CK-12 Earth Science For High School Teacher's Edition

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CHAPTER 1 HS TE What is Earth Science?

Chapter Outline

1.1 Chapter 1: What Is Earth Science?

Chapter Overview

This chapter outlines the scientific method and the use of models. It also delineates the field of Earth science and describes several of its branches.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this lab, students will learn the steps of the scientific method by identifying and applying each step to a fun activity that compares variables between two types of bubble gum. Students will be asked to form a hypothesis, collect and organize data, use scientific measurements, and differentiate between qualitative and quantitative data.

- http://serc.carleton.edu/sp/mnstep/activities/27600.html

In this inquiry lab, students will use the scientific method to solve a problem. They will develop and test a hypothesis to answer the question: Does the number of times a pendulum swings depend on the weight attached to it or to the length of the string? The URL below is the teacher page for the activity. It has links to a student guide and handout.

- http://www.biologycorner.com/worksheets/pendulum.html

These Web sites may also be helpful:

You can go the URL below for information on common student misconceptions about science and the scientific endeavor.

- http://undsci.berkeley.edu/teaching/misconceptions.php

These URLs provide tips, strategies, and background for teaching high school students about the nature and process of science.

- http://undsci.berkeley.edu/teaching/tips.php
- http://undsci.berkeley.edu/teaching/912_implications2.php

At this URL, you can find links to downloadable scientific method flowcharts that portray science inquiry as a dynamic process.

- http://undsci.berkeley.edu/teaching/teachingtools.php

Pacing the Lessons

TABLE 1.1: short caption

Lesson	Class Period(s) (60 min)
1.1 The Nature of Science	1.5
1.2 Earth Science and Its Branches	1.0

1.2 Lesson 1.1: The Nature of Science

Key Concepts

- Scientific method
- Scientific models
- Importance of community in science
- Safety in science

Lesson Objectives

- Identify the goal of science.
- Explain the importance of asking questions.
- Describe how scientists study the natural world.
- Explain how and why scientists collect data.
- Describe the three major types of scientific models.
- Explain how a scientific theory differs from a hypothesis.
- Describe appropriate safety precautions inside and outside the science laboratory.

Lesson Vocabulary

- **conceptual model:** abstract, mental representation of an object or system
- **control:** factor that is kept constant in an experiment so that only the independent variable changes
- **dependent variable:** variable in an experiment that is measured to see how it is affected by changes in the independent variable
- **hypothesis:** testable, plausible explanation for a scientific question or problem
- **independent variable:** variable in an experiment that is changed by the researcher in order to test its effect on the dependent variable
- **mathematical model:** set of equations that represents a real-world process or simulates a natural system
- **model:** representation of an object or system that is simpler than reality and easier to manipulate and study
- **physical model:** physical representation of an object or system
- **scientific method:** series of steps for investigating a testable question using empirical information gathered from experimentation, experience, or observation
- **theory:** broad scientific explanation that has been repeatedly tested and supported by evidence

Teaching Strategies

Introducing the Lesson

Use a projector to show the class the world map of volcanoes at the following URL: http://www.cccarto.com/volcanofinder.html.

Question: What do you observe about volcanoes from this map?
Sample answer: Volcanoes are concentrated in certain locations. For example, a ring of many volcanoes surrounds the Pacific Ocean.

Question: What questions do the observations raise?
Sample answer: Why do so many volcanoes occur around the Pacific? What causes volcanoes?

Point out that most scientific investigations begin with questions that arise because of observations such as these. Tell students they will learn more about scientific investigations when they read this lesson.

Discussion

Lead the class in a discussion of the importance of falsification as a criterion of a scientific hypothesis. Discuss how a falsifiable, or testable, hypothesis can be proven wrong if it is indeed wrong because observations or measurements can be made to test it. Ask students to brainstorm hypotheses that can and cannot be falsified.

Building Science Skills

Use the worksheets in the PDF document below to give students practice identifying dependent and independent variables and controls in scientific experiments. Students may work alone or in groups on the activity, which could also be assigned as homework.

http://www.lessonplansinc.com/lessonplans/identifying_variables_ws.pdf

Differentiated Instruction

Ask students to think about how a hypothesis might gain the status of a theory. Then pair any ELL students or less proficient readers with other students, and have them work together to discuss and answer the question.

Enrichment

Have students who need extra challenges collaborate on making a science safety video to share with the rest of the class. Make sure the students include safety rules that you know will be especially important for Earth science class.

Science Inquiry

The scientific method is applied to myths and legends in the Discovery Channel's Mythbusters show. Video clips from the show are available at the first URL below. Have students use the PDF worksheet at the second URL below to analyze how the scientific method was applied in each video. After students view one or more videos, challenge small groups of students to develop their own investigation to test one of the myths or legends from the show.

https://www.google.com/search?q=mythbusters%20videos&hl=en&source=ig&tbm=vid (video clips from show)

http://sciencespot.net/Media/mythbusterswkst.pdf (student worksheet)

Overcoming Misconceptions

Several terms introduced in this lesson are often confused, leading to serious misconceptions about the nature of science and scientific investigation. The terms include hypothesis, scientific law, and theory. Have students go the following URL and under "Vocabulary Mix-ups," click on each of the terms to read about them in detail.

http://undsci.berkeley.edu/teaching/misconceptions.php

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 1.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 1.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Write a list of five interesting scientific questions. Is each one testable?

- [Answers will vary. The questions are testable if data can be gathered to answer them. *Sample question*: Does the speed of flowing water affect how much soil erosion it causes?]

2. A scientist was studying the effects of oil contamination on ocean seaweed. He thought that oil runoff from storm drains would keep seaweed from growing normally, so he decided to do an experiment. He filled two aquarium tanks of equal size with water and monitored the dissolved oxygen and temperature in each to be sure that they were equal. He introduced some motor oil into one tank and then measured the growth of seaweed in each tank. In the tank with no oil, the average growth was 2.57 cm. The average growth of the seaweed in the tank with oil was 2.37 cm. Based on this experiment:

a. What was the question that the scientist started with?

- [How does oil contamination affect the growth of seaweed?]

b. What was his hypothesis?

- [Oil runoff from storm drains will keep seaweed from growing normally.]

c. Identify the independent variable, the dependent variable, and the experimental control(s).

- [The independent variable is oil/no oil; the dependent variable is amount of growth of seaweed; the experimental controls are the volume of water, dissolved oxygen, and water temperature.]

d. What did the data show?

- [The data showed that seaweed grew less when exposed to oil.]

e. Can he be certain of his conclusion? How can he make his conclusion firmer?

- [He can only be certain that the conclusion applies to this repetition of the experiment, assuming his data are accurate. He could make his conclusion firmer and more general if he repeated the experiment many times and always got the same results.]

3. Explain three types of scientific models. What are one advantage and one disadvantage of each?

- [Three types of scientific models are physical, conceptual, and mathematical models. Physical models are physical representations of subjects. They can make something abstract more concrete, but they may be difficult to modify. Conceptual models tie together many ideas in an attempt to explain a phenomenon. They do not require materials to make but they may not be as easy to understand as physical models. Mathematical models are equations or sets of equations that take many variables into account. They are usually complicated but may be able to predict complex events.]

4. Identify or design five of your own safety symbols, based on your knowledge of safety procedures in a science laboratory.

- [Answers will vary, but might include safety symbols for broken glass, open flames, sharp objects, hot objects, and electrical hazards. Symbols should make apparent the nature of the hazard they represent.]

5. Design your own experiment based on one of your questions from question 1 above. Include the question, hypothesis, independent and dependent variables, and safety precautions. You may want to work with your teacher or a group.

- [Answers will vary. *Sample answer*: The question is: Does the speed of flowing water affect how much soil erosion it causes? The hypothesis is: Faster-flowing water erodes more soil particles. The independent variable is water speed, and the dependent variable is amount of soil eroded. Safety precautions would include wearing safety goggles and gloves, washing hands after handling soil, and wiping up any spills immediately to avoid a slippery floor.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 1.1 Quiz in *CK-12 Earth Science For High School Quizzes and Tests*.

Points to Consider

What types of models have you had experience with? What did you learn from them?

- [*Sample answer*: I have had experience with physical models such as globes and maps to represent Earth's surface. From these models, I learned about the relative sizes and positions of major features on Earth's surface.]

What situations are both necessary and dangerous for scientists to study? What precautions do you think they should use when they study them?

- [*Sample answer*: I think it is necessary and dangerous for scientists to study bacteria and viruses that cause human diseases. They should take precautions to prevent becoming infected when the study them. For example, they should wear masks, goggles, and gloves. They should also thoroughly wash their hands after their investigations.]

How does the scientific meaning of the word theory differ from the common usage? Can you find an example in the media of where the word was used incorrectly in a scientific story? The misuse of the word theory is rampant in the media and in daily life.

- [*Sample answer*: In science, a theory is an important and widely accepted explanation of a phenomenon. It has been repeatedly tested and not found to be false. In common usage, a theory is any potential explanation for an event or process that may or may not be true and that may or may not be supported by evidence. I read an article in which the hypothesis that was being tested in an experiment was referred to incorrectly as a theory.]

1.3 Lesson 1.2: Earth Science and Its Branches

Key Concepts

- Overview of Earth science
- Major branches of Earth science

Lesson Objectives

- Define and describe Earth science.
- Identify the field of geology.
- Describe oceanography.
- Define meteorology.
- Understand what astronomy studies.
- List other branches of Earth science, and explain how they relate to the study of Earth.

Lesson Vocabulary

No new vocabulary terms are introduced in this lesson.

Teaching Strategies

Introducing the Lesson

Most students will have studied Earth science in middle school. Ask students to recall what they remember about the focus of this science. Call on one student after another to state a topic that they think they will learn about in high school Earth science based on their prior experience. List all the relevant topics they identify on the board and add any major topics they fail to mention. Tell the class they will learn more about the scope of Earth science when they read this lesson.

Discussion

Assign the article on Earth's four spheres (lithosphere, hydrosphere, atmosphere, and biosphere) at the URL below. You may want to have students read the article as a homework assignment. After students have read the article, discuss how the branches of Earth science relate to the four spheres.

http://www.cotf.edu/ete/ess/ESSspheres.html

Activity

Students can learn more about Earth's spheres with the interactive animations, text, and thought questions at the following URL. They will gain a deeper understanding of how the spheres interact and why studying Earth as a system must involve scientists who specialize in different branches of Earth science.

http://www.classzone.com/books/earth_science/terc/content/investigations/es0103/es0103page01.cfm

Cooperative Learning

Divide the class into groups and have each group choose one of the branches of Earth science described in the lesson. Make sure all of the major branches of Earth science are covered. Then tell students to learn more about their assigned branch, including some possible careers in that branch. Ask a volunteer in each group to share with the class what they learned about their branch of Earth science.

Differentiated Instruction

Post several pieces of poster board on the walls around the classroom. On each poster, write the name of one of the major branches of Earth science (e.g., geology, oceanography, climatology, meteorology, environmental science). Divide the class into groups, incorporating any special needs students with other students who can assist them, and give each group a different colored marker. Then have groups circulate from one poster to another, working as a group to write everything they know about each branch of Earth science and commenting on what other groups have written. When all the groups have finished, use their most relevant writings and comments to summarize their knowledge of the branches of Earth science.

Enrichment

Ask one or more interested students to interview a local Earth scientist (e.g., meteorologist, geologist, oceanographer). They should prepare for the interview by making a list of questions they have about the scientist's specialty and how it relates to other specialties in Earth science. Invite the students to share what they learn from the interview with the rest of the class.

Science Inquiry

Work with students to brainstorm a research question pertaining to one of the branches of Earth science described in the lesson. Guide students in generating a testable hypothesis and identifying data they would need to test it. Discuss as a class how the research relates to other branches of Earth science.

Chemistry Connection

Show students how Earth science relates to chemistry by describing specific examples, such as the formation of chemical rocks. Point out how chemistry is necessary to explain this and many other Earth processes.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 1.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 1.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are three major branches of Earth science?

- [Three major branches of Earth science are (any three): geology, oceanography, climatology, meteorology, and/or environmental science.]

2. What branch of science deals with stars and galaxies beyond the Earth?

- [Astronomy is the branch of science that deals with stars and galaxies beyond Earth.]

3. List some important functions of Earth scientists.

- [*Sample answer*: Some important functions of Earth scientists include monitoring and predicting earthquakes, analyzing and forecasting weather, determining how and why Earth's climate is changing, and learning ways to protect the environment from human activities.]

4. What is the focus of a meteorologist?

- [The focus of a meteorologist is the atmosphere and weather, including weather patterns, clouds, and storms.]

5. An astronomer has discovered a new planet. On the planet, she sees what appears to be a lava flow. With what type of scientist might she consult to help her figure it out?

- [She might consult with a planetary geologist, who is an expert on the geology of other planets.]

6. An ecologist notices that an important coral reef is dying off. He believes that it has to do with some pollution from a local electric plant. What type of scientist might help him analyze the water for contamination?

- [An oceanographer might help him analyze the water for contamination.]

7. Design an experiment that you could conduct in any branch of Earth science. Identify the independent variable and dependent variable. What safety precautions would you have to take?

- [Answers will vary but should reveal that students have a good grasp of the scientific method and a correct understanding of the role of independent and dependent variables in an experiment. Students should also list relevant safety precautions they would have to take, given the nature of the experiment they design.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 1.2 Quiz in *CK-12 Earth Science For High School Quizzes and Tests*.

Points to Consider

Why is Earth science important?

- [*Sample answer*: Earth science is important because it studies all aspects of our home planet, including its geology, atmosphere, and waters. Earth science helps us understand how we are impacting the planet and how we can help preserve it for future generations.]

Which branch of Earth science would you most like to explore?

- [Students can identify any of the branches of Earth science described in the lesson.]

What is the biggest problem that humans face today? Which Earth scientists may help us to solve the problem?

- [*Sample answer*: I think that the biggest problem that humans face today is pollution of Earth's waters and atmosphere. Earth scientists that may help us to solve the problem include oceanographers, climatologists, and environmental scientists.]

How do the other branches of science impact Earth science?

- [*Sample answer*: Earth science is built upon other branches of science, including chemistry and physics. Biology is also related to Earth science because living things affect and are affected by Earth's land, oceans, atmosphere.]

CHAPTER 2 HS TE Studying Earth's Surface

Chapter Outline

2.1 Chapter 2: Studying Earth's Surface

Chapter Overview

In this chapter, students are introduced to Earth's surface features. They also learn about map projections, including topographic maps, and how computers and satellites are used to study and understand Earth's surface.

Online Resources

See the following Web sites for appropriate laboratory activities:

This interactive online activity has students consider the different types of map projections and the most appropriate projections for various uses. After reading about, seeing graphics of, and taking notes on a variety of map projections, students will assume they are cartographers and will specify which types of map projections would be the most valuable for their clients.

- http://education.nationalgeographic.com/archive/xpeditions/lessons/01/g912/projections.html?ar_a=1

In this lab, students will learn how different map projections are used to view Earth. They will use an online map-generator tool to discover how well the commonly used Mercator projection represents high- and low-latitude areas. They will also see a different type of map projection, called a Mollweide Projection, which is used by many scientists.

- http://www.bigelow.org/virtual/handson/maps.html

These Web sites may also be helpful:

To learn about ways to use Google Earth as an educational tool for Earth science, go the URL below. The URL provides links to many activities that are relevant to this chapter.

- http://serc.carleton.edu/NAGTWorkshops/visualize04/tool_examples/google_earth.html

You can review map projections and how different projections compare at the following URL.

- http://www.learnnc.org/lp/editions/mapping/6433

Visit this URL to find a plethora of resources for teaching students about maps. Resources include teaching ideas, activities, and many more educator resources.

- http://education.usgs.gov/secondary.html

This is a great resource for educators looking for ways to use GPS technology to enhance their classroom lessons. Visit the GPS area for ideas for geocaching, lesson plans, and more.

- http://gis2gps.com/

At the following URL, you can access materials that explain how to teach Earth science concepts and skills using GPS and GIS.

- http://edcommunity.esri.com/arclessons/lesson.cfm?id=296

Pacing the Lessons

TABLE 2.1: short caption

Lesson	Class Period(s) (60 min)
2.1 Earth's Surface	1.0
2.2 Where in the World Are You?	1.0
2.3 Modeling Earth's Surface	1.5
2.4 Topographic Maps	2.0
2.5 Using Satellites and Computers	1.5

2.2 Lesson 2.1: Earth's Surface

Key Concepts

- Continents and landforms
- Ocean basins and their features
- Constructive and destructive forces and how they change Earth's surface

Lesson Objectives

- Briefly identify different features of continents and ocean basins.
- Define constructive forces and give a few examples.
- Define destructive forces and give a few examples.

Lesson Vocabulary

- **constructive force:** force that causes landforms to grow
- **continent:** large land mass that lies above sea level
- **continental margin:** edge of continental crust that lies beneath ocean water, where continental crust gives way to oceanic crust
- **destructive force:** force that wears away or destroys landforms
- **landform:** physical feature of Earth's surface such as a hill or peninsula
- **mid-ocean ridge:** large mountain range that runs through an ocean basin
- **ocean basin:** entire area covered by the water of an ocean
- **ocean trench:** deep valley on the ocean floor

Teaching Strategies

Introducing the Lesson

Introduce Earth's surface landforms in a familiar context. Call on students to identify and describe examples of landforms such as mountains, hills, plains, and valleys in their local area. If there are any variations in landforms close to the school, you could take students on a walk to identify them. Tell students they will learn in this lesson more about the landforms that cover Earth's surface and the forces that created them.

Demonstration

Use the 1980 massive explosive eruption of Mount St. Helens in Washington State to demonstrate forces that shape Earth's surface. It shows how a volcanic eruption can be both a destructive and constructive force. The Nova video at the URL below shows amazing footage of the event that will be sure to leave an impression on students.

http://www.youtube.com/watch?v=iqG4Vi-eu5U

Activity

Have students play the AAAS "Shape It Up" game at the URL below. Students will learn which forces of erosion create specific landforms and how long it takes them to do the job. The activity will help students understand the destructive forces that continuously shape Earth's surface features and the long time spans they typically require.

http://powermylearning.com/content/shape-it-aaas?playlist=152478

Using Visuals

Call students' attention to the figure in the text that shows major features of the world's ocean basins. Have them find and describe specific features, including the mid-ocean ridge system, continental margins, trenches, chains of volcanoes, and abyssal plains. Point out how the mid-ocean ridge is nearly continuous throughout Earth's oceans. Tell students they will learn in later chapters how these landforms were created.

Differentiated Instruction

Before students read the lesson, have them make a three-column KWL chart, with column headings of Know (K), Want to Know (W), and Learned (L). Prior to reading, they should list under K what they already know about Earth's surface features, and they should list under W what they want to know. Tell students to keep their lists in mind as they read the lesson to help focus their attention. Finally, after reading the lesson, they should record under L what they learned. Did they learn everything they wanted to know? If not, help them find answers to these questions.

Enrichment

Ask one or more interested students to investigate how new ocean floor forms and how old ocean floor is destroyed. Have them make a diagram to show the processes involved and use the diagram to explain what happens to the class. Discuss as a class how these processes differ from constructive and destructive forces on land.

Science Inquiry

Have students look at the image of the Grand Canyon that opens this chapter. Challenge them to identify the force that created this impressive feature of the landscape and how long it took to form. (The Grand Canyon was created by water erosion caused by the Colorado River. It took tens of millions of years to form.)

Overcoming Misconceptions

Go to the AAAS site at the URL below to find common misconceptions students might hold about the processes that shape Earth's surface. Select several of the misconceptions that are held most frequently by students in grades 9–12, and discuss these misconceptions with the class. Call on volunteers to reword the misconceptions so they are correct statements.

http://assessment.aaas.org/topics/WE#/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 2.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 2.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are constructive forces and what landforms do they create?

- [Constructive forces are forces that cause landforms to grow. They include forces of crustal deformation, in which crust compresses, pulls apart, or slides past other crust. These forces create hills and valleys. Continental collisions are also constructive forces. They create mountain ranges and chains of volcanoes. Another constructive force is the deposition of sediments, which creates landforms such as river deltas.]

2. What are destructive forces and what landforms do they create?

- [Destructive forces are forces that wear away or destroy landforms. They include weathering and erosion by water, wind, ice, or gravity. Volcanic eruptions can also be destructive forces if they blow apart landforms. Landforms created by destructive forces include craters, which may form when volcanoes explode or collapse; fractures, which form when rifting occurs; and scars on steep slopes, which form when landslides occur.]

3. In a single region, are only constructive or only destructive forces at work?

- [In a single region, both constructive and destructive forces are likely to be at work.]

4. In terms of Earth's surface, what is the only thing that is constant?

- [In terms of Earth's surface, the only thing that is constant is change, because constructive and destructive forces are always working to build up and wear down the surface.]

5. What are some of the landforms found in the ocean basins?

- [*Sample answer*: Some of the landforms found in the ocean basins include the mid-ocean ridge, which is a mountain range that runs through much of each ocean basin; ocean trenches, which are deep valleys in the ocean floor; and chains of volcanoes, which are found in the center of the oceans.]

6. Until recently, scientists thought the seafloor was just flat and muddy. Why do you think they thought this? What do they think now?

- [*Sample answer:* I think that scientists thought the seafloor was just flat and muddy because until recently they had not explored most of the seafloor and were only familiar with the flat, muddy seafloor close to shore. Now scientists think that the seafloor is covered with features similar to landforms on the continents, including tall mountain ridges and deep valleys called trenches.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If erosion is constantly eating away at landforms, why isn't Earth's land surface completely flat?

- [Despite erosion constantly eating away at landforms, Earth's land surface isn't completely flat because constructive forces keep creating new landforms.]

Why do you think some regions of some continents, such as the middle part of the United States, are almost entirely flat?

- [*Sample answer:* I think some regions are almost entirely flat because these areas do not have the types of constructive forces that create hills and mountains.]

Why are continents higher than ocean basins?

- [Accept all reasonable responses. Some students might guess correctly that continents are higher than ocean basins because they consist of less dense materials.]

2.3 Lesson 2.2: Where in the World Are You?

Key Concepts

- Location and direction
- Latitude and longitude

Lesson Objectives

- Understand the difference between location and direction.
- Know how a compass works and how to use one.
- Know how to determine location using latitude and longitude.

Lesson Vocabulary

- **compass:** device with a magnetic needle that is used to find magnetic north
- **compass rose:** figure on a map or nautical chart that displays the directions north, south, east, and west
- **direction:** which way an object is moving, or location of something relative to something else
- **elevation:** height or depth measured relative to sea level
- **latitude:** distance in degrees north or south of the equator
- **location:** position on Earth's surface
- **longitude:** distance in degrees east or west of the Prime Meridian, which runs north-south through Greenwich, England
- **relief:** difference in elevation of landforms in a region
- **sea level:** average height of the ocean's surface, or the midpoint between high and low tide
- **topography:** three-dimensional shape of a landform or region on Earth's surface

Teaching Strategies

Introducing the Lesson

Tell students to write down the first word that comes to mind when they hear the term location. Call on several students to read their word until you get a variety of responses. Discuss how the words relate to the definition of location as "position on Earth's surface." Ask students why it is important to be able to pinpoint locations on Earth's surface. Encourage a diversity of responses. Tell students they will learn more about location and how to find it in this lesson.

