

19 Study Guide

Big idea Evolution

Paleontologists use fossils to learn about the structure and environments of ancient organisms. Fossils also give clues to events that happened during Earth's history.

19.1 The Fossil Record

From the fossil record, paleontologists learn about the structure of ancient organisms, their environment, and the ways in which they lived.

Relative dating allows paleontologists to determine whether a fossil is older or younger than other fossils. Radiometric dating uses the proportion of radioactive to stable isotopes to calculate the age of a sample.

The geologic time scale is based on both relative and absolute dating. The major divisions of the geologic time scale are eons, eras, and periods.

Building mountains, opening coastlines, changing climates, and geological forces have altered habitats of living organisms repeatedly throughout Earth history. In turn, the actions of living organisms over time have changed conditions in the land, water, and atmosphere of planet Earth.

| | |
|--------------------------|---------------------------|
| extinct (538) | half-life (540) |
| paleontologist (539) | geologic time scale (542) |
| relative dating (540) | era (543) |
| index fossil (540) | period (543) |
| radiometric dating (540) | plate tectonics (544) |

19.2 Patterns and Processes of Evolution

If the rate of speciation in a clade is equal to or greater than the rate of extinction, the clade will continue to exist. If the rate of extinction in a clade is greater than the rate of speciation, the clade will eventually become extinct.

Evidence shows that evolution has often proceeded at different rates for different organisms at different times over the long history of life on Earth.

Two important patterns of macroevolution are adaptive radiation and convergent evolution. Adaptive radiation occurs when a single species or a small

group of species evolves over a relatively short time into several different forms that live in different ways. Convergent evolution occurs when unrelated organisms evolve into similar forms.

The relationship between two coevolving organisms often becomes so specific that neither organism can survive without the other. Thus, an evolutionary change in one organism is usually followed by a change in the other organism.

| | |
|----------------------------------|------------------------------|
| macroevolutionary patterns (546) | punctuated equilibrium (549) |
| background extinction (548) | adaptive radiation (550) |
| mass extinction (548) | convergent evolution (551) |
| gradualism (549) | coevolution (551) |

19.3 Earth's Early History

Earth's early atmosphere contained little or no oxygen. It was principally composed of carbon dioxide, water vapor, and nitrogen, with lesser amounts of carbon monoxide, hydrogen sulfide, and hydrogen cyanide.

Miller and Urey's experiment suggested how mixtures of the organic compounds necessary for life could have arisen from simpler compounds on a primitive Earth.

The "RNA world" hypothesis proposes that RNA existed by itself before DNA. From this simple RNA-based system, several steps could have led to DNA-directed protein synthesis.

The endosymbiotic theory proposes that a symbiotic relationship evolved over time between primitive eukaryotic cells and the prokaryotic cells within them.

The development of sexual reproduction sped up evolutionary change because sexual reproduction increases genetic variation.

endosymbiotic theory (556)

Think Visually Construct a table comparing the Paleozoic, Mesozoic, and Cenozoic eras. Include the approximate time periods for each era and identify the characteristic organisms.

Study Online



REVIEW AND ASSESSMENT RESOURCES

Editable Worksheets Pages of Study Worksheets A and B, Lab Manuals A and B, and the Assessment Resources Book are available online. These documents can be easily edited using a word-processing program.

Lesson Overview Have students reread the Lesson Overviews to help them study chapter concepts.

Vocabulary Review The *Flash Cards* and *Crossword* provide an interactive way to review chapter vocabulary.

Chapter Assessment Have students take an online version of the Chapter 19 Assessment.

Standardized Test Prep Students can take an online version of the Standardized Test Prep. You will receive their scores along with ideas for remediation.

Diagnostic and Benchmark Tests Use these tests to monitor your students' progress and supply remediation.

BIOLOGY.com

Search

Chapter 19

GO

• Crossword

• Chapter Assessment

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Ubd Performance Tasks

SUMMATIVE TASK Divide the class into groups of three, and assign one lesson of the chapter to each group member. Ask group members to work together to create a condensed, visual version of the chapter. Students can draw sketches, use computer graphics, or copy illustrations from the text and display them with labels on a poster board; or they can create a slideshow with presentation software.

TRANSFER TASK Have students use what they have learned about fossils, evolution, and geologic time to write about a fossil excavation in the future in which paleontologists uncover fossils of organisms living today. Tell them to include answers to these questions in their report: Where will the paleontologists find fossils? What was preserved as fossils? What evidence might these fossils provide about environmental change?

