all are based on geological observations. Further observations are needed to clarify the issue.

READING TOOLBOX

Visual Literacy Have students study the picture in the circle. Ask how the scene compares to what Earth is like today. (Plants look similar to those found today, but animals have changed dramatically.)



Answer to Research

Accept all reasonable answers. Sample answer: although the answer to this question is largely unknown, scientists have many hypotheses about how mammals and non-dinosaur reptiles survived the K-T extinction. One hypothesis states that the debris sent into the atmosphere by an impact event would have blocked much of the sun's warming rays. Cold-blooded dinosaurs would have been affected by this cold much more than smaller reptiles or warm-blooded mammals. Although not all small reptiles and mammals survived these events, enough survived to allow these species to continue to evolve.

Skills Practice

Chapter 19 Lab

30 min

Objectives

- Model the formation and analysis of strata.
- Apply the criteria used to identify index fossils to the strata model.
- Evaluate the effectiveness of the model to illustrate relative fossil age.

Materials

- graduated cylinder, 100 mL
- water, tap
- aquarium gravel, four distinct colors
- dish, small (8 per group)
- tablespoon
- beans, dried (navy, black, pinto)

Safety

Model of Rock Strata

Sedimentary strata are arranged so that, if they remain undisturbed, any layer is older than the strata on top of it but younger than the strata beneath it. One way to study strata and the fossils within them is to take core samples through the earth and compare them to samples taken at different locations. Paleontologists can determine the original order of strata by comparing multiple samples from many locations. In this lab, you will model how strata are formed and how they can be used to construct a record of Earth's geologic and biologic history.

Procedure

1. Work in groups of three or four. Each student in the group should make a separate model. You will build up a series of layers in a column. You will model eight periods of time using different colors of gravel and different beans. The gravel represents sediment and the beans represent fossils. One tablespoon represents deposition that occurs over a 10,000-year period.
2. **CAUTION: Glass items such as graduated cylinders are fragile and may break.** Add 30 mL of tap water to the graduated cylinder.
3. For the first time period, choose a color. Have each member of the group add 1 Tbsp of that gravel color to their column. Randomly choose one member of the group to omit this layer.
4. Repeat step 3 using another color of your choice until you have modeled eight time periods. At the third time period, insert some navy beans; at the fifth time period, insert pinto beans; at the seventh time period, insert black beans. Record the strata order used by your group. Keep this record as a key to your models.
5. Exchange the models from your group with those of another group. Try to determine the order of strata used by that group.
6. Clean up your lab materials according to your teacher's instructions. Wash your hands before leaving the lab.

Analyze and Conclude

1. **Recognizing Relationships** Explain how this model relates to how sedimentary strata are formed.
2. SCIENTIFIC METHODS **Analyzing Conclusions** Describe your success at inferring the other group's strata order.
3. SCIENTIFIC METHODS **Inferring Conclusions** Compare the occurrence of the three types of "fossils" across the models from each group. What is the significance of these fossils? Explain your reasoning.
4. **Analyzing Models** If the same fossils are contained within different kinds of strata, can they be classified as index fossils? Explain.

Lab

Time Required

One 30-minute class period

Ratings

Teacher Prep	
Student Setup	
Concept Level	
Cleanup	

Safety Cautions

Remind students to be careful when handling any glass objects.

Tips and Tricks

Substitutions Most of the materials in this activity can be replaced with supplies you have on hand. A large test tube or small plastic beverage container can be substituted for the graduated cylinder. If you use a beverage container, you may need to remove its neck to allow easier introduction of materials. Remember that larger containers will require a larger amount of "sediments." Inexpensive colored gravel is available at craft or pet stores. Colored beads or similar materials maybe substituted for the gravel. You can use any type of bean that will sink. You can substitute other objects, including jewelry beads, game markers, and charms. You can even have students sculpt fossil models from waterproof clay and include them in the mixture.