Activity

Have students do the "Compass Treasure Hunt" activity, which is described at the URL below. In this simple classroom activity, students will use a . compass for orientation and to follow a course. This will reinforce the importance of direction in locating features on Earth's surface. The activity could be done as a class or group activity if the number of compasses is limited.

http://www.wvgs.wvnet.edu/www/geoeduc/adaptiveactivities.PDF

Differentiated Instruction

Assign students to small groups that combine any English language learners or less proficient readers with other students. Have students within each group work together to create a Venn diagram comparing and contrasting latitude and longitude. The area of overlap might include "imaginary line on Earth's surface," "used to find location," and "expressed in degrees." Under latitude, they might include "shows distance north or south of equator" and "runs parallel to equator." Under longitude, they might include "shows distance east or west of Prime Meridian" and "passes through both poles." Follow up by having students find several locations on a map by their coordinates and then the coordinates of known locations.

Enrichment

Ask one or more interested students to find out how to convert back and forth between true north and magnetic north and when each conversion is used. A good starting point is the URL below. Invite students to explain and demonstrate the conversions to the class. Conclude with a brief class discussion of why the two north poles are found in different locations.

http://www.nauticalcharts.noaa.gov/mcd/learnnc_rose.html

Science Inquiry

Students can apply lesson concepts with a collaborative problem-solving activity. Find and make copies of a map that shows at least three labeled point of interest (e.g., cities, historic markers, highways exits). The map must be marked with latitude and longitude and have a distance scale. Choose a "mystery" location on the map other than the three points, and find its latitude and longitude and also its straight-line distance from each of the three points. Divide the class into groups and provide each group with a copy of the map. Have students within each group work together to find the mystery location by coordinates and by triangulation. Working collaboratively, they should be able to figure out how to solve the triangulation problem. Refer them to the triangulation map in the lesson if they need help. Ask groups to compare their final answer. If they are not in agreement, they should review each other's work to determine which answer is correct.

Overcoming Misconceptions

There is a widespread misconception that the end of a compass needle that points north must actually be the south end of the needle, because of the well-known fact that north and south magnetic poles attract one another. In other words, many people believe that the "N" label on a compass designates the direction the needle points and not the true polarity of the magnetic needle. This is completely incorrect, and you can demonstrate it with a regular magnet that has its north and south ends marked. If the magnet is floated on water (for example, by placing it on a cork), the north end will point north. The reason? The magnetic pole close to the geographic north pole of Earth is actually Earth's magnetic south pole. It is called the magnetic north pole only because of its proximity to the geographic north pole.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 2.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 2.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What information could you use to describe the location of a feature on Earth's surface?

- [To describe the location of a feature on Earth's surface, you could use a street address, latitude and longitude, or the straight-line distance from three different points.]

2. Give an example of a situation where you might need to describe which direction an object is moving.

- [Examples may vary. *Sample answer*: You might need to describe which direction a ball is moving so someone else can avoid being hit by it.]

3. What type of instrument can you use to tell the direction an object is moving?

- [You can use a compass to tell the direction an object is moving because the needle of a compass always points north.]

4. What is topography?

- [Topography refers to differences in elevation that give features on Earth's surface their three-dimensional shape.]

5. What landforms are highest on the continents?

- [On the continents, the highest landforms are mountains.]

6. Explain what landforms on the continents are created by erosion by wind and water. How does erosion create a landform?

- [Landforms on continents that may be created when sediments are eroded by wind or water include river valleys. Landforms may also be created when sediments are deposited. For example, a delta forms when sediments eroded by a river are deposited where the river meets the ocean.]

7. A volcano creates a new landform in Mexico. As the Earth scientist assigned to study this feature, explain how you would describe its position in your report.

- [*Sample answer*: I would describe the volcano's position by giving its exact latitude and longitude.]

8. Think about how you would draw a map to show all the different elevations around the area where you live. How might you create such a map?

- [Answers may vary. Students might say they would use symbols or shading to show differences in elevation on the map. Any students who are familiar with topographic maps might describe how they would use contour lines to show elevation.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How can a two-dimensional object, such as a map, express the features of an area in three dimensions?

- [Answers may vary. *Sample answer*: The third dimension of elevation might be expressed by using different colors on a two-dimensional map.]

To locate yourself accurately, should you use a compass or a map?

- [*Sample answer*: You should use a compass and a map. The compass would should you how the map relates to your actual position on the ground. The map would show you how your location relates to other places around you in terms of distance and direction. A map also might show you your latitude and longitude.]

Why does California have such extreme relief?

- [*Sample answer*: California has such extreme relief because it is located on the coast, which is at sea level, and also mountain ranges, which have high elevations.]

2.4 Lesson 2.3: Modeling Earth's Surface

Key Concepts

- Globes
- Maps as models
- Map projections

Lesson Objectives

- Discuss the advantages and disadvantages of using a globe.
- Describe what information a map can convey.
- Identify some major types of map projections and discuss the advantages and disadvantages of each.

Lesson Vocabulary

- **map:** any two-dimensional representation of Earth's surface
- **projection:** any way of projecting Earth's curved, three-dimensional surface onto a flat, two-dimensional map

Teaching Strategies

Introducing the Lesson

Show students examples of several different types of world map projections (see URLs below for examples). Lead students in brainstorming ways that the different projections are similar and ways they are different. Tell students they will learn more about maps like these when the read this lesson.

http://geology.isu.edu/geostac/Field_Exercise/topomaps/images/projections.jpg

http://jiscg3.blogspot.com/2011/06/reflective-teaching-practice-do-i-need.html

Activity

At the following URL, students will find an interactive animated tutorial with questions that will help them understand different types of map projections and their advantages and limitations. The activity will both reinforce and extend material in the FlexBook® lesson.

http://www.classzone.com/books/earth_science/terc/content/investigations/es0301/es0301page01.cfm?chapter_no=investigation

Differentiated Instruction

Start a compare/contrast table on an overhead transparency or the board for two or more of the map projections described in the lesson. Call on students to add information to the cells of the table. Suggest that they make a copy of the table in their science notebook. It will make a good study tool to review lesson content.

Enrichment

In the 1970s, an historian named Arno Peters introduced the Peters projection. He called his map the only non-racist projection and proposed that it replace the Mercator projection, which he referred to as racist. Both maps are flawed and people argued the pros and cons of each. The entire issue became controversial. Ask students to learn more about the controversy, starting with the URL below. Then have them chose sides and debate the issue in front of the class.

http://geography.about.com/library/weekly/aa030201a.htm

Science Inquiry

In this activity about map projections, students will work in teams and use readily available materials to create two different map projections: a planar (or polar) and a cylindrical (or Mercator) projection. They will compare and contrast the two projections and decide which is more accurate. This activity will help students understand the challenges of creating maps of Earth.

http://howtosmile.org/record/5081

Political Science Connection

Despite its problems, the Mercator projection continued to be used for centuries. In fact, because of the way it distorted the sizes of certain nations, it may have been used longer than it might have been otherwise. Share with students two ways that the Mercator projection promoted particular political interests in the second half of the twentieth century. You can learn what they are at this URL: http://www.learnnc.org/lp/editions/mapping/6434.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 2.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 2.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Which of the following gives you the most accurate representations of distances and shapes on Earth's surface?

   a. Mercator projection map
   b. Robinson projection map
   c. globe

- [A globe gives you the most accurate representations of distances and shapes on Earth's surface because it has the same spherical shape as Earth.]

2. Explain the difference between latitude and longitude.

- [Latitude is a measure of distance north or south of the equator, whereas longitude is a measure of distance east or west of the Prime Meridian. Lines of latitude circle Earth parallel to the equator. Lines of longitude circle Earth through the poles, so they are perpendicular to lines of latitude.]

3. In what country are you located if your coordinates are 60 degrees north and 120 degrees west?

- [If your coordinates are 60 degrees north and 120 degrees west, you are located in Canada.]

4. Which map projection is most useful for navigation, especially near the equator? Explain.

- [A Mercator projection is most useful for navigation, especially near the equator, because this type of projection is most accurate within about 15 degrees north or south of the equator. Also, all the compass directions on Mercator projections are straight lines, which make them useful for navigation.]

5. In many cases, maps are more useful than a globe. Why?

- [*Sample answer*: Reasons that maps are in many cases more useful than a globe include that they are easier to make and carry around and that they can be enlarged to show the details of a particular area.]

6. Which of the following map projections gives you the least distortion around the poles? a. Mercator projection map b. Robinson projection map c. conic projection

- [A conic projection gives you the least distortion around the poles.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Imagine you are a pilot and must fly from New York to Paris. Use a globe to determine the distance. Now do the same with a map. How are these activities the same and how are they different?

- [One way to use a globe to determine the distance from New York to Paris is to pull a string taut between the two locations and mark the distance on the string. Then lay the string on the equator of the globe and count the number of degrees between the marks, starting with 0 at one end. Finally, multiply the number of degrees by 69.17 miles (distance per degree at the equator) to get the distance in miles between the two locations. On a map, you can find the straight-line distance between the two cities and directly compare this distance with the map's scale. Both activities give you the distance but the globe distance is likely to be more accurate because a globe does not distort distances on Earth's surface as a map projection does.]

Would you choose a map that used a Mercator projection if you were going to explore Antarctica? What other type of map could you use?

- [Sample answer: No, I would not use a Mercator projection if I were going to explore Antarctica because this type of map is least accurate near the poles, causing areas near the poles to be very stretched out and distorted. A conic projection would be better for this purpose because it more accurately represents areas near the poles.]

Maps use a scale, which means a certain distance on the map equals a larger distance on Earth. Why are maps drawn to scale? What would be some problems you would have with a map that did not use a scale?

- [Sample answer: Maps are drawn to scale so the relative distances between different points on the map accurately represent the actual distances between the points on the ground. With a map that did not use a scale, you would not be able to determine the actual distance between points on the ground from the distance between them on the map.]

2.5 Lesson 2.4: Topographic Maps

Key Concepts

- Definition and value of topographic maps
- Contour lines and contour intervals
- Interpreting topographic maps
- Bathymetric maps
- Geologic maps

Lesson Objectives

- Explain how to read and interpret a topographic map.
- Explain how bathymetric maps are used to determine underwater features.
- Describe what a geologic map shows.

Lesson Vocabulary

- **bathymetric map:** map that shows depth below sea level of features on the floor of a body of water
- **contour interval:** constant difference in elevation between adjacent contour lines on a topographic map
- **contour line:** line connecting points with the same elevation on a topographic map
- **geologic map:** map that shows rock units and other geologic features
- **topographic map:** map that shows elevations above sea level of features on Earth's surface

Teaching Strategies

Introducing the Lesson

Show students a topographic map of a familiar nearby area. Ask students what they think the map shows. Query them specifically about the contour lines and symbols on the map. Explain that the map is a topographic map and its main purpose is to show the three-dimensional shape of the land. Tell students they will learn how to make and interpret topographic maps when they read this lesson.

Activity

Have students do the interactive activity at the URL below. In the activity, they are taken through all of the steps involved in creating a profile from a topographic map. The activity will help them understand how contour lines represent surface features and how to read topographic maps.

http://www.tasagraphicarts.com/activities/profile.html

Building Science Skills

The worksheet at the following URL will help students build topographic map reading skills.

http://teacherweb.com/CA/TehachapiHighSchool/Guy/Topo-Practice-WS.pdf

Differentiated Instruction

Have students make a main ideas/details chart for the lesson to improve their reading comprehension. One approach is to divide a sheet of paper down the middle and write the main ideas on the left side of the paper, leaving space between each main idea to fill in details on the right side of the paper. Suggest to students that they include at least one main idea for each heading in the lesson.

Enrichment

Urge interested students explore geologic maps, starting with the excellent National Park Service article at the URL below. They should find out what the maps show and how they are used. Ask the students to bring a relatively simple geologic map to class and explain it to the other students. They should point out what the colors, symbols, and lines on the map represent. Also have them discuss why geologic mapping is important.

http://www.nature.nps.gov/geology/usgsnps/gmap/gmap1.html

Science Inquiry

In the "Design an Island" inquiry activity at the following URL, students will make a map of an island, demonstrating their knowledge of landforms and mapping conventions. At the conclusion of the activity, students will be able to construct a realistic map from a mental image of a place, demonstrate how various topographic symbols and concepts are shown on a map, and explain how the topography of an area influences the location of water sources, ecosystems, and human settlements.

http://www.sitesalive.com/oil/tg/private/oiltgdesign.html

Real-World Connection

Ask students if they know what orienteering is. Some students may have familiarity with this sport through scouting or local orienteering clubs. You can learn more about orienteering yourself at the first two URLs below. Tell the class that orienteering is an Olympic sport in which participants use compasses and topographic maps to find the easiest or quickest routes between different locations. Explain (or ask students who have orienteered to explain) how topographic maps are used in the sport. If you want to teach your students the skills of orienteering as an applied mapping activity, see the third URL below.

- http://geography.about.com/od/understandmaps/a/orienteering.htm
- http://web.williams.edu/Biology/Faculty_Staff/hwilliams/Orienteering/o index.html
- http://web.williams.edu/Biology/Faculty_Staff/hwilliams/Orienteering/teachingo.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 2.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 2.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. On a topographic map, contour lines create a group of concentric, closed loops. Which of the following features could this indicate? a. a stream channel b. a hilltop c. a depression d. a cliff

- [If the contour lines do not have hatchmarks, they indicate a hilltop. If the contour lines do have hatchmarks, they indicate a depression.]

2. Describe the pattern on a topographic map that would indicate a stream valley. How do you determine the direction of water flow?

- [A series of V-shaped contour lines indicate a stream valley. You can determine the direction of water flow from the direction of the V's. The pointed ends of the V's point upstream, and water always flows from upstream to downstream, or from a higher to a lower elevation.]

3. On a topographic map, five contour lines are very close together in one area. The contour interval is 100 ft. What feature does that indicate? How high is this feature?

- [Very closely-spaced contour lines represent a cliff or really steep slope. The feature is 500 feet high (5×100 ft.).]

4. On a topographic map, describe how you can tell a steep slope from a shallow slope.

- [On a topographic map, a steep slope has closely-spaced contour lines, whereas a shallow slope has widely-spaced contour lines.]

5. On a topographic map, a river is shown crossing from Point A in the northwest to Point B in the southeast. Point A is on a contour line of 800 ft. and Point B is on a contour line of 900 ft. In which direction does the river flow?

- [All rivers flow from a higher to a lower elevation, so this river flows from Point B to Point A, or from southeast to northwest.]

6. On a topographic map, six contour lines span a horizontal map distance of 0.5 inches. The horizontal scale is 1 inch equals 2,000 ft. How far apart are the first and sixth lines?

- [The six contour lines span 0.5 inches on the map. One inch equals 2000 ft., so 0.5 inches equals 1000 ft. Therefore, the fist and sixth contour lines are 1000 ft. apart.]

7. On a geologic map of the Grand Canyon, a rock unit called the Kaibab limestone takes up the entire surface of the region. Down some steep topographic lines is a very thin rock unit called the Toroweap Formation and down more topographic lines into the canyon from that is another thin unit, the Coconino sandstone. Describe how these three rock units sit relative to each other. Which is oldest and which is youngest?

- [The Kaibab limestone is the uppermost layer, the Coconino sandstone is the lowest layer, and the Toroweap formation is in between the other two layers. The Coconino sandstone is oldest, and the Kaibab limestone is youngest.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How might a civil engineer use a topographic map to build a road, bridge, or tunnel through the area such as that shown in the figure above? What topography would be best for a road? Which areas might need a bridge? Where might a tunnel be helpful?

- [*Sample answer*: Flat land would be best for a road, so the engineer would look on a topographic map for an area where the contour lines are widely spaced. Areas with stream valleys might need a bridge. The engineer would look on the topographic map for a series of V-shaped contour lines. A tunnel might be helpful where a steep hill or mountain blocks the path of the roadway. The engineer would look for closely-spaced contour lines that form concentric closed loops.]

If you wanted to participate in orienteering, would it be better to have a topographic map or a road map? How would a topographic map help you?

- [*Sample answer*: It would be better to have a topographic map. This type of map would help you avoid steep hills, ravines, and cliffs, because the pattern of contour lines on the map would show where these features are located.]

If you were the captain of a ship, what type of map would you want and why?

- [*Sample answer*: If you were the captain of a ship, would want to have a bathymetric map. This type of map shows the elevations of features on the floor of a body of water. Knowing the elevation and location of the features could help you avoid running aground.]

2.6 Lesson 2.5: Using Satellites and Computers

Key Concepts

- Data from satellites
- Global positioning system (GPS)
- Computer-generated maps

Lesson Objectives

- Describe types of satellite images and the information that each provides.
- Explain how the global positioning system (GPS) works.
- Explain how computers can be used to make maps.

Lesson Vocabulary

- **geographic information system (GIS):** system that links GPS data with any type of spatial information to create maps
- **geostationary orbit:** type of orbit that allows a satellite to stay over the same location on Earth's surface
- **global positioning system (GPS):** system of satellites used to locate exact positions on Earth's surface
- **polar orbit:** type of orbit that passes over both poles in a direction perpendicular to Earth's rotation
- **satellite:** natural or human-made object that orbits a larger object

Teaching Strategies

Introducing the Lesson

Ask students to recall from Lesson 2.2 how triangulation is used to pinpoint an exact location. Explain that GPS uses distances to several satellites for triangulation in order to locate positions on the ground. Tell students they will learn how it's done when they read this lesson.

Activity

This is a fun activity that will engage students in using GPS and appreciating some of its applications. During the activity, students will use GPS receivers to "write" their initials or draw a simple diagram. They will download the data into their mapping software to see how accurate they were. The PDF file includes a student worksheet and teacher information.

http://sciencespot.net/Media/GPSArtists.pdf

Activity

In this activity, students will use ArcGIS Explorer Online to investigate 11 topographic map features and their surrounding landscapes. The GIS software runs entirely online and requires only a Web browser. Students can work independently or in groups through each of the activities, or they could choose just one of the activities to do. An answer key is included.

http://edcommunity.esri.com/arclessons/lesson.cfm?id=529

Differentiated Instruction

Help students distinguish between polar and geostationary orbits by having them make a table comparing and contrasting them. Tell them to include examples of satellites with each type of orbit.

Enrichment

Challenge interested students with the Earth quiz at the URL below. It is a 20 question interactive quiz based on ArcGIS Online. Although the quiz has a multiple-choice format, it provides explanations about each region and process.

http://edcommunity.esri.com/arclessons/lesson.cfm?id=683

Science Inquiry

This activity allows students to improve science inquiry skills using GIS. They will analyze extreme high and low temperatures in the U.S. from a spatial perspective. The resulting patterns are fascinating and make for excellent teaching points about altitude, latitude, proximity to coastlines, local weather, continental climate, and much more. If you have students save their work in their science notebooks, they can revisit it when you teach the class about weather and climate.

http://edcommunity.esri.com/arclessons/lesson.cfm?id=730

Overcoming Misconceptions

A common misconception about GPS is that a person with a receiver can be tracked by someone else. This reveals a fundamental misunderstanding of how the system works. Explain that GPS is a passive system. It only receives signals and does not transmit them.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 2.5 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 2.5 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Which type of satellite can be used to pinpoint your location on Earth?

a. weather satellite
b. communications satellite
c. global positioning satellite
d. climate satellite

- [c. To pinpoint your location on Earth, you need a GPS receiver and data from four global positioning satellites.]

2. Explain the difference between geostationary orbits and polar orbits.

- [Satellites with geostationary orbits are 36,000 km above Earth's surface and travel in the same direction and at the same speed that Earth orbits, so they remain over the same location on Earth's surface. Satellites with polar orbits are several hundred km above the surface and travel over the poles, perpendicular to the direction that Earth orbits. They keep moving over different locations on Earth's surface as Earth rotates beneath them.]

3. Describe how GPS satellites can find a location in which there is a receiver on Earth.

- [A GPS receiver detects radio signals from at least four nearby GPS satellites, determines how long it takes the radio signals to reach it, and calculates its distance from each satellite. The receiver uses its distance from all four satellites to triangulate its exact location.]

4. What is a geographical information system (GIS)?

- [A GIS is a system of linking any type of data to GPS locations in order to construct maps showing the geographic distribution of the data.]

5. To map the entire Earth's surface from orbit, which type of orbit would you use? Explain why this would be your best choice.

- [To map the entire Earth's surface, you would use a polar orbit. This type of orbit passes over the poles and completely orbits Earth every 90 minutes. It keeps moving over different places on Earth's surface as it orbits and Earth keeps turning beneath it. Within a short period of time, it passes over the entire surface.]

6. Explain how weather satellites can track a tropical storm from its beginnings.

- [Weather satellites are high enough above the surface to get a good view of a wide area. They can make images of tropical storms showing their location and keep making new images as the storms move. In this way, they can track the path of the storms.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.5 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Imagine tracking a hurricane across the Atlantic Ocean. What information would you need to follow its path? What satellite images might be most useful? Research how the National Weather Service tracks and monitors hurricanes.

- [*Sample answer*: I would need satellite images showing the storm's location and movement. Information on its speed and direction would also help me follow its path. Geostationary satellite images might be most useful so the hurricane could be continually monitored.]

What information and type of map would be most useful for understanding the distribution of natural resources for a particular state?

- [*Sample answer*: Information on a state's natural resources by GPS location and a GIS system could be used to make a map of the distribution of natural resources for a particular state.]

What are some ways that people use Global Positioning Systems? What problems are easier to solve using GPS?

- [*Sample answer*: People use the GPS system to find their location and give them directions when they are traveling. It is also used by the military for troops to keep track of their locations on battlefields. It is easier to find a location using GPS when there are no familiar landmarks or when the precise location must be known.]

CHAPTER 3 HS TE Earth's Minerals

Chapter Outline

3.1 Chapter 3: Earth's Minerals

Chapter Overview

This chapter describes types of minerals and explains how they form. It also explains how to identify minerals using their physical properties and describes uses of mineral resources.

Online Resources

See the following Web sites for appropriate laboratory activities:

The lab at the URL below deals with important concepts in Lesson 3.1: atoms, isotopes, and atomic mass. Students will be given a random sample of the fictitious element "M&Mium," which contains at least three different "isotopes" of the element. Students will design and carry out a procedure to determine the average "atomic" mass of the element M&Mium in their sample.

- http://serc.carleton.edu/sp/mnstep/activities/20116.html

You can introduce chemical bonding with the lab at this URL.

- http://serc.carleton.edu/sp/mnstep/activities/20131.html

In the lab at the following URL, students will use a variety of tests to identify several mineral samples. Use the lab when you teach Lesson 3.3, "Mineral Identification."