Answers

THINK VISUALLY

Students can use the information in **Figure 19-5** and in the time line pages to complete their table.

Lesson 19.1

UNDERSTAND KEY CONCEPTS

- b
- d
- a
- a
- b
- The age of a fossil is estimated by comparing its placement in rock layers with the placement of other fossils in other rock layers.
- Radioactive elements decay at a steady rate, measured in units called half-lives. Radiometric dating uses half-lives to determine the age of rocks. Scientists calculate the age of rocks based on the amount of remaining radioactive isotopes they contain.
- The geologic time scale is a timeline of Earth's history. It was developed by studying the boundaries between rock layers and by using both relative and absolute dating.
- Sample answer: An example of how the activities of organisms have affected Earth's environment is the impact photosynthetic organisms had on the composition of the atmosphere during the Proterozoic Eon. These organisms added oxygen and removed carbon dioxide from the atmosphere.

THINK CRITICALLY

- The fossil is 22,920 years old. At 1/16 the carbon-14 of living organisms, it has gone through four half-lives of carbon-14. ($5730 \text{ yrs} \times 4 = 22,920 \text{ yrs}$)
- Sample answer: Some organisms never fossilized because their remains never became part of sedimentary rock. For example, many organisms had soft bodies. With no hard body parts, such as bones or scales, they decayed without being fossilized. Some gaps are the result of erosion erasing the rock layers.

Lesson 19.2

UNDERSTAND KEY CONCEPTS

- c
- a
- b
- In adaptive radiation, a single species or small group of species evolves over a relatively short time into several different forms that live in different ways. An example of adaptive radiation is the evolution of Galápagos finches.
- Punctuated equilibrium is a pattern of evolution in which long periods of time with little or no evolutionary change are interrupted by brief periods of rapid change.
- Sample answer: Coevolution occurs when the relationship between two organisms becomes so specific that neither organism can survive without the other. As a result, an evolutionary


19 Assessment

19.1 The Fossil Record

Understand Key Concepts

- Scientists who specialize in the study of fossils are called
 - biologists.
 - paleontologists.
 - zoologists.
 - geologists.
- Sedimentary rocks usually form when layers of small particles are compressed
 - in the atmosphere.
 - in a snow field.
 - in mountains.
 - under water.
- Using C-14 to analyze rock layers
 - is a method of estimating absolute age.
 - is a method of estimating relative age.
 - can only be used on extremely ancient rock layers.
 - is impossible because rock layers do not contain carbon.
- Half-life is the time required for half the atoms in a radioactive sample to
 - decay.
 - double.
 - expand.
 - be created.
- According to the theory of plate tectonics,
 - Earth's climate has changed many times.
 - Earth's continents move very slowly.
 - evolution occurs at different rates.
 - giant asteroids crashed into Earth in the past.
- How does relative dating enable paleontologists to estimate a fossil's age?
- Explain how radioactivity is used to date rocks.
- What is the geologic time scale, and how was it developed?
- How have the activities of organisms affected Earth's environment?

Think Critically

- Calculate** The half-life of carbon-14 is 5730 years. What is the age of a fossil containing 1/16 the amount of carbon-14 of living organisms? Explain your calculation. 
- Apply Concepts** Evolutionary biologists say that there is a good reason for gaps in the fossil record.

566 Chapter 19 • Assessment

Can you explain why some extinct animals and plants were never fossilized?

19.2 Patterns and Processes of Evolution

Understand Key Concepts

- The process that produces similar-looking structures in unrelated groups of organisms is
 - adaptive radiation.
 - coevolution.
 - convergent evolution.
 - mass extinction.
- The general term for large-scale evolutionary changes that take place over long periods of time is called
 - macroevolution.
 - coevolution.
 - convergent evolution.
 - geologic time.
- Cladograms that are based on the fossil record always show
 - which organisms are direct ancestors of the others.
 - relationships based on shared derived characteristics.
 - that clades are made up only of extinct species.
 - relative ages of organisms in the clade.
- Explain and give an example of the process of adaptive radiation.
- Explain the model of evolution known as punctuated equilibrium.
- Use an example to explain the concept of coevolution.

Think Critically

- Infer** Major geologic changes often go hand in hand with mass extinctions. Why do you think this is true?
- Apply Concepts** Why is rapid evolution especially likely to occur in a small population that has been separated from the main population?
- Apply Concepts** What is the role of natural selection in adaptive radiation? How do these processes lead to diversity?

change in one organism may be followed by a change in the other organism. An example is the evolution of flowers and their specific pollinators.