Answers to Analyze and Conclude

1. When the gravel is poured into the graduated cylinder, it models the formation of sedimentary layers.
2. Answers should include reasons why the inferred order is correct or incorrect.
3. These fossils are in the same layers across all the groups. Therefore, they could be used as index fossils.
4. Index fossils are fossils of organisms that were common and had a widespread geographical distribution during a certain time in Earth's history. Therefore, the type of layer the fossils are found in is less important than when the layer was formed.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 19

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the keyword **HX8LIFS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Miller-Urey Apparatus Ask students to draw a diagram of the Miller-Urey apparatus. Have them label all components of the diagram. LS Visual

Evolution of Life Draw a table on the board. Across the top of the table, write the following headings: *Time Span, Evolutionary Developments,* and *Mass Extinctions*. Down the left side of the table write these headings: *Precambrian Time, Paleozoic Era, Mesozoic Era,* and *Cenozoic Era.* Have students take turns filling in the information. LS Visual

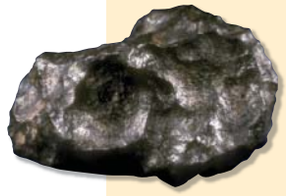
Chapter 19 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8LIFS

Key Ideas	Key Terms

1 How Did Life Begin?

- The Miller-Urey experiment showed that, under certain conditions, organic compounds could form from inorganic molecules.
- Among the scientific theories that address the origin of life, one suggests that life began close to hydrothermal vents, and another proposes that organic molecules arrived on early Earth from a meteorite.
- The formation of microspheres might have been the first step toward cellular organization.



microsphere (449)
ribozyme (449)

2 The Age of Earth

- Both the geographical distribution of organisms and when organisms lived on Earth can be inferred by examining the fossil record.
- In order to analyze fossil evidence, paleontologists use both relative and absolute dating methods to date fossils.
- The geologic time scale is based on evidence in the fossil record and has been shaped by mass extinctions.

fossil record (450)
relative dating (451)
radiometric dating (452)
half-life (452)
geologic time scale (453)
mass extinction (453)

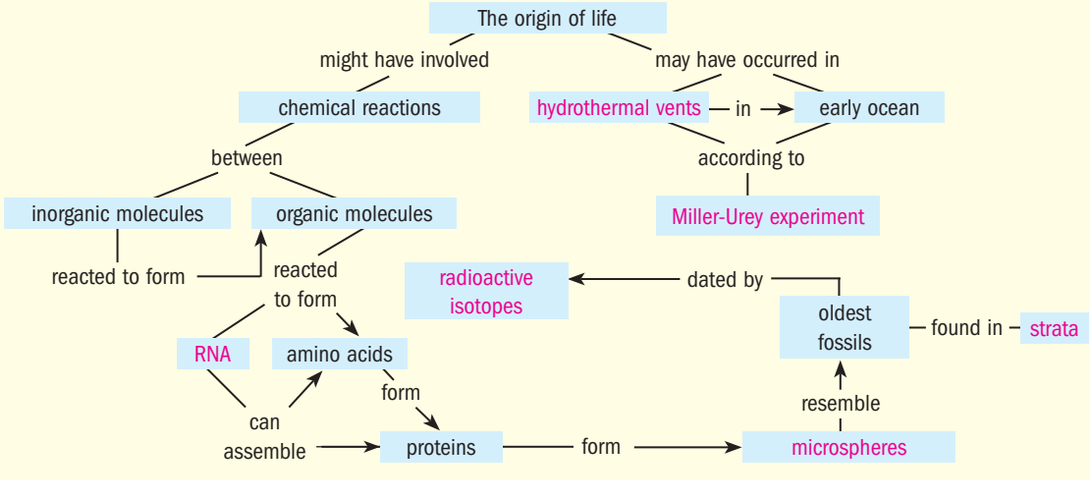
3 Evolution of Life

- Prokaryotes and later, eukaryotes, evolved in the Precambrian. The evolution of multicellular life preceded the evolution of modern life-forms. Atmospheric oxygen allowed life to survive on land.
- During the Paleozoic Era, marine invertebrates diversified, and marine vertebrates evolved. The first land plants evolved. Some arthropods, and then some vertebrates, colonized the land.
- Reptiles, dinosaurs, and birds were the dominant animals in the Mesozoic Era, and mammalian animals were dominant in the Cenozoic Era.

cyanobacteria (455)
endosymbiosis (456)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 19 Review