- http://pti.lsu.edu/Activities/A07%20Mineral_Identification_Lab.pdf

These Web sites may also be helpful:

Go to this site for mineral demonstrations for your class. The instructions for each demonstration can be downloaded freely as a PDF document.

- http://www.mineralseducationcoalition.org/classroom-demonstrations

For pictures of minerals, grouped by class, go to this URL:

- http://www.rocksandminerals4u.com/minerals.html

At the following URL, you can find properties of a wide range of minerals grouped by class.

- http://www.galleries.com/

Pacing the Lessons

TABLE 3.1: **short caption**

Lesson	Class Period(s) (60 min)
3.1 Matter Matters	1.0
3.2 Minerals and Mineral Groups	2.5
3.3 Mineral Identification	2.0
3.4 Mineral Formation	1.5
3.5 Mining and Mineral Use	1.5

3.2 Lesson 3.1: Matter Matters

Key Concepts

- Atoms and isotopes
- Ions and molecules
- Chemical bonding

Lesson Objectives

- Review basic chemistry concepts: atoms, elements, ions, and molecules.
- Understand the types of chemical bonding and how they result in molecules.

Lesson Vocabulary

- **atom:** smallest particle of an element that still has the element's properties
- **atomic mass:** number of protons and neutrons in an atom
- **chemical bond:** force that holds atoms or ions together
- **covalent bond:** chemical bond in which electrons are shared between atoms
- **electron:** negatively charged particle that orbits the nucleus of an atom
- **element:** substance that cannot be broken down into simpler substances by chemical means
- **hydrogen bond:** weak bond between oppositely charged ends of two different molecules
- **ion:** charged particle that forms when an atom gains or loses electrons
- **ionic bond:** chemical bond in which electrons are transferred between atoms
- **isotope:** atom of an element that has a different number of neutrons
- **molecular mass:** sum of the masses of all the atoms in a molecule
- **molecule:** smallest particle of a compound that still has the compound's properties
- **neutron:** uncharged particle in the nucleus of an atom
- **nucleus:** center of an atom consisting of protons and neutrons
- **polar molecule:** molecule that has slightly negative and positive ends
- **proton:** positively charged particle in the nucleus of an atom

Teaching Strategies

Introducing the Lesson

Students are likely to have some prior knowledge of atoms, elements, molecules, and compounds. Call on students to state what they already know about these concepts. Record the most important points on the board. Tell the class they will learn more about these basic ideas regarding matter when they read this lesson.

Activity

Students can learn about chemical bonding and different types of bonds by playing the bonding game at the following URL. By doing the activity, students will recognize how and why molecules form and will be able to identify four types of bonding. They will also be able to determine whether a molecule is polar.

http://www.powayusd.com/pusdphs/webquests/chemwebquest/chemsite.htm

Differentiated Instruction

Help students focus on the six most important concepts in the lesson: matter, element, atom, compound, molecule, and chemical bond. Pair students who need extra help with other students, and have partners make a concept map that relates the six terms.

Enrichment

Students who are interested in history might want to investigate the history of the atom. A few good sources of information are listed below. Ask the students to create a PowerPoint presentation to share what they learn with the rest of the class.

- http://profmokeur.ca/chemistry/history_of_the_atom.htm
- http://www.cosmosmagazine.com/features/history-atom-part-1-the-birth-atomos/
- http://www.cosmosmagazine.com/features/history-atom-part-2-towards-chaos/

Science Inquiry

Have students do the inquiry activity "Atoms Unite," which can be accessed at the URL below. The purpose of the activity is to guide students in building their own concepts about bonding. They will explore the concepts of ionic and covalent bonds and form compounds.

http://www.nslc.ucla.edu/step/gk12/lessons.htm#Chemical_Bonds_

Overcoming Misconceptions

The URL below lists numerous common student misconceptions about basic chemistry concepts, including atoms, molecules, and chemical bonds. Discuss the misconceptions that are relevant to this lesson. Call on volunteers to restate them so they are correct.

http://resources.educ.queensu.ca/science/main/concept/chem/c07/C07CDTL1.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 3.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 3.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. How is an atom different from an ion? How is an atom different from an element?

- [An atom is an uncharged particle. An ion is a charged particle that forms when an atom gains or loses an electron. An atom is the smallest particle that makes up an element and still has the element's properties.]

2. Describe the subatomic particles you learned about in this lesson.

- [The subatomic particles are protons, neutrons, and electrons. Protons are positively charged particles in the nucleus at the center of an atom. Neutrons are uncharged particles in the nucleus. Electrons are negatively charged particles that surround the nucleus.]

3. How is a molecule different from an element? Can a molecule be an element?

- [A molecule is a particle that consists of two or more atoms. If the atoms represent different elements, the molecule is compound. If the atoms represent the same element, the molecule is an element.]

4. Think of the smallest unit of water, a molecule of H_2O. Which of the vocabulary words in this lesson describe the hydrogen? Which describe the oxygen? Which terms describe the whole H_2O unit?

- [Hydrogen and oxygen are elements, and their smallest particles are atoms. H_2O is a compound, and its smallest particles are molecules.]

5. In which type of bonding are electrons shared? In which are they given or taken? Which type of bond is stronger?

- [Electrons are shared in covalent bonding. They are given or taken in ionic bonding. Covalent bonds are stronger than ionic bonds.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

The noble gases all have a full outermost electron level. How do they bind to other molecules?

- [They rarely do bind to other molecules. That's why they are also called inert gases.]

Why don't electrons fly off into space? Is electrical force the same as the gravitational force that keeps planets orbiting the Sun?

- [Electrical and gravitational forces are different. The gravitational force between planets and the sun is a force of attraction between any objects with mass. The electrical force that keeps electrons orbiting the nucleus is a force of attraction only between oppositely charged particles. Negative electrons are attracted to the positive protons in the nucleus of the atom, so they don't fly off into space.]

Water has a lot of unusual properties: It forms droplets, lightweight insects can land on it, and it is less dense in solid form (ice) than in liquid form. Can you link these properties to hydrogen bonding?

- [Water is a polar molecule, so hydrogen bonds form between water molecules. The attraction between water molecules explains why water seems to "stick" to itself by forming droplets and resisting the weight of insects. The closely spaced molecules also make water denser.]

3.3 Lesson 3.2: Minerals and Mineral Groups

Key Concepts

- Characteristics of minerals
- Groups of minerals

Lesson Objectives

- Describe the characteristics that all minerals share.
- Identify the groups in which minerals are classified and their characteristics.

Lesson Vocabulary

- **chemical compound:** unique substance made of two or more elements in a certain ratio
- **crystal:** solid in which atoms or ions are arranged in a regular repeating pattern
- **inorganic:** not organic; not relating to life or living things
- **mineral:** naturally occurring inorganic crystalline solid with a characteristic chemical composition
- **silicates:** largest group of minerals, containing silicon and oxygen

Teaching Strategies

Introducing the Lesson

Show students a quartz crystal and tell them that it is the mineral quartz. Add that there are thousands of known minerals and new minerals are being discovered each year. Then have students brainstorm common objects that they think might be made from minerals. (Possible answers include pencil "leads," glass, sheetrock, gold and silver jewelry, watch crystals, toothpaste, clay pots, and table salt.) Tell students they will learn more about minerals in this lesson, including what makes a substance a mineral and how minerals are classified.

Activity

Use the activity at the URL below to challenge students to identify which of several different substances should be classified as a mineral. They will also be required to explain which criteria of a mineral the non-mineral substances fail to meet.

http://pubs.usgs.gov/gip/2005/17/

Cooperative Learning

Divide the class into eight groups, and assign each group a different mineral group to explore in a Web quest. Give each group the same list of types of information to gather for their mineral groups, such as chemical composition, distribution, uses, and examples. After their Web quest, have them assemble the information in a well-illustrated poster. Allow class time for groups to present their posters to the class. Display the posters in the classroom and encourage students to use them as a reference as they continue to study minerals in this chapter.

Differentiated Instruction

Pair more- and less-proficient English language learners, and have partners create a cluster diagram for the characteristics of minerals. The diagram should include a separate circle for each of the defining characteristics of minerals: crystalline solid, inorganic substance, formed by natural processes, and specific chemical composition. For each characteristic, they should add an explanation or description in terms that are understandable to them.

Enrichment

The silicate minerals are the most common, and all of them form silica tetrahedrons. Challenge one or more students to create three-dimensional models of silica tetrahedrons and demonstrate them to the class. They can follow the procedure described at this URL: http://www.windows2universe.org/teacher_resources/teach_silica.html.

Science Inquiry

In the activity at the URL below, students will grow different types of mineral crystals. They will create a model of crystal growth and observe that the process of crystal growth is a type of self-assembly. By doing the activity, students will apply scientific inquiry process skills.

http://scme-nm.org/files/1-3%20Structure%20Crystals%20%20LAB%20Growing%20Crystals%20Rev%203.pdf

Overcoming Misconceptions

The document at the following URL discusses common misconceptions about minerals and how they arise. For example, the words mineral and crystal are commonly misused in everyday language. In a study that included adolescents, students were asked to describe samples of rocks, minerals, and human-made materials. Students did not use the word mineral to describe any of samples, and they used terms such as rock, stone, and pebble in an intuitive, nonscientific way. Review the misconceptions with your students to ensure that they know the correct concepts.

http://beyondpenguins.ehe.osu.edu/issue/rocks-and-minerals/common-misconceptions-about-rocks-and-minerals

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 3.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 3.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is a crystal?

- [A crystal is a solid in which atoms or ions are arranged in a regular repeating pattern.]

2. Which elements do all silicate minerals contain?

- [All silicate minerals contain silica and oxygen.]

3. Obsidian is a glass that forms when lava cools so quickly that the atoms do not have a chance to arrange themselves in crystals. Is obsidian a crystal? Explain your reasoning.

- [Obsidian is not a crystal because its atoms are not arranged in crystals. To be a mineral, a substance must be a crystalline solid.]

4. What are the eight major mineral groups?

- [The eight major mineral groups are silicates, native elements, carbonates, halides, oxides, phosphates, sulfates, and sulfides.]

5. What is the same about all minerals in the silicate group? What is different about them?

- [All minerals in the silicate group contain silicon and oxygen combined in structures called silica tetrahedrons. Silicates may or may not also contain other elements. If they contain other elements, these elements may vary. In addition, silicates may differ in the way their silica tetrahedrons combine. For example, they may stand alone or form rings or chains.]

6. One sample has a chemical composition with a ratio of two iron atoms to three oxygen atoms. Another sample has a chemical composition with a ratio of three iron atoms to four oxygen atoms. They contain the same elements: Are they the same mineral?

- [They are not the same mineral. Each mineral has a characteristic chemical composition. Therefore, if two substances have different chemical compositions, they cannot be the same mineral.]

7. How does the native elements mineral group differ from all of the other mineral groups?

- [Each mineral in the native elements group consists of a single element. Minerals in all of the other groups consist of two or more elements.]

8. On a trip to the natural history museum, you find two minerals that are similar in color. You can see from their chemical formulas that one mineral contains the elements zinc, carbon, and oxygen. The other mineral contains the elements zinc, silicon, oxygen, and hydrogen. Your friend tells you that the minerals are in the same mineral group. Do you agree? Explain your reasoning.

- [No, I do not agree. The element that contains zinc, carbon, and oxygen is a carbonate. The element that contains zinc, silicon, oxygen, and hydrogen is a silicate.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why is obsidian, a natural glass that forms from cooling lava, not a mineral?

- [Obsidian is not a mineral because it does not have a crystalline structure.]

Why are diamonds made in a laboratory not minerals?

- [Diamonds made in a laboratory are not minerals because minerals are naturally occurring substances.]

Is coal, formed mostly from decayed plants, a mineral? Is it a rock?

- [Coal is not a mineral because it is organic, whereas minerals are inorganic. Coal is an organic sedimentary rock.]

Artists used to grind up the mineral azurite to make colorful pigments for paints. Is the powdered azurite still crystalline?

- [Yes, the powdered azurite is still crystalline. The crystals have just been ground to a much smaller size.]

3.4 Lesson 3.3: Mineral Identification

Key Concepts

- Mineral color, streak, and luster
- Density and specific gravity of minerals
- Mineral hardness and Mohs hardness scale
- Cleavage and fracture of minerals
- Other identifying characteristics of minerals

Lesson Objectives

- Explain how minerals are identified.
- Describe how color, luster, and streak are used to identify minerals.
- Summarize specific gravity.
- Explain how the hardness of a mineral is measured.
- Describe the properties of cleavage and fracture.
- Identify additional properties that can be used to identify some minerals.

Lesson Vocabulary

- **cleavage:** tendency of a mineral to break along certain planes to make smooth, flat surfaces
- **density:** amount of mass per unit of volume
- **fracture:** how a mineral breaks when it does not break along a cleavage plane
- **hardness:** ability of a mineral to resist being scratched
- **luster:** how light reflects off the surface of a mineral
- **mineralogist:** scientist who studies minerals
- **streak:** color of the powder of a mineral

Teaching Strategies

Introducing the Lesson

Show the class two different mineral samples. Pass the samples around so students can inspect them closely. Call on volunteers to describe properties of the two minerals that appear to be different. Tell students they will learn in this lesson how properties of minerals can be used to identify them.

Demonstration

The eye-catching activity at the following URL makes a great classroom demonstration. It also relates to fireworks, so it will be likely to get students' attention. Using the flame test, you will produce colored flames from minerals. Discuss why the flames vary in color and how this relates to the colors of fireworks. Background information is provided in the document.

http://www.mineralseducationcoalition.org/pdfs/Tested_by_Fire.pdf

Activity

Students can test the reactivity of different minerals with the activity at the following URL. After they complete the activity, have them explain how reactivity can be used in mineral identification.

http://www.mineralseducationcoalition.org/pdfs/An_Acidic_Reaction.pdf

Differentiated Instruction

Have students click on "Properties of Common Minerals" at the URL below. It will open a reading worksheet titled "Identifying Minerals." The worksheet provides a simpler, shorter version of lesson content, followed by objective recall questions so students can check their comprehension.

http://newyorkscienceteacher.com/sci/files/topic-media.php?media=Worksheet&subject=earth+science&subtopic=Rocks+and+Minerals

Enrichment

Have a few students brainstorm a card game that can be played with the mineral ID cards at the following URL. Their game might be modeled on a card game they know, such as Go Fish or Authors. Suggest that other students in the class play the game to familiarize themselves with the properties of specific minerals.

http://www.oum.ox.ac.uk/thezone/funstuff/games/pdfs/minmast.pdf

Science Inquiry

Students can learn through inquiry about three optical mineral properties not mentioned in the text: schiller, iridescence, and pleochroism. Have them do the hands-on activity at the URL below. They will read about the causes and effects of the properties and then try to identify them in mineral specimens.

http://www.mineralseducationcoalition.org/pdfs/Wild_and_Cool_Colors.pdf

Chemistry Connection

Explain why some minerals are fluorescent and show students pictures of fluorescent minerals. The URL below provides the background science, including a useful diagram, and also shows a vivid image of numerous fluorescent minerals.

http://geology.com/articles/fluorescent-minerals/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 3.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 3.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Which properties of minerals describe the way they break apart?

- [Cleavage and fracture are properties of minerals that describe the way they break apart.]

2. A mineral looks dry and chalky. What sort of luster does it have?

- [A mineral that looks dry and chalky has an earthy luster.]

3. What causes a mineral to have the properties that it has?

- [The chemical composition and bonding of a mineral determines its properties.]

4. Apatite scratches the surface of an unknown mineral. Which mineral would you use next to test the mineral's hardnessor feldspar? Explain your reasoning.

- [I would use fluorite next to test the mineral's hardness. The mineral is scratched by apatite so it is softer than apatite. Apatite is softer than feldspar, so the unknown mineral also must be softer than feldspar. Therefore, there is no need to test it with feldspar. Fluorite is softer than apatite, but it may or may not be softer than the unknown mineral. I would have to test the unknown mineral with fluorite to find out.]

5. Why is streak more reliable than color when identifying a mineral?

- [Streak is more reliable than color when identifying a mineral because the color of a given mineral may vary, whereas its streak does not vary. Also, different minerals may be the same color, but they may have different streak.]

6. Mineral A has a density of 5 g/cm^3. Mineral B is twice as dense as Mineral A. What is the density of Mineral B?

- [The density of mineral B is 2×5 g/cm^3, or 10 g/cm^3.]

7. Why do some minerals cleave along certain planes?

- [Some minerals cleave along certain planes because of the nature of their chemical bonds. Breaking a mineral breaks its chemical bonds. Because some bonds are weaker than other bonds, each type of mineral is likely to break where the bonds between the atoms are weaker. For that reason, minerals break apart in characteristic ways, such as along certain planes.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If a mineral is magnetic, do you know for certain what mineral it is?

- [No, you do not know for certain what mineral it is because there is more than one magnetic mineral.]

Some minerals are colored because they contain chemical impurities. How did the impurities get into the mineral?

- [Impurities got into the mineral during the process of mineral formation.]

What two properties of a mineral sample would you have to measure to calculate its density?

- [To calculate the density of a mineral sample, you would have to measure the sample's mass and volume. Density is calculated as mass divided by volume.]

How much do minerals reflect the environment in which they formed?

- [One way minerals reflect the environment in which they formed is in terms of the size of the mineral crystals. Crystals are larger when magma cools slowly under the surface than when lava cools quickly on the surface.]

3.5 Lesson 3.4: Mineral Formation

Key Concepts

- Formation of minerals from magma and lava
- Formation of minerals from solutions

Lesson Objectives

- Describe how melted rock produces minerals.
- Describe how hot rock produces different minerals.
- Explain how minerals form from solutions.

Lesson Vocabulary

- **lava:** molten rock that has reached Earth's surface
- **magma:** molten rock deep inside Earth
- **rock:** mixture of minerals
- **vein:** mineral deposit from a fluid that fills a crack in rock

Teaching Strategies

Introducing the Lesson

Introduce students to mineral formation by showing them the seven stunning mineral formations at the following URL. The article provides a brief description and explanation about how each formation developed. Tell students they will read in this lesson about some of the common ways that minerals form.

http://mentalfloss.com/article/32101/7-stunning-mineral-formations

Demonstration

Use the interactive animation at the following URL to show students how rates of cooling affect the size of mineral crystals from molten rock. Then, at the second URL, show students the sizes of crystals in different rock specimens, and challenge them to infer where the rocks formed.

http://www.classzone.com/books/earth_science/terc/content/investigations/es0603/es0603page05.cfm?chapter_no=investigationhtt

http://www.classzone.com/books/earth_science/terc/content/investigations/es0603/es0603page06.cfm?chapter_no=investigation

Activity

Students can form the mineral calcium carbonate by precipitation with the simple activity at the URL below. The reaction occurs when carbon dioxide gas (CO_2) in exhaled air enters a saturated lime (CaO) solution.

http://www.mines.unr.edu/museum/activities/Precipitation%20of%20CaCO3%20activity.pdf

Differentiated Instruction

Suggest that students make a table comparing and contrasting the formation of mineral crystals from magma and lava. They should compare where the mineral crystals form (in or on Earth), how quickly they form, and their size.

Enrichment

Students may be curious about diamonds because they are expensive gemstones and also the hardest mineral known. Ask one or more volunteers to investigate how diamonds form. They can start with the URLs below. Have them summarize what they learn in a brief oral presentation to the class. Ask them to relate the hardness of diamonds to the manner in which they form.

- http://www.smithsonianmag.com/science-nature/diamond.html
- http://www.nhm.ac.uk/nature-online/earth/rock-minerals/diamonds/diamond-formation/
- http://geology.com/articles/diamonds-from-coal/

Science Inquiry

Have students heat water on a hot plate to about 60 °C and then add an equal amount of Epsom salts to make a saturated solution. Then have them separate the solution into three equal parts. One-third of the solution they should leave to cool slowly at room temperature, one-third they should cool more quickly in a refrigerator, and the remaining one-third they should cool most quickly in a freezer. As the solutions cool, ask students to predict the relative sizes of the crystals that will form in the three solutions. When all three solutions have cooled completely, have students measure the crystals. They may need to use a hand lens or microscope to observe crystal sizes.

Chemistry Connection

Relate the chemistry concept of supersaturation to the formation of minerals. Explain that the term supersaturation refers to a solution that contains more of the dissolved material than could be dissolved by the solvent under normal circumstances. For example, a supersaturated solution of salt and water can be made by heating the water. When the salt water cools, it can no longer hold as much dissolved solute, so the solute precipitates out of the solution, forming salt crystals. The same thing occurs in carbonated drinks, except in this case, the supersaturated solution forms because the solution is put under pressure. That's why opening a can of a carbonated drink leads to the formation of bubbles of carbon dioxide. The gas comes out of solution when the pressure is released. Relate this discussion of supersaturation to the formation of mineral crystals from an underground water solution that has been heated to a high temperature by magma.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 3.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 3.4 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. What is the difference between magma and lava?

   - [Both magma and lava are molten, or melted, rock. Molten rock inside Earth is called magma. If magma erupts onto the surface, it is called lava.]

2. Under what circumstances do large crystals form from a cooling magma?

   - [Large crystals form from a cooling magma when the magma cools slowly inside Earth.]

3. Under what circumstances do small crystals form from a cooling magma?

   - [Small crystals form from a cooling magma when it erupts onto Earth's surface and cools quickly.]

4. What happens to the mineral particles in salt water when the water evaporates?

   - [When salt water evaporates, the mineral particles in the water are left behind and form a solid layer of minerals]

5. Explain how mineral veins form.

   - [Mineral veins form when underground water is heated by magma, picks up dissolved particles, and then flows through cracks in rock. As the water cools, it deposits solid minerals in the cracks. These deposits are called veins.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Is a mineral a static thing or does it change? If it changes, on what time frame?

- [*Sample answer*: A mineral may change when it is heated or put under great pressure. This is likely to be a slow process.]

When most minerals form, they combine with other minerals to form rocks. How can these minerals be used?

- [*Sample answer*: The minerals in rocks can be used by processing the rocks to separate out the minerals.]

The same mineral can be formed by different processes. How can the way a mineral forms affect how the mineral is used?

- [*Sample answer*: The way a mineral forms may affect the size of the mineral crystals, where the crystals form, how much of the mineral there is, and how easy the mineral is to mine. All of these factors might affect whether or how the mineral is used.]

3.6 Lesson 3.5: Mining and Mineral Use

Key Concepts

- Finding and mining minerals
- Ore extraction
- Mining and the environment
- Valuable minerals

Lesson Objectives

- Explain how minerals are mined.
- Describe how metals are made from mineral ores.
- Summarize the ways in which gemstones are used.
- Identify some useful minerals.