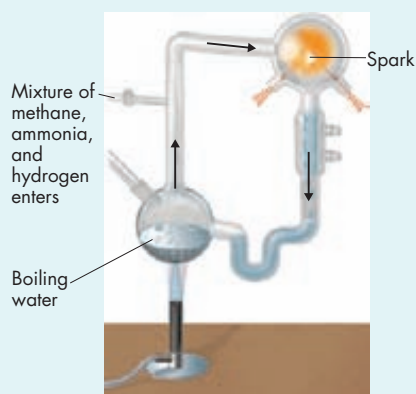
THINK CRITICALLY

- Geological changes, such as volcanic eruptions and meteorite collisions, can quickly change the climate and environmental conditions. When the environment changes in an extreme way, many organisms in that environment lack adaptations that enable them to survive.
- Once separated, a small population can evolve faster than a larger one because genetic changes spread more quickly among fewer individuals.
- Natural selection leads to adaptive radiation. Living things respond to changes in their environments, and when they enter a new environment, they are faced with a new set of selective pressures. Those organisms with adaptive characteristics will survive and reproduce.

19.3 Earth's Early History

Understand Key Concepts

- Earth's early atmosphere contained little or no
 - water vapor.
 - carbon dioxide.
 - nitrogen.
 - oxygen.
- In their experiment that modeled conditions on ancient Earth, Miller and Urey used electric sparks to simulate
 - temperature.
 - sunlight.
 - atmospheric gases.
 - lightning.
- Outlines of ancient cells that are preserved well enough to identify them as prokaryotes are
 - microfossils.
 - heterotrophs.
 - autotrophs.
 - phototrophic.
- What hypotheses have scientists proposed to explain Earth's early atmosphere and the way the oceans formed?
- The diagram below shows the apparatus that Miller and Urey used in their experiment. Explain both what water and gases were meant to represent and what Miller and Urey were hoping to accomplish.



- How are proteinoid microspheres similar to living cells?
- How did the addition of oxygen to Earth's atmosphere affect the evolution of life?
- According to the endosymbiotic theory, how did mitochondria originate?

solve the CHAPTER MYSTERY

MURDER IN THE PERMIAN

Solving a 250-million-year-old murder mystery isn't easy! In recent years, scientists have studied the chemistry of Permian rocks and changes in the fossil record. Some researchers determined that enormous and long-lasting volcanic eruptions in Siberia vented carbon dioxide into the atmosphere, causing a massive change in global climate. This put species and ecosystems under great environmental stress.

Other researchers used geochemical analyses to show that atmospheric oxygen levels dropped to roughly half of what they are today. Huge parts of the oceans lost all oxygen. Because of the reduction in available oxygen, land animals near sea level might have been gasping for breath as you would on top of Mount Everest.

Finally, there is evidence that an asteroid hit Earth! To this day, paleontologists are testing competing hypotheses that try to explain which of the events that occurred at this time caused the mass extinction. However, these hypotheses are constantly changing and have probably changed since this book was written.

- Compare and Contrast** How do current hypotheses about the Permian extinction compare with the predominant theory about the Cretaceous extinction?
- Form a Hypothesis** From the information in this book, suggest an explanation for the Permian mass extinction.
- Pose Questions** What questions could you ask to find out whether your hypothesis is correct? What evidence would answer those questions?
- Connect to the Big Idea** What role have mass extinctions played in the history of life?



CHAPTER MYSTERY

After students have read through the Chapter Mystery, have them discuss as a class factors that could have contributed to the Permian extinction.

Ask Is it possible that factors identified in all three competing hypotheses contributed to the extinction? (*Students' responses should include a well-reasoned argument for or against this possibility.*)

Ask What is one thing the three hypotheses have in common? (*All three hypotheses are related to major environmental change.*)

Ask In spite of the extinction, there were survivors. What kinds of opportunities were there for the survivors? How did they probably respond? (*New niches opened up. With little competition, there was probably adaptive radiation resulting in new species.*)

CHAPTER MYSTERY ANSWERS

- Current hypotheses propose that the Permian extinction had multiple causes, while the Cretaceous extinction may have had only one major cause—the effects of an asteroid impact on Earth's climate.
- Sample answer: Volcanic eruptions and the impact of an asteroid made environmental conditions become so harsh that many species could not survive.
- Sample answer: Is there geological evidence of multiple volcanic eruptions? Is there an impact crater that dates to this time? Materials from volcanic and asteroid fallout in sedimentary rocks might provide an answer.
- Big idea** Sample answer: Mass extinctions have occurred at least five times. Each time, the process of adaptive radiation resulted in new organisms that were able to take advantage of new environments.