READING TOOLBOX

1. **Describing Time** Describing time is an important skill when discussing historical events. Use this skill to organize the events of this chapter into a timeline.
2. **Concept Map** Construct a concept map that shows how life began based on information in the chapter. Include the following items in your map: *Miller-Urey experiment, hydrothermal vents, RNA, microspheres, strata,* and *radioactive isotopes.*

Using Key Terms

In your own words, write a definition for each of the following terms:

3. *microsphere*
4. *ribozyme*
5. *strata*

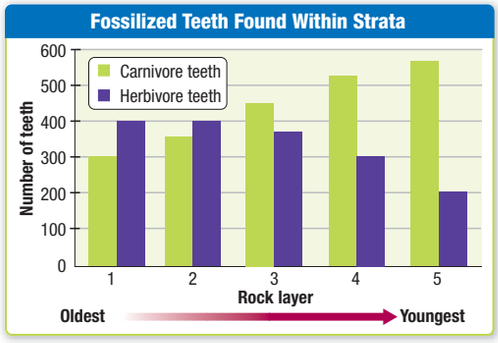
Use each of the following terms in a separate sentence.

6. *mass extinction*
7. *endosymbiosis*
8. *radiometric dating*

Understanding Key Ideas

9. Which gases did Oparin and Urey think were in the atmosphere of early Earth?
   a. water vapor, ammonia, and ozone
   b. oxygen gas, ozone, and water vapor
   c. hydrogen gas, ammonia, and methane
   d. methane, oxygen gas, and hydrogen gas
10. Which of the following can form spontaneously in water?
   a. DNA **c.** lipids
   b. proteins **d.** RNA
11. Where in the oceans do scientists think that life could have originated?
   a. in shallow bays
   b. near hydrothermal vents
   c. in areas filled with sediment
   d. in surface waters away from shore
12. The first multicellular organisms to invade land were
   a. reptiles. **c.** amphibians.
   b. mammals. **d.** fungi and plants.
13. A paleontologist can estimate the absolute age of an object by measuring the concentration of
   a. radioisotopes in the object.
   b. stable isotopes in the object.
   c. radioisotopes in rock surrounding the object.
   d. stable isotopes in rock surrounding the object.
14. Which ancient organisms were most likely responsible for the development of the ozone layer?
   a. protists **c.** cyanobacteria
   b. sulfur bacteria **d.** plantlike eukaryotes

Use the diagram to answer the following question.



15. At what point did carnivore teeth begin to outnumber herbivore teeth?
   a. between layer 1 and layer 2
   b. between layer 2 and layer 3
   c. between layer 3 and layer 4
   d. between layer 4 and layer 5

Explaining Key Ideas

16. **Distinguish** between microspheres and cells.
17. **Describe** how fossils are formed in a lake.
18. **Explain** the law of superposition.
19. **Name** the dominant types of organisms that evolved during the Mesozoic and Cenozoic eras.

Assignment Guide

Section	Questions
0	3, 4, 9, 10, 11, 16, 24, 29, 31
0	5, 6, 8, 13, 15, 17, 18, 20, 21, 22, 23, 28, 32
0	7, 12, 14, 19, 25, 26, 27, 30

Review

Reading Toolbox

1. Answers will vary.
2. See previous page for answer to concept map.

Using Key Terms

3. A *microsphere* is a tiny droplet that traps amino acids.
4. A *ribozyme* is a form of RNA with enzymatic properties.
5. *Strata* are layers of sedimentary rock.
6. *Mass extinctions* have shaped the way the geologic time scale is organized.
7. Eukaryotic cells are thought to have evolved by means of *endosymbiosis.*
8. *Radiometric dating* helps scientists to estimate the absolute age of a specimen.

Understanding Key Ideas

9. c 10. c 11. b 12. d
13. c 14. c 15. b

Explaining Key Ideas

16. Microspheres have short chains of amino acids organized into droplets. Cells have long chains of DNA that can replicate to form new cells.
17. An organism dies and is covered by sediment. As the organism decomposes, it leaves an impression in the sediment. Over time, the mold fills with sediment and forms a fossil.
18. Older strata are covered by younger strata meaning that older fossils lie below younger ones.
19. Reptiles, dinosaurs, and birds evolved during the Mesozoic era, and mammals evolved during the Cenozoic era.