Lesson Vocabulary

- **gemstone:** mineral that is cut and polished to use in jewelry
- **ore:** rock that contains useful minerals
- **ore deposit:** mineral deposit that contains enough minerals to be mined for profit
- **placer:** valuable metal found in modern or ancient stream gravels
- **reclamation:** restoration of mined land to its pre-mining state

Teaching Strategies

Introducing the Lesson

Refer students to the picture of the Bingham open-pit copper mine in the lesson and then show them the video about the mine at the URL below. The Bingham mine is a good example for introducing mining to students because it is the first and largest open-pit copper mine in the world. In fact, it is the largest artificial excavation on Earthlarge that it can be seen from space. By 2008, the Bingham mine was 0.75 mile deep and 2.5 miles wide at the top, and it covered almost 2000 acres. Share these facts with the class. Then tell students they will learn more about mines and mining when they read this lesson.

http://www.youtube.com/watch?v=IEL7Vwm1PXU

Activity

This fun class activity demonstrates the steps that are taken to find, extract, process, and use mineral resources. Teams of students will simulate all the steps a peanut "mining" company must take to find and mine the resource and then reclaim the site. They will also calculate their profit or loss.

http://www.nvmineraleducation.org/Activities/MiningInANutshellAdv.pdf

Differentiated Instruction

Have students make a Venn diagram to compare and contrast surface and open-pit mining. They should include pros and cons of each mining method in their diagram.

Enrichment

Assign a few students to debate the environmental and economic impacts of a proposed new mine in a fictitious community that is suffering financially and needs new jobs. Recommend to students that they first gather background information, starting with the URLs below. All but the last URL provide background information on environmental and/or economic impacts of mining. The last URL describes an actual community in which re-opening a mine and creating new jobs is being debated. Allow class time for students to present their debate.

- http://www.pollutionissues.com/Li-Na/Mining.html
- http://www.okinternational.org/mining
- http://www.catapa.be/en/mining/economic
- http://www.miningfacts.org/Blog/Mining-News/The-Impact-of-Mining-on-British-Columbia%e2%80%99s-Economy/
- http://ecorestoration.montana.edu/mineland/guide/problem/impacts/default.htm
- http://minnesota.publicradio.org/display/web/2013/03/02/regional/minnesota-mining-jobs

Science Inquiry

In the activity at the URL below, copper is leached from finely ground rock and recovered by reduction on iron paper clips. The activity models the actual procedures used for recovering some metals, including gold. Students will understand the chemistry involved in leaching and recovering a metal from solution.

http://www.nvmineraleducation.org/Activities/OpChem_Metal_From_Rocks.pdf

Real-World Connection

The concept of sustainable development is important for nonrenewable resources such as minerals. In this group activity, students will see how sustainable development can be applied to help resolve controversial issues associated with mineral mining.

http://www.nvmineraleducation.org/Activities/Sustainable_Development_V_3_LV_2006.pdf

Social Science Connection

Share with students the importance of minerals throughout human history and prehistory. Tell them that the main ages of ancient human civilization are defined by the use of minerals. They include the Stone Age, Bronze Age, and Iron Age. Encourage students to learn more about each of these ages.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 3.5 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 3.5 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. What category of mining would be used to extract ore that is close to the surface? Why?

   - [Surface mining would be used to extract ore that is close to the surface because this type of mining is cheaper and safer than underground mining if ores are close enough to the surface.]

2. Describe some surface mining methods.

   - [Sample answer: Some surface mining methods include open-pit mining, in which a large, open hole is blasted and excavated to remove the ore; mountaintop removal, in which the top of a mountain is blasted away and removed to get at the ore; and strip-mining, which is like open-pit mining except that material is removed along a strip.]

3. What are some disadvantages of underground mining?

   - [Underground mining is more expensive than surface mining. Tunnels must be blasted into rock to get to the ore. Underground mining is also very dangerous to the miners. The miners breathe in particles and dust and there is a risk of explosions and mine collapses.]

4. What are some ways an area can undergo reclamation after being mined?

   - [After being mined, an area is reclaimed by restoring it to a natural state. Pit mines may be refilled with soil and native vegetation may be planted. Another option is to let the pits fill with water to create lakes. Underground mines may be sealed off or left open as homes for bats.]

5. What steps are taken to extract a pure metal from an ore?

   - [To extract a pure metal from an ore, rocks from a mine are crushed so that the valuable minerals can be separated from the waste rock. Then the minerals are separated out of the ore. Methods for extracting ore include heap leaching, flotation, and smelting.]

6. What makes a gemstone valuable?

   - [A gemstone is valuable because it is beautiful, usually rare, and does not break or scratch easily.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.5 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Are all mineral deposits ores?

- [Mineral deposits are ores only if the concentration of minerals is great enough that the deposits are profitable to mine.]

Why might an open pit mine be turned into an underground mine?

- [An open-pit mine might be turned into an underground mine if all the minerals near the surface had been mined and the remaining minerals were too far below the surface to be mined except by an underground mine.]

How well does reclaimed land resemble the land before mining began?

- [How well reclaimed land resembles the land before mining began depends on how the land was reclaimed. If topsoil was returned and native vegetation planted, the land might look similar to the land before mining began. On the other hand, the land might have been converted to a lake or landfill rather than to its original state.]

Diamonds are not necessarily the rarest gem so why do people value them more than most other gems?

- [People may value diamonds more than most other gems because they are very sparkly and beautiful and also the hardest gems. Because diamonds are so hard, they have many uses in addition to being used as gemstones in jewelry.]

Under what circumstances might a mineral deposit be an ore one day and not the next?

- [*Sample answer*: A mineral deposit might be an ore one day and not the next if it was no longer profitable to mine it. This might happen if the price of the mineral fell or if the cost of mining was increased by a new tax or for some other reason.]

CHAPTER 4 HS TE Rocks

Chapter Outline

4.1 Chapter 4: Rocks

Chapter Overview

This chapter describes the rock cycle and the three major types of rocks that form on Earth: igneous, sedimentary, and metamorphic rocks. A separate lesson is devoted to each of these three rock types.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this lab, students receive two small blocks of chocolate (white and dark) and follow them through the entire rock cycle by melting, grinding, and otherwise processing them. Students compare the chocolate "rocks" in each of the stages with real rock samples. As the final step, they describe the life story of a rock sample.

- http://serc.carleton.edu/NAGTWorkshops/intro/activities/23590.html

Have students do the metamorphic rock lab described on pages 13-18 of the URL below. In the activity, they will use a hand lens to compare and contrast different metamorphic textures and learn how to identify foliated texture.

- http://www.msnucleus.org/membership/html/jh/earth/metamorphic/jhmetamorphic.pdf

These Web sites may also be helpful:

These URLs are good sources of photos of the different types of rocks covered in this chapter:

- http://geology.com/rocks/igneous-rocks.shtml
- http://geology.com/rocks/sedimentary-rocks.shtml
- http://geology.com/rocks/metamorphic-rocks.shtml

You may want to teach the processes involved in the rock cycle with some of the activities described in this useful resource:

- http://geoscience.msc.sa.edu.au/library/dynamic_rock_cycle.pdf

The PowerPoint presentations at the following URLs may be useful when you teach your students about (1) the rock cycle and (2) the three types of rocks (igneous, sedimentary, and metamorphic).

1. http://www.science-class.net/PowerPoints/Predicting%20the%20Rock%20Cycle_files/frame.htm
2. http://schools.paulding.k12.ga.us/ischooldistrict/teacherhome_more.php?TeacherHomePage_ID=6391&school_ID=52&user_ID=2708

Pacing the Lessons

TABLE 4.1: **short caption**

Lesson	Class Period(s) (60 min)
4.1 Types of Rocks	2.0
4.2 Igneous Rocks	2.0
4.3 Sedimentary Rocks	2.0
4.4 Metamorphic Rocks	1.5

4.2 Lesson 4.1: Types of Rocks

Key Concepts

- Definition of rock
- Three main categories of rocks
- Overview of the rock cycle
- Processes of the rock cycle

Lesson Objectives

- Define rock and describe what rocks are made of.
- Know how to classify and describe rocks.
- Explain how each of the three main rock types formed.
- Describe the rock cycle.

Lesson Vocabulary

- **crystallization:** formation of mineral crystals as molten rock cools
- **erosion:** transport of weathered sediments by water, wind, ice, or gravity
- **igneous rock:** rock that forms when magma or lava cools
- **metamorphic rock:** rock that forms when existing rock is changed by extreme heat and/or pressure inside Earth
- **metamorphism:** process in which existing rock changes inside Earth to metamorphic rock due to extreme heat and/or pressure
- **outcrop:** exposed rock formation that extends out of the ground
- **precipitate:** solid that separates out of a liquid, usually when the liquid evaporates
- **rock cycle:** continuous series of processes by which rocks change from one type to another
- **sediment:** small particle of soil or rock deposited by wind, water, or other agent of erosion
- **sedimentary rock:** rock that forms when sediments are compacted and cemented or precipitate from liquid
- **sedimentation:** process in which sediments are laid down in a deposit
- **weathering:** chemical or physical breakdown of rocks, soils, or minerals at Earth's surface

Teaching Strategies

Introducing the Lesson

Show students examples of igneous, sedimentary, and metamorphic rock. Ask them to speculate how one type of rock might change to another. Tell them they will learn how when they read this lesson.

Activity

A good starting point in teaching your class about the rock cycle is the interactive rock cycle animation at the URL below.

http://www.classzone.com/books/earth_science/terc/content/investigations/es0602/es0602page02.cfm

Building Science Skills

Students can model processes of the rock cycle with the relatively quick and simple activity at the following URL. Using crayons and other commonly available materials, they will simulate melting, crystallization, weathering, sedimentation, and metamorphism. Then they will relate the simulations to the actual processes of the rock cycle.

http://www.geosociety.org/educate/LessonPlans/RockCycleLab.pdf

Differentiated Instruction

Use the activity at the URL below for kinesthetic learners and students who have less proficient verbal skills. The purpose of this activity is to gain an understanding of the rock cycle by physically traveling through the stages of the cycle.

http://www.eequalsmcq.com/rock%20cycle.pdf

Enrichment

Challenge a small group of students to make a rock cycle board game. They might model their game on the game at the following URL. After they complete their board game, have them explain it to the rest of the class. Encourage other students in the class to play the game.

http://edweb.sdsu.edu/courses/edtec670/cardboard/board/r/rockcyclerace/index.htm

Science Inquiry

An important step in science inquiry is basic background research. Have students do the rock cycle Web quest at the URL below. They will be guided through a series of animations, illustrations, and articles to gain more in-depth knowledge about the rock cycle and its processes. The Web site includes a packet of pages for students to complete in their own words as they go through the Web quest.

http://brandon06.gar.groupfusion.net/modules/groups/group_pages.phtml?gid=1965778&nid=188559&sessionid=

Creative Writing Connection

Story telling can be used to help students understand the changes a rock undergoes as it passes through the rock cycle. In this activity, students will use creative storytelling and their own illustrations to describe the rock cycle.

http://www.pbs.org/americanfieldguide/teachers/rocks/rocks_sum.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 4.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 4.1 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. Describe the difference between a rock and a mineral.

   - [A mineral is a naturally occurring inorganic, crystalline solid with a characteristic chemical composition. A rock is also a naturally occurring solid, but its chemical composition is likely to vary because a rock is a mixture of minerals. A rock may also be organic, and it may or may not be crystalline.]

2. Why can the minerals in a rock be a clue about how the rock formed?

   - [Different minerals form under different environmental conditions, so the minerals in a rock contain clues about the conditions in which the rock formed. For igneous rocks, the size of the mineral crystals also gives clues about where the rock formed. Igneous rocks that form from magma inside Earth have large crystals because the magma cools slowly, giving crystals time to grow large. Igneous rocks that form from lava on Earth's surface have small crystals because the lava cools quickly, giving crystals too little time to grow large.]

3. What are the three main types of rocks and how does each form?

   - [The three main types of rocks are igneous, sedimentary, and metamorphic rocks. Igneous rock forms when magma cools and its minerals crystallize. Sedimentary rock forms when sediments are compacted and cemented together or when a chemical precipitate is left behind after a liquid evaporates. Metamorphic rock forms when the minerals in an existing rock are changed by heat and/or pressure within Earth.]

4. Describe how an igneous rock changes into a metamorphic rock.

   - [An igneous rock changes into a metamorphic rock when it is exposed to high temperatures and/or placed under great pressure.]

5. Describe how an igneous rock changes into a sedimentary rock.

   - [An igneous rock changes into a sedimentary rock when it is weathered and its sediments are eroded, deposited, compacted, and cemented together.]

6. Explain how sediments form.

   - [Sediments form when rocks are weathered physically by being broken down into smaller fragments.]

7. In which rock type do you think fossils, which are the remains of past living organisms, are most often found?

   - [*Sample answer*: I think fossils are most often found in sedimentary rock.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If Earth's interior were no longer hot but all other processes on Earth continued unchanged, what would happen to the different rock types in the rock cycle?

- [*Sample answer*: If Earth's interior were no longer hot, rocks would not melt inside Earth. Therefore, there would be no molten rock to cool and form igneous rocks. Without high temperatures inside Earth, less metamorphism would occur, so there also would be fewer metamorphic rocks. The only rocks that would not be affected directly would be sedimentary rocks]

Stone tools were important to early humans. Are rocks still important to humans today?

- [*Sample answer*: Yes; rocks are still important to humans today. We use rocks for many purposes, such as for building. We also use them as a source of metals and other minerals.]

4.3 Lesson 4.2: Igneous Rocks

Key Concepts

- Composition of magma
- Intrusive and extrusive igneous rocks
- Classification of igneous rocks

Lesson Objectives

- Describe how igneous rocks form.
- Describe the properties of some common types of igneous rocks.
- Relate some common uses of igneous rocks.

Lesson Vocabulary

- **Bowen's Reaction Series:** order in which minerals undergo melting or crystallization as temperature increases or decreases
- **extrusive rock:** any type of igneous rock that forms on Earth's surface from rapidly cooling lava
- **felsic rock:** type of igneous rock that is made mostly of low-density, light-colored minerals such as quartz and feldspar
- **fractional crystallization:** crystallization of a fraction of the minerals in magma
- **intermediate rock:** type of igneous rock that is intermediate in density and color between felsic rock and mafic rock
- **intrusive rock:** any type of igneous rock that forms beneath Earth's surface from slowly cooling magma
- **mafic rock:** type of igneous rock that is made mostly of high-density, dark-colored minerals such as olivine and pyroxene
- **partial melting:** melting of some but not all of the minerals in rock
- **pluton:** intrusive igneous rock that has cooled in the crust
- **porphyritic:** type of igneous rock texture in which large, visible crystals are found within a matrix of tiny crystals
- **ultramafic rock:** type of igneous rock that contains more than 90 percent mafic minerals such as olivine and pyroxene
- **vesicular:** type of igneous rock texture that includes holes left by gas bubbles in the magma
- **volcanic rock:** another name for extrusive igneous rock because it forms from volcanic activity

Teaching Strategies

Introducing the Lesson

Pass a piece of pumice around the class so students can feel how light it is. Point out the tiny holes in the rock. Ask students if they know why pumice is full of holes and so light in weight. Tell them they will learn why when they read this lesson.

Demonstration

Use the interactive animation at the URL below to show students how igneous rocks form. Clicking on the labeled features show microscopic views of igneous crystals forming under different cooling conditions and relates cooling rates to rock texture.

http://www.classzone.com/books/earth_science/terc/content/investigations/es0603/es0603page05.cfm

Building Science Skills

You can use the lesson plan at the following URL when you teach your class about igneous rocks. The purpose of the lesson is to compare and contrast intrusive and extrusive igneous rocks, demonstrate how the rate of cooling affects an igneous rock's texture, and classify igneous rocks according to texture and composition

http://alex.state.al.us/lesson_view.php?id=23943

Differentiated Instruction

Pair less proficient readers with other students, and ask partners to create a Venn diagram comparing and contrasting intrusive and extrusive igneous rocks.

Enrichment

Have students read the detailed analogy at the URL below, which explains how granite is like ice cream. Challenge the students to think of their own, unique analogy for an igneous rock such as granite. Ask them to explain their analogy to the class.

http://uts.cc.utexas.edu/ rmr/analogy.html

Science Inquiry

Provide groups of students with an igneous rock sample. Have them identify and describe important features of their rock and classify it as intrusive or extrusive. You may also want to have them try to classify their rock by composition based on color and density. Discuss with the class what minerals might make up the different rocks.

Real-World Connection

Discuss the diversity of everyday uses of igneous rocks. Call on students to identify igneous rocks in or around their home. (Answers might include buildings, statues, paving, countertops, jewelry, and toothpaste.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 4.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 4.2 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. What is the visible difference between an intrusive and an extrusive igneous rock?

- [An intrusive igneous rock has larger mineral crystals than an extrusive igneous rock.]

2. How does the difference in the way intrusive and extrusive rocks form lead to the differences in how the rocks appear?

- [Intrusive rocks form when magma cools slowly under Earth's surface, giving large mineral crystals time to form. Extrusive rocks form when lava cools quickly on Earth's surface, not giving large crystals time to form.]

3. What causes solid rocks to melt?

- [Solid rocks melt if they are raised to a high temperature. The exact temperature depends on many factors, including pressure, addition of water, and

rock composition.]

4. How are partial melting and fractional crystallization the same and different from each other?

- [Partial melting occurs when the temperature of a rock is high enough to melt only some of the minerals it contains. Fractional crystallization is the opposite of partial melting. It occurs when the temperature of a molten rock is low enough to crystallize only some of its minerals.]

5. How are igneous rocks classified?

- [Igneous rocks are classified by how they formed as intrusive or extrusive. They are classified by their composition as felsic, intermediate, mafic, or ultramafic.]

6. Describe two ways granite is different from basalt.

- [*Sample answer*: Granite is an intrusive igneous rock with large mineral crystals, and basalt is an extrusive igneous rock with small mineral crystals. Granite is a felsic rock that is relatively high in silica, and basalt is a mafic rock that is relatively low in silica.]

7. List three common uses of igneous rocks.

- [*Sample answer*: Three common uses of igneous rocks are for buildings, statues, and abrasives.]

8. Occasionally, igneous rocks contain both large crystals and tiny mineral crystals. Propose a way that both sizes of crystals might have formed in the rock.

- [*Sample answer*: Both sizes of crystals might have formed in the rock if some of it cooled slowly under Earth's surface and then it erupted in a volcano and finished cooling quickly on the surface.]

9. How do you imagine an igneous rock will cool on the seafloor, and what will be the size of its crystals?

- [An igneous rock will cool quickly in the cold water on the seafloor. It will have small crystals because large crystals won't have time to form.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Are igneous rocks forming right now?

- [Yes; they are forming within Earth and wherever there is volcanic activity.]

Why don't all igneous rocks with the same composition have the same name?

- [Rocks with the same composition may form in different ways and be different types of rock, such as intrusive or extrusive.]

Could an igneous rock cool at two different rates? What would the crystals in such a rock look like?

- [Yes; it could cool at different rates if it started to cool under the surface and then finished cooling on the surface.]

4.4 Lesson 4.3: Sedimentary Rocks

Key Concepts

- Weathering, erosion, and deposition of sediments
- Sedimentary rock formation
- Clastic, chemical, and biochemical rocks
- Uses of sedimentary rocks

Lesson Objectives

- Describe how sedimentary rocks form.
- Describe the properties of some common sedimentary rocks.
- Relate some common uses of sedimentary rocks.

Lesson Vocabulary

- **biochemical sedimentary rock:** rock that forms mostly from the remains of organisms
- **bioclastic rock:** sedimentary rock that forms from sediments that include organic remains
- **cementation:** sticking together of sediments by mineral crystals from fluids
- **chemical sedimentary rock:** rock that forms from the hardening of chemical precipitates
- **clastic rock:** sedimentary rock that forms from inorganic sediments
- **compaction:** squeezing together of sediments by the weight of overlying sediments
- **lithification:** formation of rock from sediments by the processes of compaction and cementation
- **organic:** related to living things

Teaching Strategies

Introducing the Lesson

Show the class several different sedimentary rocks, either photos or actual specimens. The URLs below are good sources for photos. Call on students to point out properties of the rocks. Tell them that all of the specimens are sedimentary rocks, or rocks formed from sediments. Review the meaning of sediments with the class, including chemical precipitates. Tell students they will learn more about sedimentary rocks in this lesson.

http://www.rocksandminerals4u.com/igneous_metamorphic_sedimentary_rock.html

http://geology.com/rocks/sedimentary-rocks.shtml

Activity

Assign the article and interactive table on sedimentary rocks at the URL below. Students can explore how sedimentary rocks contain clues to ancient environments.

http://www.windows2universe.org/earth/geology/sed_facies.html&edu=mid

Building Science Skills

Have students do the online sedimentary rock identification exercise at the following URL. They will use an interactive dichotomous key to identify sedimentary rock specimens. Excellent background on sedimentary rock identification is also provided at the Web site.

http://newterra.chemeketa.edu/afrank1/rocks/sedimentary/sedrxs.htm

Differentiated Instruction

Make sure students do not confuse the crystallization of molten rock to form igneous rock with the crystallization of mineral precipitates to form sedimentary rock. Point out that precipitates are transported and deposited by water so they are sediments, like sand or other sediments deposited by water or other agents of erosion.

Enrichment

Students may not appreciate the long time scale involved in the formation of sedimentary rocks. Ask one or more students to create a time scale for the rocks in the Grand Canyon that correctly (to scale) shows how short a time humans have existed since the oldest rock layers started to form. The article below provides background information and ideas. Post their time line in the classroom.

http://southwest.library.arizona.edu/azso/back.1_div.1.html

Science Inquiry

In the inquiry activity at the URL below, groups of students will design an experiment to show how sedimentary rocks form when dissolved minerals precipitate from water. They will develop a hypothesis and procedure, identify variables and controls, list materials needed, and identify safety measures. (A sample experiment might involve placing table salt in water, then heating the water until it evaporates.) If time permits, allow students to carry out their experiments.

http://alex.state.al.us/lesson_view.php?id=23945

Overcoming Misconceptions

Students commonly think that cementation of sediments results from drying and requires pressure. You can model cementation with a simple procedure that clearly counters these misconceptions. Pour a supersaturated solution of sodium acetate trihydrate over gravel in an aquarium. Within minutes, the gravel will be cemented together with easy-to-see sodium acetate crystals. The model shows students that drying and pressure are not needed because they are clearly not present in the demonstration. The idea for this demonstration is based on the following URL:

https://gsa.confex.com/gsa/2011NE/finalprogram/abstract_185053.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 4.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 4.3 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. What are three categories of things that might be part of the sediments in sedimentary rock?

- [The sediments in sedimentary rocks might include fragments of other rocks, organic materials, or chemical precipitates.]

2. If you see a sedimentary rock outcrop with layers of red sandstone on top of layers of tan sandstone, what do you know about the ages of the two layers?

- [The layers of tan sandstone formed first so they are older than the layers of red sandstone.]

3. Why do sedimentary rocks sometimes have layers of different colors?

- [Sedimentary rocks sometimes have layers of different colors because they formed in different environments. For example, red rocks form when oxygen is present. Darker sediments form when the environment is oxygen poor.]