Students can explore fossils with the Untamed Science crew by watching **Stories in Stone**.

Lesson 19.3

UNDERSTAND KEY CONCEPTS

- d
- d
- a
- When Earth was young, a collision with a very large object produced enough heat to melt Earth. Elements then rearranged themselves by density. The least dense elements, including hydrogen and nitrogen, formed the first atmosphere. About 4.2 billion years ago, Earth cooled enough for water to condense. Rain fell, and permanent oceans formed.

- The water was meant to simulate the ocean. The gases were meant to simulate Earth's early atmosphere. Miller and Urey were trying to show that early Earth conditions could have produced organic compounds.
- Proteinoid microspheres are similar to cells because they have a selectively permeable membrane across which water and nutrients can travel and a means of storing and releasing energy.
- The addition of oxygen to the atmosphere caused some organisms to become extinct or restricted to oxygen-free habitats

because they had evolved in an oxygen-free atmosphere. Some organisms, however, evolved new metabolic pathways that used oxygen for respiration.

- Mitochondria may have evolved from endosymbiotic prokaryotes that were able to use oxygen to generate energy-rich ATP molecules.

THINK CRITICALLY

- 29. Condensing water vapor represents rain. Rain would have carried many chemicals from the atmosphere into the primitive oceans. The oceans were probably the site of the first steps in chemical evolution.
- 30. When cells engulfed bacteria that evolved into mitochondria they obtained a way to get energy from food molecules. When engulfed bacteria evolved into chloroplasts, cells obtained a way to make food molecules (photosynthesis).

Connecting Concepts

USE SCIENCE GRAPHICS

- 31. Fossils in layer C are probably older. Layer C is buried more deeply than layer A.
- 32. None of the rock layers in Location 2 are the same age as layer C in Location 1.
- 33. Useful index fossils are easily identified and occur in only a few rock layers, but the rock layers will be found in many places.

WRITE ABOUT SCIENCE

- 34. Answers will vary but should include the following ideas: Volcanic activity was very common on early Earth but is now relatively rare. The atmosphere on early Earth was made mainly of carbon dioxide, nitrogen, and water vapor. Now it is mainly nitrogen and oxygen. The temperatures on early Earth were much hotter, and Earth was bombarded by asteroids.
- 35. Sample answer: Sharks, dolphins, and penguins belong to three different groups of animals—fish, mammals, and birds. However, they all live in an aquatic environment. Because of the similar selection pressures experienced, all three animals, though distantly related, developed similarities in body shape such as streamlined bodies and fins or flippers. This is an example of convergent evolution.
- 36. **Big idea** Students' responses should include the fact that sedimentary rock usually forms as mud, silt, and sand gradually fall to the bottom of a body of water, covering the bodies of organisms that also fell to the bottom. The deepest layers of sediment are the oldest, and, therefore, fossils found in the deepest layers are the oldest. Fossil organisms in layers near the top of the formation are younger and more recently evolved than those in the deeper layers.
- 37. **Big idea** Sample answer: Gould and Eldredge were acknowledging that in the history of life, lack of change (stasis) can be just as important as change. Their model of punctuated equilibrium described a pattern of evolution in which long periods of equilibrium are interrupted by short bursts of change.

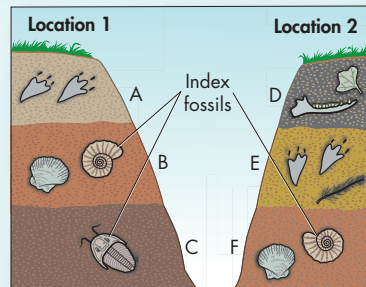
Think Critically

- 29. **Use Models** What part of Miller and Urey's apparatus represents rain? What important role would rain play in chemical evolution?
- 30. **Relate Cause and Effect** How do you think the cells that took in the ancestors of mitochondria and chloroplasts benefited from the relationship?

Connecting Concepts

Use Science Graphics

The diagram shows rock layers in two different places. Use the diagram to answer questions 31 and 32.



- 31. Which fossils are probably older—those in layer A or those in layer C? How do you know?
- 32. Which rock layer in location 2 is probably about the same age as layer C in location 1? How do you know?
- 33. What are the characteristics of a useful index fossil?