Using Science Graphics

20. two
21. 12,500
22. The radioactive sample decays by half at each half-life, which produces an exponential curve rather than a straight line.
23. between the fourth and fifth half-lives

Using Science Graphics

Suppose the mass of a radioactive isotope is 100 kg, or 100,000 g. Use the table to answer the following questions.

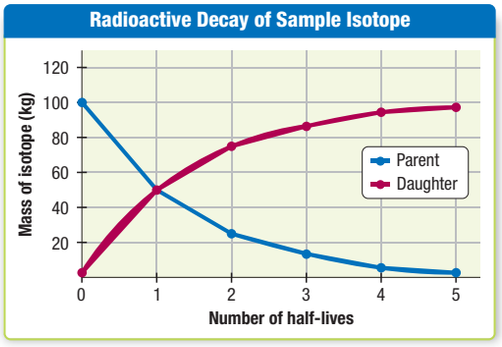
Radioactive Isotope Half-Life

Number of half-lives	Parent isotope	Daughter isotope
0	100,000 g	0 g
1	50,000 g	50,000 g
2	25,000 g	75,000 g
3	12,500 g	87,500 g
4	6,250 g	93,750 g
5	3,125 g	96,875 g

20. How many half-lives have passed when there is three times more daughter isotope than parent isotope?

21. How many grams of the parent isotope are left in the sample after three half-lives?

The data from the table can be plotted in a line graph. Use the line graph to answer the following questions.



22. Why is the line graph a curve instead of a straight line?

23. If a sample contained 94,000 g of the daughter isotope, where on the line graph would the sample be shown?

Critical Thinking

24. Making Inferences If the building blocks for life came to Earth on a meteorite, under what conditions might those building blocks have formed in space?

25. Judging Validity A classmate states that birds are living dinosaurs. Is the classmate correct? Explain.

26. Predicting Consequences Some forms of air pollution reduce the thickness of Earth's ozone layer. How might this change affect modern life?

27. Recognizing Relationships Propose a hypothesis for the appearance of all animal phyla on Earth within a relatively short period during late Precambrian time and the early Cambrian Period.

28. Justifying Conclusions Justify the argument that today's organisms would not exist if mass extinctions had not occurred.

Methods of Science

29. Forming Hypotheses State the hypothesis that was tested in the Miller-Urey experiment.

Alternative Assessment

30. Life Timeline Create a timeline or visual display that shows the major events of life from Precambrian time to the Mesozoic and Cenozoic eras.

31. Oral Report Thomas Cech and Sidney Altman shared a Nobel prize in 1989 for their work on RNA. Research their work and the rewards associated with winning a Nobel prize. Present your findings in an oral report.

Math Skills

32. Create a Graph The half-life of the radioisotope lead-210 is about 22.3 years. Construct a line graph that shows how lead-210 decays over 120 years.

Critical Thinking

24. They might have formed in an atmosphere that was rich in hydrogen and that experienced electrical storms.

25. The classmate may be correct. Birds likely evolved from feathered dinosaurs, so the dinosaurs still have descendants that are alive on Earth. However, birds are very different from the dinosaurs that lived millions of years ago, so it may be incorrect to call them dinosaurs.

26. Damage to the ozone would allow more ultraviolet radiation to reach Earth. UV radiation can damage DNA.

27. Students may propose that changes in the sea environment might have increased selection pressure and resulted in rapid evolution and diversification.

28. Adaptations help ensure the reproductive success of an organism in changing environments. Mass extinctions occurred as a result of environmental change. Without this change, features of today's organisms would likely be quite different.

Methods of Science

29. In an atmosphere rich in hydrogen and lacking oxygen, organic compounds could form spontaneously during chemical reactions.

Alternative Assessment

30. Timelines should include the development of prokaryotes and eukaryotes, formation of the ozone layer, origins of organelles and multicellularity, mass extinction events, and the evolution of plants, fungi, arthropods, fishes, amphibians, reptiles, dinosaurs, birds, and mammals.

31. Answers will vary. Accept all reasonable responses.

Math Skills

32. Graphs should show the following: The *Mass of Isotope Remaining* is the label for the *y*-axis. The *Number of Years* is shown on the *x*-axis and ranges from 0 to 120. At 22.3 years, $\frac{1}{2}$ the sample is left. At 44.6 years, $\frac{1}{4}$ of the sample is left. At 66.9 years, $\frac{1}{8}$ of the sample is left. At 89.2 years, $\frac{1}{16}$ of the sample is left. At 111.5 years, $\frac{1}{32}$ of the sample is left.