4. Describe the two processes necessary for sediments to lithify into sedimentary rock.

- [The two processes necessary for sediments to lithify into sedimentary rock are compaction and cementation. Compaction occurs when sediments are squeezed together by the weight of overlying sediments. Cementation occurs when fluids move through the spaces between the loose particles of sediment and minerals crystalize from the fluids to fill in the spaces.]

5. How are bioclastic rocks different from clastic rocks? Give an example of a bioclastic rock.

- [Bioclastic rocks form from sediments that include organic material. Clastic rocks form from sediments that contain only inorganic material. An example of a bioclastic rock is limestone.]

6. What type of sedimentary rock is coal?

- [Coal is an organic, or biochemical, sedimentary rock.]

7. In what environment do you think chemical sedimentary rocks are most likely to form?

- [*Sample answer*: I think that chemical sedimentary rocks are most likely to form in a wet environment because these rocks form when dissolved minerals precipitate out of water.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Is a rock always made of minerals? Do the requirements for something to be a mineral need to be met for something to be a rock?

- [*Sample answer*: For something to be a mineral, it must be inorganic. This requirement need not be met for something to be a rock because some rocks, such as coal, are made of organic materials.]

Which type of rocks do you think yields the most information about Earth's past?

- [*Sample answer*: I think that sedimentary rocks yield the most information about Earth's past because they are deposited in layers that create a record through time of the environment when the rocks formed. Also, sedimentary rock layers often contain fossils, which provide a record of organisms through time.]

Could a younger layer of sedimentary rock ever be found under an older layer? How do you think this could happen?

- [*Sample answer*: Yes; I think a younger layer of sedimentary rock could be found under an older layer. This could happen if the layers were disturbed after they formed. Some type of geological process or human actions might disturb the layers.]

Could a sedimentary rock form only by compaction from intense pressure?

- [*Sample answer*: Cementation as well as compaction must occur to lithify loose sediments and turn them into sedimentary rock.]

4.5 Lesson 4.4: Metamorphic Rocks

Key Concepts

- Formation of metamorphic rocks
- Regional and contact metamorphism
- Uses of metamorphic rocks

Lesson Objectives

- Describe how metamorphic rocks form.
- Describe the properties of some common metamorphic rocks.
- Relate some common uses of metamorphic rocks.

Lesson Vocabulary

- **contact metamorphism:** changes in rock due to heating by contact with hot magma
- **foliation:** formation of layers in rock due to extreme pressure
- **regional metamorphism:** changes in rock over a large area due to pressure from other rock or geological processes

Teaching Strategies

Introducing the Lesson

Have one or more students crumple a sheet of paper between their hands. Then tell the class to look in the lesson at the figure of foliated metamorphic rock. Tell students that a similar force created the crumpled folds in the rock as was exerted on the paper. They will learn about it when they read this lesson.

Activity

Have students complete the interactive module at the URL below to explore the causes and consequences of metamorphism.

http://ees.as.uky.edu/sites/default/files/elearning/module02swf.swf

Differentiated Instruction

Pair students who need extra help with other students, and have partners collaborate on making a compare/contrast table for foliated and non-foliated metamorphic rocks. They might compare and contrast how the two types of rocks form and how they appear. Suggest that they include examples and sketches of each type of rock.

Enrichment

Have a few students use rock specimens to create a display that shows how rocks change with metamorphism. They can use the table in the lesson as a guide. For example, their display might show that the sedimentary rock sandstone changes by contact metamorphism to quartzite, and the sedimentary rock limestone changes by contact metamorphism to marble. Alternatively they might show how increasing pressure and temperature change the sedimentary rock shale first into slate, then into phyllite, then into schist, and last into gneiss. Provide a prominent place for their display in the classroom.

Science Inquiry

The class activities at the following URL simulate one or more ways that metamorphic rocks form. Activity 1 simulates contact metamorphism, activity 2 simulates the formation of slate by regional metamorphism, and activity 3 simulates the distortion of fossils under pressure using plaster of Paris models.

http://www.rsc.org/education/teachers/resources/jesei/meta/home.htm

Chemistry Connection

Explain that metamorphic minerals are those that form only at the high temperatures and pressures associated with the process of metamorphism. These minerals, known as index minerals, include sillimanite, kyanite, staurolite, andalusite, and some garnet. Other minerals, such as olivines, pyroxenes, amphiboles, micas, feldspars, and quartz, may be found in metamorphic rocks, but are not necessarily the result of the process of metamorphism. These minerals formed during the crystallization of igneous rocks. They are stable at high temperatures and pressures and may remain chemically unchanged during the metamorphic process. However, all minerals are stable only within certain limits, and the presence of certain minerals in metamorphic rocks indicates the approximate temperatures and pressures at which they formed.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 4.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 4.4 in *CK-12 Earth Science for High School*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

1. Why do minerals change composition as they undergo metamorphism?

- [Minerals change composition as they undergo metamorphism to form new minerals that are more stable in the new environment of high temperature and/or extreme pressure.]

2. Describe the process by which minerals in a rock rearrange to become different minerals when exposed to heat or pressure.

- [When exposed to heat or pressure, ions move between minerals to create minerals of different chemical compositions.]

3. Describe the conditions that lead to foliated versus non-foliated metamorphic rocks.

- [Foliated metamorphic rocks form when rocks are squeezed by pressure, normally pressure exerted in just one direction. Non-foliated metamorphic rocks form when rocks are heated by contact with hot magma.]

4. List and describe the two main types of metamorphism.

- [The two main types of metamorphism are contact metamorphism and regional metamorphism. Contact metamorphism occurs when magma contacts a rock and changes it by extreme heat. Regional metamorphism occurs when rocks over a wide area are exposed to pressure from overlying rock and sediment layers or from other geological processes.]

5. What can geologists look at in a metamorphic rock to understand that rock's history?

- [*Sample answer*: They can look at the rock's mineral composition and whether it has layers that show evidence of foliation.]

6. Suppose a phyllite sample was metamorphosed again. How might it look different after this second round of metamorphism?

- [It would look like schist. It would have larger grains than the phyllite sample because grain size increases with greater temperature and pressure.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What type of rock forms if an existing rock heats up so much that it melts completely and then forms a different rock?

- [If it melts completely, it forms an igneous rock.]

What clues can a rock give about its history if it was so altered by metamorphism that it is unrecognizable?

- [It might give clues about the temperatures and pressures to which it had been exposed.]

CHAPTER 5 HS TE Earth's Energy

Chapter Outline

5.1 Chapter 5: Earth's Energy

Chapter Overview

This chapter discusses nonrenewable energy resources, including fossil fuels and nuclear energy; and renewable energy resources, including solar, wind, water, geothermal, and biomass energy.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this lab, students will investigate the law of conservation of energy. They will develop and carry out a lab procedure to maximize the conversion of potential energy to kinetic energy.

- http://serc.carleton.edu/sp/mnstep/activities/19872.html

Students can explore nuclear energy with the lab at the URL below. The lab is based on a nuclear fission simulation at the same Web site.

- http://phet.colorado.edu/en/contributions/view/3335

The booklet below provides high school students with a variety of projects to broaden their knowledge of renewable energy resources and the scientific method. Projects are available on biofuels, wind, and solar energy.

- http://www1.eere.energy.gov/biomass/pdfs/highschool_projects.pdf

These Web sites may also be helpful:

The following URL provides several fossil fuel study guides and activities for high school students.

- http://www.fossil.energy.gov/education/energylessons/Study_Guides_and_Activities.html

Go to the URL below for a guide to teaching high school students about renewable energy.

- http://www.ucsusa.org/assets/documents/clean_energy/renewablesready_fullreport.pdf

Pacing the Lessons

TABLE 5.1: short caption

Lesson	Class Period(s) (60 min)
5.1 Energy Resources	1.5
5.2 Nonrenewable Energy Resources	2.5
5.3 Renewable Energy Resources	2.0

5.2 Lesson 5.1: Energy Resources

Key Concepts

- The need for energy
- Energy, fuel, and heat
- Types of energy resources

Lesson Objectives

- Compare ways in which energy changes from one form to another.
- Discuss what happens when a fuel burns.
- Describe the difference between renewable and nonrenewable resources.
- Classify different energy resources as renewable or nonrenewable.

Lesson Vocabulary

- **chemical energy:** energy that is stored in the chemical bonds of molecules
- **energy:** ability to do work or produce change in matter
- **fuel:** material that can release energy in a chemical change
- **heat:** energy associated with the movement of atoms or molecules
- **kinetic energy:** energy that an object in motion has because of its motion
- **law of conservation of energy:** law stating that energy cannot be created or destroyed
- **nonrenewable resource:** resource that is used more quickly than it is replaced or that is limited to what is currently available on Earth
- **potential energy:** energy stored within a physical system that has the potential to do work
- **renewable resource:** resource that is limitless or that is replaced as quickly as it is used

Teaching Strategies

Introducing the Lesson

Hold a pen, book, or other object at arm's length in each hand. As students observe, hold one of the objects motionless while dropping the other object to the floor. Ask students which object had more energy while one object was falling. (Students are likely to think that the falling object had more energy while it was moving.) Tell students that the stationary object and falling object have the same amount of energy. They will learn why when they read this lesson.

Activity

You may want to use the lesson plan and activity at the URL below when you teach this lesson. This is a multi-day lesson plan that includes an introduction to energy resources, an activity to understand the value of renewable energy resources, and research on specific energy resources.

http://www.clarkson.edu/highschool/k12/project/documents/energysystems/5-Energy-Sources-and-Systems.pdf

Demonstration

Show students the video clip "Conservation of Mechanical Energy" at the URL below. The video defines potential and kinetic energy and shows how energy is conserved when it changes form.

http://ocw.mit.edu/high-school/physics/work-energy-power/conservation-of-energy/

Discussion

Have students watch the high-speed video of a roller coaster at the following URL to observe how the coaster changes back and forth between kinetic and potential energy. Discuss how some energy is "lost" as heat because of friction between the wheels and track and between the car and air (air resistance).

http://serc.carleton.edu/sp/compadre/teachingwdata/examples/48922.html

Differentiated Instruction

Have students create a table comparing and contrasting renewable and nonrenewable energy resources. They should include in their table several examples of each type of energy resource.

Enrichment

Ask a student who has knowledge of chemistry to find and write on the board the equation for the combustion of the fuel methane ($CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$). Have the student explain the equation to the rest of the class and identify the products of combustion (CO_2 and H_2O). Relate the production of CO_2 to the effects of fossil fuel combustion on the greenhouse effect and global climate change.

Science Inquiry

Have groups of students do simulation activity 1 in the "Four Skate Park Activities" PDF document at the URL below. Students will explain the conservation of energy using kinetic and gravitational potential energy as an example. Then they will design a simulated skate park using the concepts.

http://phet.colorado.edu/en/contributions/view/3134

Overcoming Misconceptions

The URL below lists a number of misconceptions about energy that have been documented in students in grades 9–12. Read the misconceptions that are relevant to lesson content, and ask students if they think the statements are true or false. For any misconceptions students identify as true, explain why the statements are false.

http://assessment.aaas.org/topics/EG#/,tabs-247/2

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 5.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 5.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is needed by anything that moves or changes in any way?

- [Anything that moves or changes in any way needs energy.]

2. What is the original source of most energy used on Earth?

- [The sun is the original source of most energy used on Earth.]

3. In what form does a living creature store energy from food?

- [A living creature stores energy from food in the form of chemical energy.]

4. When we burn a fuel, what is released that allows work to be done?

- [When we burn a fuel, energy is released that allows work to be done.]

5. For biomass, solar, coal, natural gas, oil, and geothermal energy, identify each energy resource as renewable or nonrenewable and explain why.

- [Biomass energy is renewable because it is the energy of plants or other living things and more plants can be grown to replace the ones we use. Solar energy is renewable because it is nearly limitless in supply and will continue to exist for billions of years. Coal, natural gas, and oil are nonrenewable energy resources because they are limited in supply and take far longer to form than they are being used. Geothermal energy is renewable because it comes from hot rocks inside Earth and there are always more hot rocks available.]

6. What factors are important in judging how helpful an energy resource is to us?

- [Factors important in judging the helpfulness of an energy resource include whether the resource is renewable or nonrenewable, whether using the resource for energy is practical, and how using the resource affects human health and the environment.]

7. Is the energy from a rechargeable battery renewable? (A rechargeable battery can be recharged by being put into a device that is plugged into the wall.) Explain.

- [The energy from a rechargeable battery is renewable in the sense that the battery can be recharged and reused over and over again. However, the electricity that recharges the battery may or may not be generated from a renewable source of energy.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How long do fossil fuels take to form?

- [Fossil fuels take millions of years to form.]

Are all fossil fuels nonrenewable resources?

- [Yes; all fossil fuels are nonrenewable resources because they form much more slowly than they are being used.]

Do all fossil fuels affect the environment equally?

- [No; coal is the most polluting, and natural gas is the least polluting.]

How is food energy measured?

- [Food energy measured in kilocalories or kilojoules.]

Is a rechargeable battery a renewable source of energy?

- [No, not really, because the energy needed to recharge it usually is produced from fossil fuels.]

5.3 Lesson 5.2: Nonrenewable Energy Resources

Key Concepts

- Formation of fossil fuels
- Coal, oil, and natural gas
- Nuclear energy

Lesson Objectives

- Describe the natural processes that form the different fossil fuels.
- Describe different fossil fuels, and understand why they are non-renewable resources.
- Explain how fossil fuels are turned into useful forms of energy.
- Understand that when we burn a fossil fuel, its energy is released as heat.
- Describe how a nuclear power plant produces energy.

Lesson Vocabulary

- **coal:** solid fossil fuel that formed over millions of years from dead swamp plants
- **crude oil:** unrefined oil as it is taken from below Earth's surface
- **fossil:** any remains or traces of a long-dead organism
- **fossil fuel:** substance consisting of hydrocarbons that formed from the remains of dead organisms and can be burned for energy; coal, oil, or natural gas
- **hydrocarbon:** any chemical compound consisting only of hydrogen and carbon
- **natural gas:** gaseous fossil fuel that formed over millions of years from dead sea organisms and that consists mainly of the hydrocarbon methane (CH_4)
- **nuclear energy:** energy released from the nucleus of an atom when it is changed into another atom by a nuclear reaction
- **oil:** liquid fossil fuel that formed over millions of years from dead sea organisms

Teaching Strategies

Introducing the Lesson

Students are unlikely to have given much thought to where their electricity comes from. Ask them if they know what energy resource is used to make the electricity that supplies their community. Chances are the electricity comes from coal, natural gas, or nuclear energy, all of which are nonrenewable energy resources. Share the **Table** 5.2 with the class, and tell them they will learn more about these nonrenewable energy resources in this lesson.

TABLE 5.2: Sources of Electricity

Energy Resource	Percent of U.S. Electricity Generated with this Resource (2011)
Coal	42%
Natural Gas	25%
Nuclear Energy	19%
All Other Energy Resources	14%

Building Science Skills

In the document below, have students read the background on ocean energy (page 4) and petroleum and natural gas (pages 5–6). Then assign groups of students to do activities 2–4 (pages 15–17). In the activities, they will create models of stationary and floating oil rigs and simulate drilling for oil on the ocean floor. The activities will address the following research questions: What are the challenges of finding and producing oil form offshore basins? What is the maximum depth in which a stationary rig could be used? What are some unique challenges of drilling in deep water?

http://www.fossil.energy.gov/education/OceanEnergyMMS.pdf

Differentiated Instruction

Have pairs of students make an illustrated flow chart showing how coal or petroleum forms. In their flow chart, they might include the following steps: plants or animals dying and their remains settling on the ground, deposition of overlying sediment layers, thick layers of sediments creating intense heat and pressure, and formation of hydrocarbons (coal or oil) from the organic remains.

Enrichment

Ask a few interested students to do a Web quest to investigate the following questions:

1. What is clean coal?
2. How does clean coal differ from other coal?
3. Is clean coal really clean (nonpolluting)?
4. What is the future of clean coal use in the U.S.?

Invite students to share the results of their investigation with the rest of the class in a PowerPoint presentation.

Science Inquiry

In this problem-solving classroom activity, students will gather and analyze data to determine how much it costs to light their school. They will also compute the amount of coal needed to produce the electricity.

http://www.fe.doe.gov/education/energylessons/coal/How_Much_Does_It_Cost_to_Light_Your_Scho.pdf

Physics Connection

Explain in greater detail how nuclear fission reactions occur and why they release so much energy. You and/or your students can learn more at this URL: http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/fission.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 5.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 5.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is a hydrocarbon?

- [A hydrocarbon is any chemical compound consisting only of hydrogen and carbon. Fossil fuels are made up of hydrocarbons and burned for energy.]

2. How do fossil fuels form?

- [Fossil fuels form when dead organisms settle to the bottom of swamps, lakes, or seas. The remains are then covered with sediments, which place great pressure and heat on them. Over millions of years, the heat and pressure change the remains to hydrocarbons.]

3. Why is anthracite harder and cleaner than other kinds of coal?

- [Anthracite is harder and cleaner than other kinds of coal because it is metamorphic rock. It forms when sedimentary coal is exposed to even greater heat and pressure. This changes the coal to a purer form that is harder and contains fewer impurities. With fewer impurities, anthracite burns more cleanly than other kinds of coal.]

4. What byproduct of nuclear energy has caused concerns about the use of this resource and why?

- [Nuclear energy is produced when uranium atoms are split. This creates radioactive waste as a byproduct. The radioactive waste remains dangerous for thousands or even hundreds of thousands of years. As yet, there is no long-term solution for safely storing this waste.]

5. What are two important fuels that come out of the oil refining process?

- [*Sample answer*: Two important fuels that come out of the oil refining process are gasoline and heating oil.]

6. Which chemical element exposed in surface coal mining can cause environmental problems in nearby bodies of water?

- [The chemical element sulfur is exposed in surface coal mining. Sulfur mixes with air and water to make sulfuric acid. If the sulfuric acid gets into nearby bodies of water, it can kill plants, fish, and other animals that live in or near the water.]

7. Why does natural gas need to be processed before it can be used as a fuel?

- [Natural gas needs to be processed before it can be used as a fuel because it contains chemicals that are poisonous to humans or that make the gas less useful as a fuel. Processing natural gas removes almost everything except the methane.]

8. What characteristic of gasoline is most important in making it a useful fuel for transportation? Explain.

- [The characteristic of gasoline that is most important in making it a useful fuel for transportation is that it is a concentrated form of energy. A relatively small amount of gasoline releases a large amount of energy when it is burned. This makes gasoline convenient for use in cars and other transportation vehicles because enough fuel can be carried by the vehicle to run it without adding too much weight.]

9. Since nuclear power is clean, why is it not used more extensively in the United States?

- [Nuclear power does not release air pollution or carbon dioxide, but it produces radioactive waste that remains dangerous for thousands or hundreds of thousands of years. This is one reason people fear the use of nuclear power. Accidents at nuclear power plants, such as Three Mile Island, Chernobyl, and Fukushima Daiichi, have added greatly to the fear of nuclear power. For these reason, nuclear power is not used more extensively in the United States.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What are the main categories of nonrenewable energy discussed in this chapter?

- [The main categories of nonrenewable energy discussed in this chapter are fossil fuels and nuclear energy.]

Why is nuclear energy considered nonrenewable?

- [Nuclear energy is considered nonrenewable because it uses as a fuel the radioactive element uranium, which is finite in supply and may eventually run out.]

Are nonrenewable energy sources equally harmful? What are the advantages of using them?

- [Both fossil fuels and nuclear energy are harmful, although the nature of the harm they cause is different. Reasonable arguments could be made for either fossil fuels or nuclear energy being more harmful. Fossil fuels create air pollution and greenhouse gases, whereas nuclear power creates dangerous radioactive wastes and the risk of nuclear disasters. The advantages of using nonrenewable energy sources include the high-quality energy they provide and the ease of transporting them (especially oil and natural gas).]

Are renewable energy sources harmful or beneficial for the environment?

- [Compared with nonrenewable energy sources, renewable energy sources are less harmful for the environment. For example, most renewable energy sources are not burned so they do not produce air pollution or greenhouse gases as fossil fuels do. Renewable energy sources also do not produce dangerous wastes as nuclear energy does. The environment would benefit if fewer nonrenewable and more renewable energy sources were used.]

5.4 Lesson 5.3: Renewable Energy Resources

Key Concepts

- Solar energy
- Water energy
- Wind energy
- Geothermal energy
- Biomass energy

Lesson Objectives

- Describe different renewable resources and understand why they are renewable.
- Discuss how the sun is the source of most of Earth's energy.
- Describe how energy is carried from one place to another as heat and by moving objects.
- Discuss why some renewable energy sources cost less than others do and why some cause less pollution than others.
- Explain how renewable energy resources are turned into useful forms of energy.
- Describe how the use of different renewable energy resources affects the environment.

Lesson Vocabulary

- **biofuel:** fuel made from biomass, or living things, usually crop plants such as corn
- **conduction:** transfer of heat by direct contact from a higher-temperature to a lower-temperature object
- **radiation:** transfer of energy through space or matter by electromagnetic waves

Teaching Strategies

Introducing the Lesson

Share the following facts and figures with the class to spur interest in solar energy. Then tell students they will read about solar and other renewable energy resources in this lesson.

- Earth receives more energy from the sun in an hour than is used in the entire world in one year.
- It would take only around 0.3 % of the world's land area to gather enough solar energy for the world's electricity needs.
- If only 5 % of American households were to go solar, it would be the equivalent of taking 7.7 million cars off the road and removing almost 90 million pounds of CO2 from the environment.

Building Science Skills

With the activity "Solar Water Heater" at the following URL, students will build a model water heater, which is based on home solar water heaters. The modeling activity will demonstrate to students how sunlight can be used to heat water.

http://www.ucsusa.org/assets/documents/clean_energy/renewablesready_fullreport.pdf

Cooperative Learning

Have your class investigate renewable energy technologies. Divide the class into groups and have each group read about and explain to the class the scientific principles and technology underlying the following renewable energy resources:

- solar thermal energy for heating homes and water
- photovoltaic cells
- wind energy
- biomass for electricity generation, heat, and transportation fuels
- hydropower
- geothermal energy

Differentiated Instruction

Before students read the lesson, have them start a cluster diagram of renewable energy resources. They should label the center circle "Renewable Energy Resources," and they should label each surrounding with one of the forms of renewable energy described in the lesson. Then, as students read the lesson, they should add one or two of the most important details to each surrounding circle. Tell them to add their diagrams to their science notebook.

Enrichment

Ask a few students to research the following question, take different stances on the issue, and then debate the issue in front of the rest of the class.

Question: Should we develop nonrenewable energy resources, renewable energy resources, or both?