Write About Science

- 34. **Explanation** Write a paragraph comparing conditions on early Earth with those on modern Earth.
- 35. **Description** Use the example of body shape in sharks, dolphins, and penguins to explain convergent evolution.
- 36. **Assess the Big idea** Explain how the formation of sedimentary rock gives paleontologists information about the sequence in which life forms appeared on Earth.
- 37. **Assess the Big idea** When describing their theory of punctuated equilibrium, Stephen Jay Gould and Niles Eldredge often used the motto “stasis is data.” Stasis is another word for equilibrium. Explain what Gould and Eldredge meant.

Analyzing Data

The table below compares the half-life of several radioactive atoms. Use the table to answer questions 38 and 39.

| Isotope and Decay Product | Half-Life (years) |
|----------------------------|-------------------|
| Rubidium-87 → Strontium-87 | 48.8 billion |
| Thorium-232 → Lead-208 | 14.0 billion |
| Uranium-235 → Lead-207 | 704.0 million |
| Uranium-238 → Lead-206 | 4.5 billion |

- 38. **Interpret Data** Which atoms have half-lives that are longer than the age of the oldest microfossils?
 - a. uranium-235 only
 - b. thorium-232, rubidium-87, and uranium-235
 - c. rubidium-87, thorium-232, and uranium-238
 - d. uranium-235 and rubidium-87
- 39. **Apply Concepts** Lead-207 is found only in rocks that also contain uranium-235. Analysis of a sample shows that it has three times as many atoms of lead-207 as there are atoms of uranium-235. How many half-lives have passed since this rock formed?
 - a. one
 - b. two
 - c. three
 - d. four

Analyzing Data

PURPOSE Students will analyze data to demonstrate an understanding of isotope decay and half-life.

PLANNING Have students review half-lives using the Lesson 19.1 **Quick Lab**. Point out that information about the age of the oldest microfossils is found in Lesson 19.3.

ANSWERS

- 38. c
- 39. b

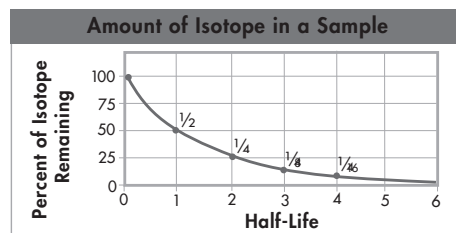
Standardized Test Prep

Multiple Choice

- Useful index fossils are found
 - in a small area for a short time.
 - in a small area for a long time.
 - over a large area for a short time.
 - over a large area for a long time.
- What happens if the rate of extinction in a clade is greater than the rate of speciation?
 - The clade will eventually become extinct.
 - The clade will continue to exist.
 - The species in the clade will become more varied.
 - The number of species in the clade will stay the same.
- Which of the following is evidence for the endosymbiotic theory?
 - Mitochondria and chloroplasts contain DNA similar to bacterial DNA.
 - Mitochondria and chloroplasts have similar functions in the cell.
 - Mitochondria and chloroplasts have no DNA of their own.
 - Mitochondria and chloroplasts can live independently when removed from the eukaryotic cell.
- Carbon-14 is NOT useful for dating most fossils because
 - it has a very long half-life.
 - it has a very short half-life.
 - most organisms contain more potassium than carbon.
 - it is found only in certain rock layers.
- The movement of continents has played a significant role in evolution because
 - continents move rapidly and some organisms cannot adjust.
 - without the movement of continents, there would be no water on Earth.
 - the movement of continents has caused environments to change.
 - all mass extinctions are the result of continental drift.

Questions 6 and 7

The graph shows the decay of radioactive isotopes. Use the information in the graph to answer the questions that follow.



- The half-life of thorium-230 is 75,000 years. How long will it take for $\frac{7}{8}$ of the original amount of thorium-230 in a sample to decay?
 - 75,000 years
 - 225,000 years
 - 25,000 years
 - 150,000 years
- The half-life of potassium-40 is about 1.3 billion years. After four half-lives have passed, how much of the original sample will be left?
 - $\frac{1}{16}$
 - $\frac{1}{16} \times 1300$ million grams
 - $\frac{1}{4}$
 - $\frac{1}{4} \times 1300$ million grams

Open-Ended Response

- How does the process by which sedimentary rock forms allow scientists to determine the relative ages of fossils?