Chapter 19 Standardized Test Prep

TEST TIP If time permits, take short mental breaks to improve your concentration during a test.

Science Concepts

1. In the Miller-Urey experiment, which of the following substances were formed after electricity activated chemical reactions?

A ozone **C** hydrocarbons
B methane **D** inorganic molecules

2. What is the function of a ribozyme?

F to form microspheres
G to catalyze protein assembly
H to catalyze RNA formation
J to store genetic information

3. Which of the following environments is least likely to cause fossil formation?

A stream **C** wet lowland
B desert plain **D** area near a volcano

4. In an area that has not been disturbed, which rock layer is the oldest?

F the layer closest to Earth's surface
G the layer right above Earth's crust
H the layer deepest within Earth's crust
J the layer that contains fossils

5. Most scientists believe that mitochondria are formed from

A aerobic bacteria.
B photosynthetic bacteria.
C aerobic eukaryotes.
D anaerobic archaea.

6. What were the first vertebrates?

F reptiles **H** amphibians
G jawed fishes **J** jawless fishes

7. What percentage of land species was eliminated during the mass extinction that occurred 65 million years ago?

A about 45% **C** about 70%
B about 67% **D** about 96%

Using Science Graphics

The table depicts the estimated abundance of certain elements on Earth and in meteorites. Use the table to answer the following questions.

Estimated Abundance of Elements

Element	Percentage of total mass of Earth	Percentage of total mass of meteorites
Iron	36.0	27.2
Oxygen	28.7	33.2
Magnesium	13.6	17.1
Silicon	14.8	14.3
Sulfur	1.7	1.9

8. Which element is found in a greater abundance on Earth than in meteorites?

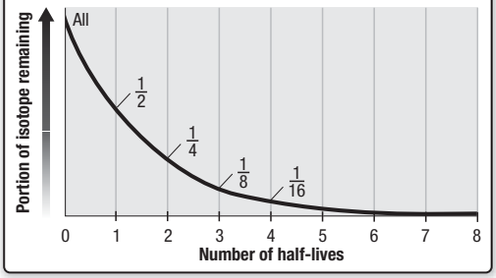
F iron **H** oxygen
G sulfur **J** magnesium

9. If this table is typical of the abundance of all elements on Earth, in meteorites, and on other planets, which statement would be supported?

A Earth and meteorites have similar origins.
B Earth and meteorites have different origins.
C All meteorites formed from parts of Earth.
D All elements on Earth come from meteorites.

Use the graph to answer the following question.

Decay of Radioactive Isotope



10. If the half-life of carbon-14 is 5,730 years, how many years would it take for 7/8 of the original amount of carbon-14 in the sample to decay?

F 5,014 years **H** 17,190 years
G 11,460 years **J** 22,920 years

State Resources

For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. C **2.** G **3.** B
4. H **5.** A **6.** J
7. B **8.** F **9.** A
10. H

TEST DOCTOR

Question 3 **A.** Incorrect. A stream can leave sediment layers over an organism to form a fossil. **B.** Correct. A dry desert is least likely to allow fossil formation. **C.** Incorrect. Fossils can form in wet lowlands because of wet layers of soil. **D.** Incorrect. A volcano can cause fossilization by covering an organism in layers of lava.

Question 5 **A.** Correct. Mitochondria are thought to have evolved from symbiotic, aerobic bacteria. **B.** Incorrect. Chloroplasts are descendants of photosynthetic bacteria. **C.** Incorrect. Eukaryotes contain mitochondria and other organelles. **D.** Incorrect. Anaerobic archaea are prokaryotic, single-celled organisms that evolved early in Precambrian time.

Question 6 **F.** Incorrect. Reptiles evolved from amphibians. **G.** Incorrect. Jawed fishes evolved from the jawless fishes 100 million years later. **H.** Incorrect. Amphibians were the first land vertebrates that came out of the sea. **J.** Correct. Jawless fishes are considered the first vertebrates of the oceans.