Science Inquiry

In Activity 6 ("The Answer is Blowing in the Wind") at the URL below, students will make three wind machines and test them in order to determine the factors that affect how well they turn with the least amount of wind and how much electricity they can generate. This engineering connection will help them appreciate some of the technical issues involved in developing renewable resources.

http://www.nrel.gov/docs/gen/fy01/30927.pdf

Economics Connection

Have students play the game "Playing It Cool: A Renewable Energy Economics Game" at the following URL. The game simulates some of the economic changes necessary to make renewable energy resources successful as large-scale sources of electricity. In the activity, students will buy and sell electricity from various nonrenewable and renewable sources and learn about economic considerations in using renewable energy resources.

http://www.ucsusa.org/assets/documents/clean_energy/renewablesready_fullreport.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 5.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 5.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. If you turn on the burner of a gas stove under a pan of cold water, energy moves from the burner to the pan of water. What is this type of energy transfer called? How does this energy move?

- [This type of energy transfer is called conduction. This energy moves by direct contact from an object with a higher temperature (the burner) to an object with a lower temperature (the pan).]

2. If solar power needs sunshine, how can solar power be a viable option for power?

- [Solar power is extremely abundant and widespread and will never run out, but it is not useful in locations that are often cloudy or at night. However, storage technology is being developed so that solar energy acquired on sunny days can be stored for use on cloudy days or at night.]

3. If you burn wood in a fireplace, which type of energy resource are you using?

- [If you burn wood in a fireplace, you are using biomass energy.]

4. Which form of energy is an important factor in making electricity from water power?

- [Kinetic energy of moving water is an important factor in making electricity from water power. The kinetic energy of the moving water is used to make a turbine spin. The spinning turbine is connected to a generator, which uses the kinetic energy to make electricity.]

5. Most of the energy that travels from the sun to Earth arrives in the form of visible light. What is this movement of energy called?

- [The movement of light energy from the sun to Earth is called radiation.]

6. Explain how mirrors are used in some solar energy plants.

- [In some solar energy plants, large groups of mirrors are used to focus sunlight in one place, called a receiver. At the receiver, a liquid such as oil or water is heated to a high temperature. This energy is used to make electricity.]

7. Explain how wind power uses kinetic energy.

- [Wind is moving air, so it has kinetic energy. The moving air spins a turbine, which is uses the kinetic energy to create electricity.]

8. NIMBY means "Not in My Backyard." How do various green energy projects, like Cape Wind, qualify as NIMBY projects?

- [Cape Wind is a project to build windmills off Cape Cod in order to supply electricity to Cape Cod and nearby islands. Local residents (and tourists) are unhappy about wind farms being built near beaches. Opponents are in favor of wind power but not at that location.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What areas do you think would be best for using solar energy?

- [*Sample answer*: Areas that receive a lot of sun and have very little cloud cover would be best for using solar energy. Areas covered by deserts would probably be good places for using solar energy. Solar power is being developed in some western states that get a lot of sunlight, including California, Arizona, and Nevada.]

What causes the high temperatures deep inside Earth that make geothermal energy possible?

- [The high temperatures deep inside Earth that make geothermal energy possible are caused by left over heat from the planet's formation and by the decay of radioactive elements in Earth's interior.]

Do you think your town or city could use wind or water power?

- [Answers may vary, depending on the local availability of wind or water. A town or city in an open area that gets strong sustained winds could potentially use wind power. A town or city with a nearby stream suitable for damming might be able to use water power.]

CHAPTER 6 HS TE Plate Tectonics

Chapter Outline

6.1 Chapter 6: Plate Tectonics

Chapter Overview

This chapter covers properties of Earth's interior, continental drift, seafloor spreading, the theory of plate tectonics, and plate boundaries.

Online Resources

See the following Web sites for appropriate laboratory activities:

Use the continental drift lab at the following URL when you teach the first two lessons in this chapter. The lab incorporates collaborative groups and introduces the basic principles that underlie the theory of plate tectonics. It will help students visualize Earth as a "living" planet" that is constantly changing. This lab was created as a result of the Girls Engaged in Math and Science Project.

- http://alex.state.al.us/lesson_view.php?id=23948

In the lab activity at the following URL, students will gain an understanding of how geologists determine rates of sea floor spreading. They will also practice applying some basic mathematical concepts, including conversion from one set of units to another.

- http://www.beloit.edu/sepm/Earth_Works/Sea_floor_spreading.html

In the following plate tectonics lab, students will analyze the tectonics of a simple hypothetical planet that features continents with ancient mountain ranges, oceans (complete with magnetic "stripes" and a hotspot volcanic chain), an island arc, and a trench. They will estimate rates of plate movement and reconstruct past and future plate tectonic regimes. The lab will give students a deeper understanding of fundamental plate tectonic concepts.

- http://serc.carleton.edu/sp/library/guided_discovery/examples/geoworld.html

These Web sites may also be helpful:

The online USGS publication This Dynamic Earth (see URL below) provides excellent background for you or your advanced students on plate tectonics.

- http://pubs.usgs.gov/gip/dynamic/dynamic.html

This URL contains links to numerous Web sites related to the study of plate tectonics: http://www.tectonicplate.com/resource/

The videos below provide excellent visuals and explanations of seafloor spreading and plate movements.

- http://www.youtube.com/watch?v=ryrXAGY1dmE
- http://www.youtube.com/watch?v=1-HwPR_4mP4
- http://www.youtube.com/watch?v=JmC-vjQGSNM

Pacing the Lessons

TABLE 6.1: short caption

Lesson	Class Period(s) (60 min)
6.1 Inside Earth	2.0
6.2 Continental Drift	1.5
6.3 Seafloor Spreading	1.0
6.4 Theory of Plate Tectonics	2.5

6.2 Lesson 6.1: Inside Earth

Key Concepts

- Exploring Earth's interior
- Seismic waves and other evidence about Earth's interior
- Earth's layers (crust, mantle, and inner and outer core)
- Asthenosphere and lithosphere

Lesson Objectives

- Compare and describe each of these Earth layers: lithosphere, oceanic crust, and continental crust.
- Compare some of the ways geologists learn about Earth's interior.
- Describe how convection takes place in the mantle.
- Compare the two parts of the core and describe why they are different from each other.

Lesson Vocabulary

- **conduction:** transfer of heat by direct contact from a higher-temperature to a lower-temperature object
- **continental crust:** thicker, denser part of Earth's crust that makes up the continents
- **convection:** transfer of heat by the movement of molecules in currents through a fluid
- **convection cell:** circular current of warm material rising and cool material sinking
- **core:** dense, metallic innermost layer of Earth, consisting of the inner and outer core
- **crust:** rocky, outermost layer of Earth, consisting of continental and oceanic crust
- **lithosphere:** rigid part of Earth that consists of the crust and upper mantle
- **mantle:** middle layer of Earth, consisting of hot rock that circulates by convection
- **meteorite:** rocky fragment of a planetary body that strikes Earth's surface from space
- **oceanic crust:** thinner, less dense part of Earth's crust that makes up the ocean basins
- **P-wave:** primary waves, or seismic waves that arrive first at a seismograph
- **S-wave:** secondary waves, or seismic waves that arrive second at a seismograph
- **seismic wave:** earthquake wave that transports energy from an earthquake through the ground in all directions

Teaching Strategies

Introducing the Lesson

Use the video collage and layers of Earth song at the following URL to introduce your class to Earth's interior. The song also makes a good review of Earth's layers after students have read the lesson.

http://www.youtube.com/watch?v=Q9j1xGaxYzY

Demonstration

Demonstrate how Earth's layers are sorted by density, using as a model three liquids of different densities: water, vegetable oil, and pancake syrup. Ask students to predict the relative densities of the three liquids and what will happen if they are placed in the same container. Test their predictions by gently pouring the three liquids into a clear glass container. The liquids will form separate layers by density, with the syrup on the bottom, the water in the center, and the vegetable oil on top. Compare the relative densities of Earth's layers to the densities of the liquid layers. Tell students that Earth's core consists of the densest materials, followed by the mantle, with the crust consisting of the least dense materials. You can also go into more detail regarding the actual composition of each layer. Then relate the sorting of Earth materials into layers by density to the way in which the planet formed.

Differentiated Instruction

Suggest that students make a compare/contrast table for the three main layers of Earth. They should compare and contrast the layers in terms of position, temperature, thickness, and composition.

Enrichment

Have a few creative students collaborate on writing a story in which the main character travels to the center of Earth. They should include information about each layer as the character passes through it. In their story, they should give the reason for the trip and describe obstacles the character must overcome to get to the center of Earth. Invite the students to share their story with the class.

Science Inquiry

In the activity at the following URL, students can experiment with thermal convection and observe how thermal energy (heat) can generate motion (flow) in a fluid. The activity will model thermal convection similar to the convection that is inferred for Earth's mantle. It will show how convection can produce horizontal flow that can cause plate motions. Students will also investigate the viscosity of a fluid and learn that Earth's mantle can be thought of as a solid for short duration processes (such as the propagation of seismic waves), and as a very viscous fluid for long duration processes (such as mantle convection and plate tectonic movements).

http://web.ics.purdue.edu/ braile/edumod/convect/convect.htm

Overcoming Misconceptions

Several common misconceptions about Earth's interior structure are listed at the URL below. Discuss each of the misconceptions with your students. Call on volunteers to explain why each misconception is false.

http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 6.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 6.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are the two main ways that scientists learn about Earth's interior and what do these two things indicate?

- [The two main ways that scientists learn about Earth's interior are by studying seismic waves and meteorites. Evidence from seismic waves indicates that the mantle is more dense and rigid than the outer core. Meteorites are thought be similar to material in Earth's core. This evidence indicates that Earth's core is made of dense metals such as iron and nickel.]

2. What is the difference between crust and lithosphere? Include in your answer both where they are located and what their properties are.

- [The crust is the outermost layer of Earth based on composition. It is Earth's cold, thin, brittle, rocky shell. It consists of mafic and felsic rock. The lithosphere is the outermost layer of Earth based on mechanical properties. It behaves as a brittle, rigid solid. When stresses act on it, it breaks. The lithosphere consists of all of the crust and the uppermost mantle.]

3. How do the differences between oceanic and continental crust lead to the presence of ocean basins and continents?

- [Oceanic crust is thinner and denser than continental crust, so oceanic crust rests lower in the mantle and forms ocean basins. Continental crust is thicker and less dense than oceanic crust, so continental crust rises higher than oceanic crust and forms continents.]

4. What type of rocks makes up the oceanic crust and how do they form?

- [The oceanic crust is made up of mafic igneous rocks, including both basalt and gabbro. The rocks form when magma erupts on the seafloor to create basalt lava flows or cools deeper down to create the intrusive igneous rock gabbro.]

5. What types of rocks make up the continental crust?

- [The continental crust is made up of many different types of igneous, sedimentary, and metamorphic rocks. The average composition is granite.]

6. How do scientists know about the liquid outer core? How do scientists know that the outer core is liquid?

- [Scientists know about the liquid outer core by studying seismic waves. Seismic waves called P-waves move more slowly through less dense and less rigid material. They slow down when they pass from the mantle to the outer core, so the outer core must be less dense and rigid than the mantle. Seismic waves called S-waves cannot travel through liquids and disappear at the mantle-core boundary. From both types of seismic waves, scientists know that the outer core is liquid.]

7. Describe the properties of each of these parts of Earth's interior: lithosphere, mantle, and core. What are they made of? How hot are they? What are their physical properties?

- [The lithosphere is made of cold, solid rock. It is brittle and rigid, so it breaks when stresses act on it. The mantle is made of very hot, solid rock. It is hotter than the lithosphere but cooler than the core. The rock of the mantle can move in convection currents that transfer heat through the mantle. The core is the hottest part of Earth. It is very dense and made mainly of iron and nickel metals. The core consists of two parts: a solid inner core and a liquid outer core. Convection currents in the liquid outer core create Earth's magnetic field.]

8. When you put your hand above a pan filled with boiling water, does your hand warm up because of convection or conduction? If you touch the pan, does your hand warm up because of convection or conduction? Based on your answers, which type of heat transfer moves heat more easily and efficiently?

- [When you put your hand above the pan, your hand warms up because of convection. If you touch the pan, your hand warms up because of conduction. Sample answer: I think that conduction transfers heat more easily and efficiently because the hand that touches the pan feels more heat and feels it more quickly than the hand that is above the pan.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Oceanic crust is thinner and denser than continental crust. All crust sits atop the mantle. What might Earth be like if this were not true?

- [*Sample answer*: If oceanic crust were not thinner and denser than continental crust, it might rest higher atop the mantle and not form ocean basins. If so, Earth would not have oceans.]

If sediments fall onto the seafloor over time, what can sediment thickness tell scientists about the age of the seafloor in different regions?

- [In a given region, sediments will be thicker the longer they have been building up on the seafloor and might give an indication of the age of the seafloor. However, sediments are thickest near the shore where they come off the continents in rivers and on wind. Therefore, sediment thickness may be misleading if used to tell the age of the seafloor in different places.]

How might convection cells in the mantle affect the movement of solid crust on the planet's surface?

- [*Sample answer*: The horizontal movement of mantle at the top of convection cells might move pieces of solid crust over the planet's surface, like items on a conveyor belt.]

6.3 Lesson 6.2:Continental Drift

Key Concepts

- The idea of continental drift
- Wegener's original evidence for continental drift
- More recent magnetic polarity evidence for continental drift

Lesson Objectives

- Explain the continental drift hypothesis.
- Describe the evidence Wegener used to support his continental drift idea.
- Describe later evidence for continental drift.

Lesson Vocabulary

- **apparent polar wander:** way in which Earth's magnetic pole appears to shift position over time
- **continental drift:** early 20th century hypothesis that the continents move over Earth's surface
- **magnetic field:** area surrounding a magnet over which it exerts magnetic force
- **magnetic polarity:** direction of a magnetic field, such as Earth's magnetic field
- **magnetite:** magnetic mineral that aligns with Earth's magnetic polarity as it crystalizes
- **magnetometer:** instrument that measures the intensity of a magnetic field

Teaching Strategies

Introducing the Lesson

Introduce continental drift with the animation at the URL below. Ask students to describe what they are observing. (The continents are drifting.) Tell them they will read about evidence for continental drift when they read this lesson.

http://education.sdsc.edu/optiputer/flash/pangea_4.htm

Demonstration

The video at the URL below is an excellent, grade-appropriate way to introduce students to Alfred Wegener, his continental drift hypothesis, and the diversity of evidence for it.

http://education-portal.com/academy/lesson/alfred-wegeners-theory-of-continental-drift.html

Activity

Students can further explore continental drift using the interactive animated module at the following URL. They can control the timeline of continental drift to see where the continents were located during different geologic time periods. Locations of fossils and other evidence are marked on the drifting continents.

http://www.exploratorium.edu/origins/antarctica/ideas/gondwana2.html

Differentiated Instruction

Have students do a think-pair-share activity about continental drift. First ask students to think about the following questions:

1. What is continental drift?
2. What is the evidence for continental drift?
3. Does the evidence convince you that continents really do drift?
4. How do you think continental drift might occur?

After students have had time to think about the questions, divide the class into pairs, matching any English language learners with native English speakers. Have partners share and discuss their answers to the questions.

Enrichment

Ask one or more students to write a brief biography of Alfred Wegener. They can begin their research with the following URLs. Encourage other students to read the biographies.

- http://www.ucmp.berkeley.edu/history/wegener.html
- http://www.pbs.org/wgbh/aso/databank/entries/bowege.html
- http://pangaea.org/wegener.htm

Science Inquiry

The inquiry activity at the URL below guides students through the history of continental drift. Students will gather evidence and use scientific reasoning to reconstruct Pangaea. They will also propose their own mechanism for how drift occurs.

http://www.wilson.wnyric.org/david/images/stories/history_labs/pt_history_cont_drift.doc

History Connection

The way that Alfred Wegener and his continental drift hypothesis were treated by most other scientists of his time is a good example of how difficult it can be to change science orthodoxy. The historical context of Wegener's life and work are well described in the article below. Assign it to your students to read, and then discuss it as a class.

http://www.smithsonianmag.com/science-nature/When-Continental-Drift-Was-Considered-Pseudoscience.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 6.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 6.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why can paper cutouts of the continents including the continental margins be pieced together to form a single whole?

- [The continents can be pieced together because all of them were once part of a single supercontinent. Then the supercontinent broke up, and the individual continents drifted apart.]

2. How can the locations where ancient fossils are found be used as evidence for continental drift?

- [Fossils of the same ancient organisms have been found on continents that are now far apart. This provides evidence that the ancient organisms lived together and their remains have since been separated on different continents.]

3. To show that mountain ranges on opposite sides of the Atlantic formed as two parts of the same range and were once joined, what would you look for?

- [You would look for the same rock types, structures, and ages in mountain ranges on opposite sides of the Atlantic.]

4. What are the three possible explanations for apparent polar wander? Considering all the evidence, which explanation is the only one likely to be true and why?

- [Three possible explanations for apparent polar wander are: the continents remained fixed and the north magnetic pole moved; the north magnetic pole remained fixed and the continents moved; and both the continents and the north magnetic pole moved. The only explanation likely to be true is that the north magnetic pole remained fixed and the continents moved. It is less likely that the north pole moved.]

5. With so much evidence to support continental drift, how could scientists reject the idea?

- [Scientists rejected the idea of continental drift because there was no known mechanism by which continents could move over Earth's surface. It seemed impossible that solid continents could plow through solid oceanic crust.]

6. Look at a world map. Besides the coast of west Africa and eastern South America, what are some other regions of the world that look as they could be closely fit together?

- [*Sample answer*: Eastern North America and western Europe look as they could fit together, as could western Antarctica and eastern Australia.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why is continental drift referred to as a hypothesis (or idea) and not a theory?

- [Continental drift is referred to as a hypothesis because it was not widely accepted by other scientists and did not explain how continents could move. To be a theory, a hypothesis has to have explanatory power and be supported by so much evidence that virtually all scientists accept it.]

What did Wegener's idea need for it to be accepted?

- [For Wegener's idea to be accepted, it needed a reasonable mechanism by which continents could move over Earth's surface.]

What other explanations did scientists come up with to explain the evidence Wegener had for continental drift?

- [*Sample answer*: They might have attributed to the evidence to change or coincidence. For example, they might have explained the fossil evidence by saying that similar organisms evolved on separate continents by chance. They might have explained matching rocks and mountain ranges by saying they formed on different continents by coincidence.]

6.4 Lesson 6.3: Seafloor Spreading

Key Concepts

- Seafloor bathymetry and seafloor features
- Seafloor magnetism
- Seafloor spreading hypothesis

Lesson Objectives

- Describe the main features of the seafloor.
- Explain what seafloor magnetism tells scientists about the seafloor.
- Describe the process of seafloor spreading.

Lesson Vocabulary

- **abyssal plain:** one of the flat areas that make up most of the ocean floor
- **echo sounder:** device that uses sound waves to calculate distances to underwater objects and the seafloor
- **seafloor spreading:** hypothesis explaining how the ocean floor forms and how continents can drift
- **trench:** deep crack in the ocean floor

Teaching Strategies

Introducing the Lesson

Show students the brief video about the discovery of seafloor spreading at the URL below. Tell them they will learn more about this amazing discovery when they read the lesson.

http://science.discovery.com/tv-shows/greatest-discoveries/videos/100-greatest-discoveries-sea-floor-spreading.htm

Activity

Have students use the interactive animation at the following URL to simulate seafloor spreading and magnetic reversals. By doing the activity, they will see how the pattern of magnetic stripes forms on the seafloor.

http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_paleomag.html

Building Science Skills

If you use the activity at the URL below, students can further explore some of the evidence that led to the discovery of sea floor spreading. They will use a simple seafloor model and collect magnetic polarity evidence to identify the ages of seafloor rock and the location of a mid-ocean ridge.

http://www.sea.edu/academics/k-12_detail/mid_ocean_magnetism

Differentiated Instruction

Ask students to make a concept map of seafloor spreading that includes the process of seafloor spreading, evidence for seafloor spreading, and the relationship of seafloor spreading to continental drift. Suggest that students keep their concept map in their science notebook.

Enrichment

Have students learn more about the work of Harry Hess, the scientist credited with the discovery of seafloor spreading. They can start with the URL below, which explains how Hess's skills and observations allowed him to develop the hypothesis of seafloor spreading and support the theory of plate tectonics.

http://www.amnh.org/education/resources/rfl/web/essaybooks/earth/p_hess.html

Science Inquiry

The URL below describes how to build a model of the seafloor that will help them develop a better understanding of seafloor spreading, the pattern of magnetic stripes "frozen" into the seafloor, subduction, and related topics.

http://jclahr.com/science/earth_science/platemod/index.html

Overcoming Misconceptions

Make sure that students do not hold the misconception that the seafloor spreads only because of the pushing of new seafloor away from the axis of a mid-ocean ridge. Explain that the pulling of old seafloor into a deep-sea trench is also an important force in seafloor spreading. Add that both forces occur because of gravity. Gravity pulls the new seafloor down the slope of a mid-ocean ridge, and gravity also pulls old seafloor down into the mantle at a deep-sea trench. This can be thought of as analogous to a rug on a table with little friction. When part of the rug is off of the table, its weight pulls the rest of the rug down with it.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 6.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 6.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe how sound waves are used to develop a map of the features of the seafloor.

- [Sound waves are sent out from a ship by a device called an echo sounder. When the sound waves strike underwater objects or the seafloor, they reflect back and are received by the echo sounder. Based on the known speed of sound waves through seawater and the time it takes the sound waves to return to the device, the distance to underwater objects or the seafloor can be calculated. By piecing together the ocean depths measured by echo sounders, scientists have been able to produce bathymetric maps that show the features of the seafloor.]

2. Why is the oldest seafloor less than 180 million years when the oldest continental crust is about 4 billion years old?

- [The oldest seafloor is less than 180 million years old because new seafloor keeps forming and older seafloor is continuously being destroyed. Continental crust does not keep forming and being destroyed in the same way, so it is much older.]

3. Describe the major features and the relative ages of mid-ocean ridges, deep-sea trenches, and abyssal plains.

- [Mid-ocean ridges are long mountain ranges on the ocean floor. Hot magma from the mantle rises up at a mid-ocean ridge and forms new seafloor, so the youngest seafloor occurs at mid-ocean ridges. Deep-sea trenches are deep cracks in the ocean floor. They are the deepest places on Earth. They are found near chains of active volcanoes at the edges of continents. The oldest seafloor occurs at deep-sea trenches. Abyssal plains are flat areas of the ocean floor, generally found between mid-ocean ridges and deep-sea trenches. The seafloor of abyssal plains is younger than that at deep-sea trenches but older than the youngest seafloor at mid-ocean ridges.]

4. Describe how continents move across the ocean basins as if they are on a conveyor belt.

- [When lava erupts at a mid-ocean ridge and forms new seafloor, the existing seafloor is pushed away from the ridge axis. At the edges of continents, the moving oceanic crust pushes the continents away from the ridge axis as well. This explains how the continents appear to move across the ocean basins as if they are on a conveyor belt.]

5. If you were a paleontologist who studies fossils of very ancient life forms, where would be the best place to look for very old fossils: on land or in the oceans?