If You Have Trouble With . . .

| Question | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------|------|------|------|------|------|------|------|------|
| See Lesson | 19.1 | 19.2 | 19.3 | 19.1 | 19.1 | 19.1 | 19.1 | 19.1 |

History of Life **569**

Answers

- C
- A
- A
- B
- C
- B
- A
- Sedimentary rock usually forms when particles of sand, silt, clay, or lime settle in layers at the bottom of a body of water. These layers cover the bodies of dead organisms. Other layers with other organisms build up over the lower layers. Unless the layers of rock are disturbed, scientists can infer that fossil specimens in lower layers are older than specimens buried in more recent layers that were deposited on top.

Test-Taking Tip

REVIEW ANSWERS

Tell students to use any time remaining after they have answered all of the questions on a test to review their answers. Point out that they should change only those responses they are sure are incorrect. If the answer booklet is separate from the test question booklet, students should make sure the question numbers correctly correspond with their responses in the answer booklet.



Plan Ahead

Have students preview the Unit 5 Project a few days before writing to give them time to think through what they need to include in their scripts. If possible, provide students with an example of a script for a documentary. You may find one online or in a library. Point out that a script includes both text for a narrator to speak and descriptions of the images shown throughout the documentary. It might also include interviews with experts.

Monitor the Project

Suggest students begin by making a basic outline of how the documentary will proceed. As students write their scripts, circulate through the class, asking individual students how the script addresses the five misconceptions about evolution.

Ask What example are you including that demonstrates the process of natural selection?

Ask What are you including that addresses the misconception that gaps in the fossil record disprove evolution?

Project Assessment

Make sure students use the rubric and reflection questions to assess their work. Then, use the rubric to assign a final score. Note that it is important to value the creativity of students' work as well as the content when you score their projects. If desired, talk with students about any differences between their self-assessment scores and your assigned score.



NATIONAL SCIENCE EDUCATION STANDARDS

UCP IV

CONTENT C.3.a, C.3.b, C.3.c, C.3.d

INQUIRY A.1.f, A.2.e, A.2.f

Unit Project

Evolution Documentary

Have you ever flipped through the channels and stopped on a documentary that caught your eye? And before you knew it an hour had passed? Documentaries can be a great way to learn about fascinating topics. Imagine you are a TV producer and have been hired to produce a documentary on evolution for a public television station. Your target audience is the general public.

Your Task Write a script for a 5–10 minute segment of an evolution documentary and present it to your class.

Be sure to

- discuss evidence for evolution by bringing in specific examples.
- present the information clearly and in an engaging manner.
- explain why the misconceptions listed below are *not* true:
 - 1) Evolution causes organisms to improve—life has gotten better over time.
 - 2) Evolution is not observable or testable.
 - 3) Gaps in the fossil record disprove evolution.
 - 4) Natural selection involves organisms “trying” to adapt.
 - 5) Natural selection is the only way that populations can change over time.



Reflection Questions

1. Score your documentary using the rubric below. What score did you give yourself?
2. What did you do well in this project?
3. What needs improvement?
4. What do you think a member of the general public would learn from your documentary?

Assessment Rubric

| Score | Scientific Content | Quality of Documentary Script |
|-------|---|---|
| 4 | Documentary provides accurate evidence for evolution and clearly corrects several misconceptions. | Information is presented in a clear, organized, and engaging manner. |
| 3 | Documentary provides some accurate evidence for evolution and attempts to correct misconceptions. | Information is presented in a clear and organized manner, but it could be more engaging. |
| 2 | Documentary provides little evidence for evolution and does not correct misconceptions well. | Information could be presented in a clearer manner. The script needs editing. |
| 1 | Documentary does not provide evidence for evolution and does not attempt to correct misconceptions. | Information is presented in a disorganized and confusing manner. The script needs a lot of editing. |

570 Unit 5 Project

21st Century Skills

To be successful in the 21st century, students need skills and learning experiences that extend beyond subject area mastery. The Unit 5 Project helps students build the following 21st Century Skills: *Information and Media Literacy; Communication Skills; Creativity and Intellectual Curiosity; Self-Direction; and Accountability and Adaptability.*

FOCUS ON PROBLEM IDENTIFICATION, FORMULATION, AND SOLUTION Extend this Unit Project by having students talk with other students, relatives, friends, and neighbors about their understanding of evolution. Then, have students discuss any misunderstandings of evolution they have encountered. Suggest they think of ways a documentary could address these misconceptions.

For more practice building 21st Century Skills, see The Chapter Mystery pages in **Study Workbook A.**