- [The best place to look for very old fossils would be on land because continental crust is much older than oceanic crust.]

6. Imagine that Earth's magnetic field was fixed in place and the polarity didn't reverse. What effect would this have on our observations of seafloor basalts?

- [If Earth's magnetic field did not reverse polarity, the basalts of the seafloor would not have alternating stripes of normal and reverse polarity.]

7. Look at a map of the Atlantic seafloor with magnetic polarity stripes and recreate the history of the Atlantic Ocean basin.

- [The pattern of magnetic polarity stripes shows that the newest seafloor, where magnetic polarity is normal, is at the mid-ocean ridge. Older seafloor a little farther from the ridge has reversed polarity. This shows that this older seafloor formed when Earth's magnetic polarity was reversed. Still older seafloor even farther from the ridge has normal polarity, showing that this seafloor formed even earlier when Earth's magnetic polarity was normal. This pattern of alternating and reverse magnetic polarity continues across the seafloor on both sides of the mid-ocean ridge.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How were the technologies that were developed to fight World War II used by scientists for the development of the seafloor-spreading hypothesis?

- [During World War II, echo sounders and magnetometers were developed to locate enemy submarines. These technologies also revealed a lot of new information about the ocean floor. Echo sounders were used by scientists to map the seafloor and discover seafloor features, such as mid-ocean ridges and deep-sea trenches. Magnetometers were used by scientists to determine the polarity of the ocean floor. Scientists discovered that the seafloor had a regular pattern of normal and reverse polarity, showing the sequence in which the ocean floor had formed. This information, along with information on the ages of seafloor rocks, allowed scientists to develop the hypothesis of seafloor spreading.]

In what two ways did magnetic data lead scientists to understand more about continental drift and plate tectonics?

- [Magnetic data led scientists to understand that new seafloor forms at mid-ocean ridges and that old seafloor is destroyed at deep-sea trenches. Seafloor has normal polarity at a mid-ocean ridges and stripes of alternating reverse and normal polarity on either side of the ridge. This shows the sequence in which the seafloor formed, with the newest seafloor at a mid-ocean ridge and increasingly older seafloor as one moves away from both sides of the ridge axis. This is explained by the idea of plate tectonics, or the movement of lithospheric plates over Earth's surface. Plate tectonics, in turn, explains how continents can drift.]

How does seafloor spreading provide a mechanism for continental drift?

- [Seafloor spreading explains how continents can move. Where oceanic crust meets a continent, the moving oceanic crust pushes the continent, causing it to move as well.]

Look at the features of the North Pacific Ocean basin and explain them in seafloor spreading terms.

- [In the North Pacific Ocean basin, new seafloor forms at a ridge near the eastern edge of the North American continent. Magma erupts out of the ridge and the lava cools to form new rock on the ocean floor. As this continues, new rock keeps forming and older rock moves away from the axis of the ridge. The moving seafloor eventually reaches a deep-sea trench at an edge of the North Pacific Ocean basin. At the deep-sea trench, the seafloor is pulled down into the mantle.]

What would have to happen if oceanic crust was not destroyed at oceanic trenches, but new crust was still created at mid-ocean ridges?

- [The new oceanic crust created at mid-ocean ridges would keep older crust moving away from the ridges. However, if the oldest crust was not pulled into the mantle at oceanic trenches, it might push against continents and cause buckling of the crust due to the pressure.]

6.5 Lesson 6.4: Theory of Plate Tectonics

Key Concepts

- Earth's tectonic plates
- How tectonic plates move
- Divergent, convergent, and transform plate boundaries
- Earth's changing surface and the supercontinent cycle
- Intraplate activity and hotspots
- Plate tectonics theory

Lesson Objectives

- Describe what a plate is and how scientists can recognize its edges.
- Explain how mantle convection moves lithospheric plates.
- List the three types of boundaries. Are they prone to earthquakes or volcanoes?
- Describe how plate tectonics processes lead to changes in Earth's surface features.

Lesson Vocabulary

- **batholith:** large body of intrusive igneous rock at the edge of a subducting plate
- **continental arc:** line of coastal volcanic islands at the edge of a subducting plate
- **continental rifting:** splitting of a continent at a divergent plate boundary
- **convergent plate boundary:** edge where two lithospheric plates come together
- **divergent plate boundary:** edge where two lithospheric plates move apart
- **epicenter:** point on Earth's surface directly above the focus of an earthquake
- **hotspot:** plume of hot material that rises through the mantle and can cause volcanoes
- **intraplate activity:** geologic activity that takes place within a plate away from plate boundaries
- **island arc:** line of ocean island volcanoes resulting from subduction beneath oceanic lithosphere
- **plate:** slab of lithosphere that can move over Earth's surface
- **plate boundary:** location where two lithospheric plates meet
- **plate tectonics:** theory that Earth's surface is divided into lithospheric plates that move over the planet's surface
- **subduction:** sinking of one lithospheric plate beneath another
- **subduction zone:** area where two lithospheric plates come together and one sinks beneath the other
- **supercontinent cycle:** repeated formation and breakup of one supercontinent after another
- **transform fault:** fracture in rock where one plate slides past another
- **transform plate boundary:** edge where two lithospheric plates slide past one another

Teaching Strategies

Introducing the Lesson

Introduce plate tectonics by showing students the map of Earth's lithospheric plates at the following URL. Briefly discuss the thought questions below the map with the class. Tell students to keep these questions in mind as they read the lesson.

http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_plates.html

Discussion

Use the animation at the URL below when you discuss subduction with your class. You can use the key points listed below the animation when you explain how subduction occurs and why it generates volcanoes and earthquakes. Discuss as a class the thought questions at the bottom of the Web page.

http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_subduction.html

Differentiated Instruction

Work with students to make a compare/contrast table of types of plate boundaries (divergent, convergent, and transform). Suggest that they add sketches to the table to show how each type of plate boundary occurs.

Enrichment

Challenge interested students to investigate how the Global Positioning System (GPS) is used to measure the movement of Earth's tectonic plates and why measuring plate movement is important. The following URLs provide relevant information. Ask the students to summarize what they learn in a brief report to the class.

- http://pubs.usgs.gov/gip/dynamic/understanding.html
- http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/14/1.GPS_Background.pdf
- http://www.e-education.psu.edu/earth520/content/l7_p7.html

Science Inquiry

In the "Discovering Plate Boundaries" inquiry activity at the following URL, students will use four global data maps (earthquakes, volcanoes, seafloor age, and topography/bathymetry) to discover the processes that occur at plate boundaries. The activity requires students to observe and classify data.

http://terra.rice.edu/plateboundary/

Overcoming Misconceptions

A dozen student misconceptions about plate tectonics are presented at the URL below. Use these misconceptions as a true-false quiz to identify misconceptions held by your students. After the quiz, discuss these misconceptions with the class and explain why they are false.

http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 6.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 6.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are the three types of plate boundaries and what type of geologic activity is found at each?

- [The three types of plate boundaries are divergent plate boundaries, where two plates move away from each other; convergent plate boundaries, where two plates move towards each other; and transform plate boundaries, where two plates slide past each other in opposite directions. Both divergent and convergent plate boundaries have volcanoes and earthquakes. Continent-continent convergent plate boundaries have mountain building with earthquakes but not volcanoes. Transform plate boundaries have earthquakes.]

2. As a geologist, you come across a landscape with a massive fault zone that produces a lot of large earthquakes but has no volcanoes. What type of plate boundary is this? What are the movements of plates there? Where is this type of boundary found in California?

- [This is a transform plate boundary, where two plates move past each other in opposite directions. An example of this type of plate boundary in California occurs between the Pacific and North American plates, creating the San Andreas fault.]

3. Next you find a chain of volcanoes along a coast on land, not too far inland from the ocean. The region experiences frequent large earthquakes. What type of plate boundary is this? What types of plates are involved? Where is this type of boundary found in California?

- [This is a convergent plate boundary, where an oceanic and continental plate come together. In California, this type of boundary is found between the Juan de Fuca oceanic plate and the North American continental plate. It creates the Cascade volcanoes.]

4. What is the driving force behind the movement of lithospheric plates on the Earth's surface? About how fast do the plates move?

- [The driving force behind the movement of lithospheric plates is convection in the mantle. Convection cells cause seafloor spreading and subduction zones that move the plates over Earth's surface. The plates move at a rate of a few centimeters a year.]

5. How does the theory of plate tectonics explain the locations of volcanoes, earthquakes, and mountain belts on Earth?

- [According to the theory of plate tectonics, the lithosphere is divided into plates that move over Earth's surface. Plates interact at their edges, or plate boundaries. Plates may move together, pull apart, or slide past each other. These plate interactions are responsible for almost all geologic activity on Earth. This explains why most volcanoes, earthquakes, and mountain belts occur at plate boundaries.]

6. What causes earthquakes and at what types of plate boundaries are earthquakes common? Explain.

- [Earthquakes are caused by the interaction of lithospheric plates. Earthquakes occur at all types of plate boundaries. At plate boundaries, there is movement of crust, and this is what creates earthquakes. Earthquakes occur where oceanic crust subducts under continental crust, two plates of continental crust push together at a convergent boundary, or two slabs of crust grind past each other at a transform plate boundary.]

7. Thinking about the different types of plate boundaries, where do mountain ranges that do not include volcanoes occur and why?

- [Mountains ranges that do not include volcanoes occur at convergent plate boundaries between two continental plates. The continental crust is too thick for magma to reach the surface and cause volcanoes. The Appalachian Mountains in the eastern United States formed this way when North America and Western Europe converged to form Pangaea.]

8. Why are there no volcanoes along transform plate boundaries? At continent-continent convergent plate boundaries?

- [There are no volcanoes along transform plate boundaries because neither plate subducts. The plates move past each other in opposite directions along a transform fault. There are no volcanoes along continent-continent convergent plate boundaries because continental crust is too thick to allow magma to reach the surface.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

On the map in the figure above, the arrows show the directions that the plates are going. The Atlantic has a mid-ocean ridge, where seafloor spreading is taking place. The Pacific Ocean has many deep sea trenches, where subduction is taking place. What is the future of the Atlantic plate? What is the future of the Pacific plate?

- [The future of the Atlantic plate is to continue to grow lager. The future of the Pacific plate is to continue to grow smaller. Eventually, the Pacific Ocean will disappear and a new supercontinent will form.]

Using your hands and words, explain to someone how plate tectonics works. Be sure you describe how continents drift and how seafloor spreading provides a mechanism for continental movement.

- [Students' explanations may vary, both verbally and in terms of hand gestures, but they should reveal a correct understanding how plate tectonics explains seafloor spreading and the movement of continents over Earth's surface.]

Now that you know about plate tectonics, where do you think would be a safe place to live if you wanted to avoid volcanic eruptions and earthquakes?

- [If you wanted to avoid volcanic eruptions and earthquakes, you could live anywhere except near plate boundaries, faults, and hotspots.]

CHAPTER 7 HS TE Earthquakes

Chapter Outline

7.1 Chapter 7: Earthquakes

Chapter Overview

This chapter describes the stresses on rocks and how mountain building occurs. It also discusses the causes of earthquakes, seismic waves, tsunamis, earthquake prediction, and earthquake safety.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this fieldwork lab, students will use fractures in sidewalks as an analog for natural rock outcrops in a study of rock fractures. They will make systematic observations and measurements of sidewalk fractures, manipulate and analyze the data, and consider the origin and significance of the fractures. This is a good lab to launch the chapter.

- http://serc.carleton.edu/NAGTWorkshops/structure04/activities/3860.html

In the lab at the URL below, students use walking and running speeds and travel times to simulate S-waves and P-waves and their arrival times at seismographs. Based on the data, a hypothetical earthquake epicenter is calculated by triangulation. The lab can be performed outdoors or in the classroom.

- http://web.ics.purdue.edu/ braile/edumod/walkrun/walkrun.htm

These Web sites may also be helpful:

Go to this URL for animations of the major types of faults:

- http://www.iris.edu/gifs/animations/faults.htm

This resource provides a series of short articles on earthquake basics for students, teachers, and parents originally. It was originally published as weekly features in The San Francisco Chronicle.

- http://pubs.usgs.gov/gip/2006/21/

You can link with several earthquake photo collections at these URLs:

- http://earthquake.usgs.gov/learn/photos.php
- http://www.exploratorium.edu/faultline/activezone/photos.html

The URL below has links to several short video lectures on earthquakes.

- http://www.iris.edu/hq/programs/education_and_outreach/videos#H

Numerous useful publications and other media relating to earthquakes can be accessed at this URL:

- http://www.exploratorium.edu/faultline/activezone/links.html

At the following URL, you can find information and links for using an AS-1 seismograph and AmaSeis software (which can be used with or without the seismograph). Also available are several teaching modules so students can use the data to locate earthquakes and determine their magnitude.

- http://web.ics.purdue.edu/ braile/edumod/as1lessons/as1lessons.htm

A series of seismology resources for teachers from the Seismological Society of America can be accessed at the following URL. The resources include reference information, maps, slide sets, videotapes, computer hardware and software, seismographs, and data sets.

- http://web.ics.purdue.edu/ braile/edumod/seisres/seisresweb.htm

Pacing the Lessons

TABLE 7.1: short caption

Lesson	Class Period(s) (60 min)
7.1 Stress in Earth's Crust	2.5
7.2 The Nature of Earthquakes	2.0
7.3 Measuring and Predicting Earthquakes	1.5
7.4 Staying Safe in Earthquakes	1.5

7.2 Lesson 7.1: Stress in Earth's Crust

Key Concepts

- Causes and types of stress in Earth's crust
- Folds, fractures, joints, and faults
- Stress and mountain building

Lesson Objectives

- List the different types of stresses that cause different types of deformation.
- Compare the different types of folds and the conditions under which they form.
- Compare fractures and faults and define how they are related to earthquakes.
- Compare how mountains form and at what types of plate boundaries they form.

Lesson Vocabulary

- **anticline:** fold in rock that arches upward so older rock is at the center
- **basin:** circular syncline that forms a depression in the ground
- **compression:** stress that squeezes rocks together
- **confining stress:** stress from the weight of material above buried rocks that does not allow the rocks to change shape
- **deformation:** change in the shape of rocks due to stress
- **dip:** angle of a fault relative to the horizontal surface of Earth
- **dip-slip fault:** fault in which the dip of the fault plane is inclined relative to the horizontal surface of Earth
- **dome:** circular anticline that forms a mound on the ground
- **elastic deformation:** strain that temporarily alters the shape of rocks
- **fault:** fracture along which one side has moved relative to the other
- **fold:** bend in rocks caused by compression
- **fracture:** crack in rocks caused by stress
- **joint:** break in rocks along which there is no movement
- **monocline:** bend in rocks that causes them to be inclined relative to the horizontal
- **normal fault:** dip-slip fault in which the hanging wall drops down relative to the footwall
- **plastic deformation:** strain that permanently alters the shape of rocks
- **reverse fault:** dip-slip fault in which the hanging wall pushes up relative to the footwall
- **shear:** parallel stresses on rocks that push them past each other in opposite directions
- **slip:** distance rocks move along a fault
- **strain:** deformation in rocks because of a stress that exceeds the rocks' internal strength
- **stress:** force per unit area on rocks
- **strike-slip fault:** fault in which the dip of the fault plane is vertical
- **syncline:** fold in rocks that bends downward so younger rocks are at the center

- **tension:** stress that pulls rocks in opposite directions
- **thrust fault:** reverse fault in which the dip of the fault plane is nearly horizontal
- **uplift:** upward movement of a block of rocks

Teaching Strategies

Introducing the Lesson

Ask students to recall the three types of plate boundaries from the FlexBook® chapter "Plate Tectonics." Call on volunteers to describe how plates move relative to one another at each type of boundary. Explain that these plate movements place stresses on Earth's crust. Tell students they will read about the stresses in this lesson.

Building Science Skills

In the activity at the following URL, students model faults and stresses using processed cheese food, which acts quite similar to homogeneous rocks. Students make predictions before each of several brief experiments with the model. At the end of the activity, ask each group explain their results to the rest of the class.

http://serc.carleton.edu/introgeo/demonstrations/examples/cheese.html

Differentiated Instruction

Have students make a compare/contrast table for types of faults, including the type of stress that causes each type of fault and how rocks move at each type of fault. Students should illustrate their table with simple sketches of the different types of faults. Tell them to use arrows to show the direction rocks move at each type of fault.

Enrichment

Ask one or more students to create a Web page titled "How the Himalayas Were Born." They should include plenty of photos and a detailed explanation of the plate tectonics and types of stresses that built the highest mountains on Earth. Tell other students to visit the finished Web site.

Science Inquiry

This inquiry activity is based on QuickTime movies and color digital photographs derived from sandbox experiments that produce normal faults in a variety of boundary conditions. Students will view specially edited movies to gain awareness of the evolution of normal fault systems. Then they will investigate the formation and evolution of a fault system for a particular structural setting by tracing and labeling individual faults on a set of photographs taken at regular intervals during an experiment. This activity helps students develop an awareness of how faults occur and how they deform rocks. The activity was written for college undergraduates but can be adapted for high school students.

http://serc.carleton.edu/NAGTWorkshops/structure04/activities/3861.html

Overcoming Misconceptions

A common student misconception is that the ground opens up during an earthquake. Explain to students that shallow crevasses may form during an earthquake, but the surface does not actually "open up" along a fault line. If it did, it

would relieve the stress and prevent an earthquake.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 7.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 7.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why don't rocks deform under confining stress?

- [Rocks don't deform under confining stress because they are being pushed from all sides. Therefore, the rocks are unable to move and change shape.]

2. What type of stress is compression and at what type of plate boundary is this found?

- [Compression is stress that squeezes rocks together. It is found at convergent plate boundaries.]

3. What type of stress is tension and at what type of plate boundary is it found?

- [Tension is stress that pulls rocks apart. It is found at divergent plate boundaries.]

4. What type of stress is shear and at what type of plate boundary is it found?

- [Shear is stress that pushes rocks past each other in opposite directions. It is found at transform plate boundaries.]

5. What is the difference between plastic and elastic strain?

- [Plastic strain is a permanent deformation of rock. Even after the stress is removed, the rock remains in the deformed shape. Elastic strain is a temporary deformation of rock. After the stress is released, the rock returns to its original shape.]

6. Under what conditions is a rock more likely to deform plastically than to break?

- [A rock is more likely to deform plastically than to break if the rock is beneath Earth's surface and the stress is applied gradually.]

7. In the picture of the Grand Canyon geologic column (see the figure above), what type of fold do you see?

- [The fold in the picture of the Grand Canyon is a monocline.]

8. While walking around in the field you spot a section of rocks in which the oldest are on top and the youngest are on the bottom. How do you explain this?

- [The rock section was overturned.]

9. Describe an anticline and name the age order of rocks.

- [An anticline is a fold in rocks in which the rock layers arch upward. The older rocks are at the center of the anticline, and the younger rocks are draped over them.]

10. Describe a syncline and name the age order of rocks.

- [A syncline is a fold in rocks in which the rock layers dip downward. The younger rocks are at the center of the syncline, and the older rocks are at the outside.]

11. What are domes and basins, and what is the age order of rocks in each?

- [Domes are circular anticlines that form a mound on the ground. Basins are circular synclines that form a depression in the ground. In a dome, older rocks are at the center with younger rocks draped over them. In a basin, younger rocks are at the center with older rocks outside of them.]

12. Name one similarity and one difference between a fracture and a fault.

- [Both a fracture and a fault are cracks in rocks where rocks have broken due to stress. When a fracture occurs, the rocks may or may not move. If the rocks do not move, the fracture is called a joint. If the rocks do move, the fracture forms a fault.

13. What are the two types of dip-slip faults and how are they different from each other?

- [The two types of dip-slip faults are normal faults and reverse faults. In a normal fault, the hanging wall drops down relative to the footwall. In a reverse fault, the hanging wall pushes up relative to the footwall.]

14. Why are so many severe earthquakes located along the San Andreas fault?

- [There are so many severe earthquakes along the San Andreas fault because it is a massive transform fault under tremendous shear stress.]

15. Describe the plate tectonics processes and associated stresses that have led to the formation of the Himalayas, the world's largest mountain range.

- [The Himalayas formed at a convergent plate boundary, where two continental plates (the Indian and Eurasian plates) are colliding. The mountains are still growing from the collision. The rocks at a convergent plate boundary are subject to compression stresses, which push rocks together and crumple the continental crust to build mountains.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Where in an ocean basin would you find features that indicate tensional stresses? Where would you find the features that indicate compressional stresses?

- [In an ocean basin, you would find tensional stresses at divergent plate boundaries. These occur at mid-ocean ridges. You would find compressional stresses at convergent plate boundaries. These occur at deep-sea trenches or where oceanic plates converge with continental plates.]

Earthquakes are primarily the result of plate tectonic motions. List the three types of plate boundaries and what you think the stresses are that would cause earthquakes there.

- [The three types of plate boundaries are convergent, divergent, and transform plate boundaries. At a convergent plate boundary, compression stress would cause earthquakes. At a divergent boundary, tension stress would cause earthquakes. At a transform boundary, shear stress would cause earthquakes.]

Which type of plate boundary do you think has the most dangerous earthquakes? How do earthquakes cause the greatest damage?

- [*Sample answer*: I think that convergent plate boundaries have the most dangerous earthquakes. Earthquakes cause the greatest damage where the greatest numbers of people live. In cities there are many buildings and other structures that might be damaged or even collapse due to the shaking of the ground during an earthquake.]

7.3 Lesson 7.2: The Nature of Earthquakes

Key Concepts

- Causes of earthquakes
- Earthquake zones
- Seismic waves
- Tsunamis

Lesson Objectives

- Be able to identify an earthquake focus and its epicenter.
- Identify earthquake zones and what makes some regions prone to earthquakes.
- Compare the characteristics of the different types of seismic waves.
- Describe how tsunamis are caused by earthquakes, using the 2004 Boxing Day Tsunami as an example.

Lesson Vocabulary

- **amplitude:** height of a wave from the center to the top of a crest (or bottom of a trough)
- **body wave:** type of seismic wave that travels through Earth's interior; either a primary wave or a secondary wave
- **crest:** highest point of a wave
- **earthquake:** ground movement caused by the sudden release of energy stored in rocks
- **elastic rebound theory:** theory that earthquakes occur when rocks break and snap back to their original position after being deformed elastically until they cannot deform any more
- **focus:**point beneath the surface where rocks break and start an earthquake
- **seismology:** study of seismic waves
- **surface wave:** type of seismic wave that travels along the surface of the ground; either a Love wave or a Rayleigh wave
- **trough:** lowest point of a wave
- **tsunami:** large water wave caused by a shock to ocean water, often due to an undersea earthquake
- **wavelength:** horizontal distance between two corresponding points on adjacent waves, such as the distance between two crests or two troughs

Teaching Strategies

Introducing the Lesson

Introduce earthquakes by sharing with students some of the earthquake facts at the following URL. Tell students they will learn more about earthquakes when they read this lesson.

http://earthquake.usgs.gov/learn/facts.php

Demonstration

You may want to use the USGS PowerPoint slideshow presentation entitled "Earthquakes 101" when you teach this lesson. It covers all the basics, from plate tectonics to seismic waves.

http://earthquake.usgs.gov/learn/topics/EQ101.zip

Activity

Have students use the interactive wave maker at the following URL to investigate the different types of seismic waves, including how they move rocks and what they can tell us about Earth's interior. The activity includes questions and answers.

http://aspire.cosmic-ray.org/labs/seismic/index.htm

Building Science Skills

With the activity at the URL below, students will plot the locations of faults and then map recent earthquakes in order to see the relationship between earthquakes and faults.

http://www.teachingboxes.org/earthquakes/lessons/lesson2.jsp

Differentiated Instruction

Using a spring toy, demonstrate different types of seismic waves to visual learners. Give volunteers a change to make the different types of waves themselves. Relate the spring toy waves to the corresponding seismic waves. You can learn more at this URL: http://www.geo.mtu.edu/UPSeis/making.html.

Enrichment

Ask one or more students to investigate careers in seismology. They can find excellent information at the following URL. Have the students use the information to make "help-wanted" ads for a few of the careers. Share the ads with the class.

http://www.seismosoc.org/society/education/careers.php

Science Inquiry

In the inquiry activity at the following URL, students will learn about the four types of seismic waves, including their characteristics and effects. Then students will predict the level of damage each wave might cause in a residential area. Finally, they will test their predictions against several computer animations.

http://www.teachingboxes.org/earthquakes/lessons/lesson4.jsp

History Connection

Share information from the URL below with your class, or assign the article for students to read. It provides a brief history of seismology to 1910. The history is a good example of the cumulative nature of scientific knowledge and how researchers all over the world make contributions to science.

http://projects.crustal.ucsb.edu/understanding/history/history3.html

Literature Connection

Suggest that students read first-hand accounts of famous earthquakes written by Mark Twain, Jack London, and other authors (see URL below). The accounts will give students unique insights into the nature of earthquakes.

http://projects.crustal.ucsb.edu/understanding/accounts/twain.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 7.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 7.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is an earthquake's focus? What is its epicenter?

   - [An earthquake's focus is the point beneath the surface where rocks break and start an earthquake.]

2. Why do most earthquakes take place along plate boundaries?

   - [Most earthquakes take place along plate boundaries because this is where plates interact and cause stresses on rock that lead to earthquakes.]

3. Using elastic rebound theory, describe what triggers an earthquake.

   - [According to elastic rebound theory, most earthquakes occur when rock is strained to a point that it can no longer deform elastically. The rock snaps and springs back to its original position, releasing energy that begins an earthquake.]

4. Why are there far more earthquakes around the Pacific Ocean than anywhere else?

   - [There are far more earthquakes around the Pacific Ocean than anywhere else because the Pacific Ocean is rimmed with convergent and transform faults where earthquakes are most likely to occur.]

5. What causes intraplate earthquakes?

- [Intraplate earthquakes are the result of stresses caused by plate motions acting in solid slabs of lithosphere.]

6. Besides the San Andreas Fault zone, what other type of plate boundary in or near California can produce earthquakes?

- [The San Andreas fault is one of a number of transform faults at the transform boundary between the Pacific and North American plates. Many earthquakes occur along transform faults. The Juan de Fuca plate and North American plate have a convergent plate boundary in the Pacific Northwest near northern California. Subduction along convergent plate boundaries may also produce earthquakes.]

7. Using plate tectonics and elastic rebound theory, describe why Juan de Fuca plate subduction produces so few earthquakes. What will happen in the future?

- [Sample answer: Juan de Fuca plate subduction produces few earthquakes because it takes a relatively long time for enough strain to build up to produce an earthquake. In the future, the buildup of strain may cause an earthquake.]

8. What type of faulting is found where two slabs of continental lithosphere are converging?

- [Reverse faulting is found where two slabs of continental lithosphere are converging.]

9. What are the characteristics of body waves? What are the two types?

- [Body waves are seismic waves that travel through the interior of the planet. The two types of body waves are primary waves (P-waves) and secondary waves (S-waves).]

10. What types of materials can P-waves travel through and how fast are they? Describe a P-wave's motion.

- [P-waves can travel through solids, liquids, and gases. They travel at about 6 to 7 km per second. P waves move material forward and backward in the same direction that the waves are traveling.]

11. What material can S-waves travel through and how fast are they? Describe an S-wave's motion.

- [S-waves can travel only through solids. They travel at about 3.5 km per second. They move material up and down perpendicular to the direction that the waves are traveling.]

12. How are surface waves different from body waves? Which are more damaging?

- [Surface waves travel over the surface of the ground, whereas body waves travel through Earth's interior. Surface waves are more damaging.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Do the largest earthquakes cause the most deaths and the most damage to property?

- [Not necessarily; earthquake damage depends on other factors in addition to earthquake size. If an earthquake's focus is close to the surface, it typically causes greater damage than if it is far below the surface. Earthquakes that occur where a lot of people live generally cause more death and destruction than earthquakes that occur where few people live.]

The last time there was a large earthquake on the Hayward Fault in the San Francisco Bay area of California was in 1868. Use elastic rebound theory to describe what may be happening along the Hayward Fault today and what will likely happen in the future.

- [*Sample answer*: Rocks along the fault may be undergoing strain and elastic deformation. In the future, they are likely to reach a point at which they cannot deform any longer. Then they will likely break and snap back, releasing energy and causing an earthquake.]

Why is California so prone to earthquakes?

- [California is so prone to earthquakes because it has so many faults.]

How could coastal California be damaged by a tsunami? Where would the earthquake occur? How could such a tsunami be predicted?

- [*Sample answer*: A tsunami might flood or even wash away buildings, highways, and other structures on California's coast. It would no doubt also cause loss of life. Coastal California could be damaged by a tsunami that occurs anywhere on the West Coast or around the Pacific Ocean. The earthquake might occur in the Pacific Northwest, for example, or along the coast of California, in Alaska, or in Japan. The tsunami could be predicted by monitoring earthquakes in these areas. In the short term, you could watch for the water to recede from shore. This is a sign that a tsunami is coming.]

7.4 Lesson 7.3: Measuring and Predicting Earthquakes

Key Concepts

- Measuring earthquake magnitude
- Finding the epicenter of an earthquake
- Earthquake intensity
- Earthquake prediction

Lesson Objectives

- Describe how to find an earthquake epicenter.
- Describe the different earthquake magnitude scales and what the numbers for moment magnitude mean.
- Describe how earthquakes are predicted and why the field of earthquake prediction has had little success.

Lesson Vocabulary

- **seismogram:** paper record of seismic activity produced by a seismograph
- **seismograph:** older type of device that measures and records seismic waves using a suspended, weighted pen that writes on a drum of paper that moves with the ground
- **seismometer:** modern device that uses electronic motion detectors to measure and record seismic waves and other ground motions

Teaching Strategies

Introducing the Lesson

Show the class a video clip of a recent major earthquake, showing how it felt to people on the ground and the damage it caused. The first few minutes of the video at the URL below provide good examples. It shows scenes from the 1989 Loma Prieta earthquake that affected the San Francisco region of California. Tell students they will learn in this chapter more about earthquakes and the damage they cause and why predicting earthquakes is so important.

http://www.youtube.com/watch?v=VvTCNgZwygg

Building Science Skills

In the real-world problem-solving activity at the URL below, students will play the role of geologist hired by the city of San Francisco to evaluate urban development in the earthquake-prone San Francisco Bay area. They will use

1973 and 1999 satellite images of the region along with other data to determine whether development is getting too close to active faults.

http://www.ebsinstitute.com/EBS.EQ1_RS.html

Differentiated Instruction

Have students make a main ideas/details chart of lesson content. This will help them identify and focus on the most important ideas in the lesson. Tell them to draw a line down the center of a sheet of paper and record the main ideas in the left column, leaving room between the ideas to add supporting details in the right column.

Enrichment

The Richter and moment magnitude scales of earthquake magnitude are logarithmic scales. A logarithmic scale is a scale of measurement that displays the value of a physical quantity using intervals corresponding to orders of magnitude rather than linear increases in magnitude. Ask any students who excel in math and have a good understanding of logarithms to explain how a logarithmic scale is constructed and how it is interpreted. Have them find and share examples of other common logarithmic scales (e.g., decibel scale of sound intensity and pH scale of hydrogen ion concentration, or acidity).

Science Inquiry

In this inquiry activity, students will use an earthquake simulator to determine the location of an earthquake's epicenter and estimate its Richter magnitude. They will be working with seismograms from three locations to triangulate the earthquake's epicenter.

http://www.sciencecourseware.org/eec/Earthquake/

Overcoming Misconceptions

At the URL below, you can find a list of many common earthquake myths. Share the myths with students and point out why they are not true. Discuss as a class which of the myths might lead to greater risk of injury during an earthquake.

http://www.consrv.ca.gov/index/Earthquakes/Pages/qh_earthquakes_myths.aspx

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 7.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 7.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. How can a seismograph measure ground shaking if all parts of it must be attached to the ground?

- [Part of a seismograph is weighted so it moves less when the ground shakes because of its inertia. In addition, an adjustment can be made to account for the small amount that it moves.]

2. On a seismogram, which waves arrive first, second, and last?

- [On a seismogram, P-waves arrive first, S-waves arrive second (if at all), and surface waves arrive last.]

3. What information is needed to calculate the distance from a seismic station to an earthquake's epicenter?

- [To calculate the distance from a seismic station to an earthquake's epicenter, the P- and S-wave arrival times are needed. The greater the difference is between P- and S-wave arrival times, the farther away the earthquake was from the seismic station.]

4. If a seismogram records P-waves and surface waves but not S-waves, where was the earthquake epicenter located relative to the seismograph and why?

- [The earthquake epicenter was located on the opposite side of Earth relative to the seismograph. S-waves cannot travel through liquids, so they stop when they reach Earth's liquid outer core and do not continue passing through Earth to the other side. P-waves, in contrast, can pass through liquids, so they travel all the way through Earth. Surface waves travel over Earth's surface, so they also reach the opposite side.]

5. On the Richter or magnitude moment scale, what is the difference in energy released by an earthquake that is a 7.2 versus an 8.2 in magnitude? A 7.2 versus a 9.2?

- [An 8.2 magnitude earthquake releases about 30 times as much energy as a 7.2 magnitude earthquake. A 9.2 earthquake releases about 900 (30 x 30) times as much energy as a 7.2 magnitude earthquake.]

6. Why do you need at least three seismographs to locate an earthquake epicenter?

- [To locate an earthquake epicenter, you need at least three seismographs because you can determine only how far away the epicenter from any given seismograph. To locate the epicenter, you need to calculate distance from each of three seismic stations to the epicenter and draw a circle around the station with this distance as the radius. The point where all three circles intersect is the epicenter.]

7. What were the problems with the Mercalli scale of measuring earthquake magnitudes? Why did Richter and moment magnitude scales need to be developed?

- [The problems with the Mercalli scale are due to the fact that it does not directly measure earthquake magnitude. Instead, it measures how the earthquake feels to people and the damage it does. Other factors besides earthquake magnitude influence these factors. For example, the amount of damage done by an earthquake depends on how buildings are constructed as well as the earthquake's magnitude. The Richter and moment magnitude scales needed to be developed so seismologists could directly measure earthquake magnitude without the influence of other factors.]

8. Why is the moment magnitude scale thought to be more accurate than the Richter scale for measuring earthquake magnitudes?

- [The Richter scale measures the magnitude of the largest jolt produced by an earthquake, whereas the moment magnitude scale measures the total amount of energy released by an earthquake. With the Richter scale, a single sharp jolt measures higher than a very long earthquake that releases more energy, which would measure higher on the moment magnitude scale. The moment magnitude scale more accurately reflects the energy released and the damaged caused by earthquakes.]

9. What is the difference in energy released between a 6 and a 7 on the Richter scale? How about a 6 and a 7 on the moment magnitude scale?

- [On both scales, an earthquake with magnitude 7 releases about 30 times as much total energy as an earthquake with magnitude 6.]

10. How do seismologists use earthquake foreshocks to predict earthquakes? Why are foreshocks not always an effective prediction tool?

- [Seismologists predict an earthquake may occur if they detect foreshocks because these small tremors sometimes occur before a major earthquake. However, foreshocks are not always an effective prediction tool because they don't always occur and if they do occur, they may happen from a few seconds to a few weeks before a large earthquake.]

11. For earthquake prediction to be really useful, what would need to be predicted?

- [The place, time, and magnitude of earthquakes would need to be predicted for earthquake prediction to be really useful.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If you live in an earthquake-prone area, how do you feel about your home now? What can you do to minimize the risk to you and your family? If you do not live in an earthquake-prone area, what would it take to get you to move to one? What risks from natural disasters do you face where you live?

- [Answers may vary. Students who live in an earthquake-prone area may wonder if their home was built to withstand the ground shaking of earthquakes. To minimize risk from an earthquake, people should know what to do in case of an earthquake. For example, they should know the safest place to be in their home if the ground starts shaking. They should also make sure their home is built to withstand earthquakes. Students who do not live in an earthquake-prone area may or may not think it is worth the risk to move to an earthquake-prone area. Other risks from natural disasters that students face where they live might include hurricanes or tornadoes.]

What do you think are the most promising clues that scientists might someday be able to use to predict earthquakes?

- [*Sample answer*: I think that the most promising clues for predicting earthquakes are signs of growing stress in rocks, such as foreshocks and ground tilt.]

What good does information about possible earthquake locations do for communities in those earthquake-prone regions?

- [*Sample answer*: Information about possible earthquake locations could be used to avoid constructing buildings and highways where earthquakes are most likely to occur, such as along faults.]

7.5 Lesson 7.4: Staying Safe in Earthquakes

Key Concepts

- Damage from earthquakes
- Earthquake-safe structures
- Protecting yourself in an earthquake

Lesson Objectives

- Describe different types of earthquake damage.
- Describe the features that make a structure earthquake safe.
- Describe how to protect a person or household in earthquake country.

Lesson Vocabulary

- **liquefaction:** process in which saturated sediments become like quicksand during an earthquake

Teaching Strategies

Introducing the Lesson

Show students dramatic images of buildings that have collapsed in an earthquake while other nearby buildings remain standing. Some examples are shown in the URLs below. Ask students why they think some buildings collapsed while others withstood the earthquake. Tell them they will learn how buildings can be constructed to withstand earthquakes when they read this lesson.

- http://www.terradaily.com/reports/Taiwan_to_boost_quake_warning_system_with_undersea_facility_999.html
- http://www.newenglandpost.com/2011/09/28/northeastern-university-student-designs-system-earthquake-proofing-buildings/
- http://www.nist.gov/public_affairs/factsheet/earthquake2009.cfm

Activity

In the activity at the following URL, students will construct towers out of drinking straws that must withstand simulated earthquake vibrations and an increasing load. By doing the activity, students will learn basic principles

of earthquake engineering and design, as well as practice team skills that are needed in all fields of science and engineering.

http://teachers.egfi-k12.org/activity-earthquake-proof-structure/

Differentiated Instruction

Have students do a think-pair-share activity. First ask students to think about the following questions: How can a building be made earthquake safe? How can you stay safe in an earthquake? After students have time to think about the questions, divide the class into pairs, matching any English language learners or less proficient readers with other students. Then ask partners to discuss how they would answer the questions.

Enrichment

Have interested students learn about earthquake building codes in an earthquake-prone region such as California (see URLs below). Ask them to report back to the class on some of the building requirements and to explain how they help buildings withstand earthquakes.

http://homeguides.sfgate.com/california-building-codes-earthquakes-2592.html

http://www.ehow.com/about_4692663_california-seismic-building-codes.html

Science Inquiry

In the lesson at the following URL, students will use both online and hands-on inquiry activities to explore landslides, liquefaction, and structural failures caused by earthquakes.

http://www.teachingboxes.org/earthquakes/lessons/lesson6.jsp

Overcoming Misconceptions

Some students may think that it is now possible to construct completely earthquake-proof buildings. In reality, buildings can be designed and constructed to withstand most, but not all, earthquakes. Earthquake damage is always a possibility, especially in very strong earthquakes.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 7.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 7.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What usually kills or injures people in an earthquake?

- [In an earthquake, people are usually killed or injured by buildings falling, roadways collapsing, or from the fires or tsunamis that may also occur with an earthquake.]

2. In two earthquakes of the same magnitude, what could produce more damage in a location further from the epicenter than in one nearer the epicenter?

- [Several factors could cause greater damage in a location further from the epicenter in earthquakes of the same magnitude. The factors might include the geology of the region, how and where buildings were constructed, and the amount of development in the area.]

3. Describe why Mexico City was so devastated in 1985 by an 8.1 earthquake with an epicenter far from the city.

- [Mexico City was so devastated by the 1985 earthquake because the city is built on sediments instead of bedrock. During the earthquake, the shaking of saturated sediments caused them to undergo liquefaction and become like quicksand. This caused the collapse if many buildings.]

4. What is liquefaction and how does it cause damage in an earthquake?

- [Liquefaction is the process in which saturated sediments become more like a liquid than a solid due to the shaking that occurs during an earthquake. Liquefaction causes damage because it causes the sediments to behave like quicksand, so buildings and other structures cannot be supported.]

5. If you live in an old home in an earthquake-prone region, what should you do to minimize the harm that will come to yourself and your home?

- [If you live in an old home, you can make it more earthquake safe by retrofitting it with steel or wood to reinforce the building's structure and its connections, such as where walls meet the foundation. You can also brace a brick chimney to the roof; move heavy objects near the floor or secure them to walls; use fluorescent light bulbs to minimize fire risk; use flexible gas lines and make sure everyone knows how to turn off the gas; secure gas-using appliances; place flashlights and fire extinguishers around the house; and have a first aid kit and know basic first aid and CPR. In the event of an earthquake, you should drop to the floor, get beneath a sturdy table or desk, cover your head, and hold on. You should stay away from windows and mirrors. After the earthquake, follow your family's evacuation plan.]

6. What can an architect do to make a skyscraper earthquake safe?

- [To make a skyscraper earthquake safe, an architect can build it on bedrock or anchor the building to bedrock if it is built on soft ground. Counterweights and diagonal steel beams can be installed to prevent the building from swaying so much during an earthquake that it touches nearby buildings. The skyscraper could be placed on rollers so it moves with the ground, or it could be placed on layers of steel and rubber to absorb the shock of seismic waves. There must be strong connections between walls and the foundation, and the first story especially must be well supported.]

7. Which types of buildings deserve the greatest protection from earthquake hazards?

- [*Sample answer*: Buildings constructed close to faults or buildings that are used as schools or hospitals deserve the greatest protection from earthquake hazards.]

8. Using what you know about elastic strength, will a building better withstand an earthquake if it is built absolutely solid or if it is able to sway? Why?

- [A building that is able to sway will better withstand an earthquake because it will be more likely to bend than break when the ground shakes.]

9. Why do wealthy communities tend to have greater earthquake protection than poorer communities, e.g., communities in developed versus developing nations?

- [Wealthy communities tend to have greater earthquake protection because constructing buildings to withstand earthquakes is expensive. Poor communities are unlikely to be able to afford the cost.]

10. What are the two goals of earthquake preparation?

- [The two goals of earthquake preparation are to make buildings earthquake safe and to educate people on how to prepare for, and stay safe in, earthquakes.]

11. What should you include in an earthquake kit?

- [In an earthquake kit, you should include a three-day supply of food and water, a radio, batteries, and a first aid kit. Flashlights and fire extinguishers should also be kept handy.]

12. Under what circumstances should you run outside in an earthquake?

- [You should run outside in an earthquake only if the building you are in is structurally unsound. Then you should get outside as quickly as possible and run to an open area.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Many people think that in a large earthquake, California will fall into the ocean and that Arizona and Nevada will become beachfront property. Why is this not true?

- [The San Andreas fault system that runs through California is a transform boundary between the Pacific and North American plates. The Pacific Plate is moving toward the northwest relative to the North American plate. This movement is horizontal. Los Angeles may move closer to San Francisco, but the state will not fall into the ocean.]

If you were the mayor of a small city in an earthquake-prone area, what would you like to know before choosing the building site of a new hospital?

- [*Sample answer*: As mayor, I would want to know the location of faults and the probability of earthquakes at different locations. I would also want to know the geology of the area in order to choose a location where the hospital could be built on bedrock instead of sediments.]

How are decisions made for determining how much money to spend preparing people and structures for earthquakes?

- [Decisions are made by weighing how great the risk of earthquakes is against the cost of building earthquake-safe buildings and educating the public. If the risk of a major earthquake is high, more money is likely to be spent preparing people and structures for earthquakes.]

Why do wealthy communities (such as those in California) tend to have greater earthquake protection than poorer communities (such as those in developing nations)?

- [Cost is the main factor. Earthquake-proof structures are expensive to build and out of the reach of poorer communities, such as those in developing nations.

CHAPTER 8 HS TE Volcanoes

Chapter Outline

8.1 Chapter 8: Volcanoes

Chapter Overview

This chapter explains how and where volcanoes form, types of magma and types of eruptions, and landforms from lava and magma.

Online Resources

See the following Web sites for appropriate laboratory activities:

In the lab "Volcano on Io," students will use simple materials and graphics to study features associated with active volcanoes on Jupiter's moon Io. They will learn how the shape and size of a volcano, as well as the explosiveness of its eruptions, is related to the chemical composition of its magma. They will also learn how volcanoes on Io differ from those found on Earth.

- http://europa.la.asu.edu/education/activities/voi/voi.pdf

In the lab activity at the following URL, small groups of students will work with maps, rocks, photographs of volcanic deposits, and a variety of other data to construct a hazard map and a risk communication plan for a specific volcano. Each group is assigned a different "volcano scenario," which is based on a real volcano.

- http://serc.carleton.edu/NAGTWorkshops/assess/activities/srogi.html

This online lab activity uses highly interactive animations, illustrations, activities, and quizzes to show how eruptions at Mount St. Helens were accurately predicted by USGS scientists. It then allows students to predict an actual eruption using real data.

- http://volcanoes.usgs.gov/about/edu/predict/index.php

These Web sites may also be helpful:

For a diversity of educational resources on volcanoes, see this URL:

- http://vulcan.wr.usgs.gov/Outreach/framework.html

You can link with a variety of volcano videos at the following URL.

- http://dsc.discovery.com/video-topics/other/other-topics-volcano-videos.htm

These URLs have links to volcano Web sites for teachers and students:

- http://voices.yahoo.com/great-volcano-web-sites-teachers-students-3069577.html
- http://exworthy.tripod.com/sciearthvolcanoes.htm
- http://www.lpi.usra.edu/education/step2012/participant/VolcanoResources.pdf

Pacing the Lessons

TABLE 8.1: short caption

Lesson	Class Period(s) (60 min)
8.1 Where Volcanoes Are Located	1.0
8.2 Volcanic Eruptions	2.5
8.3 Types of Volcanoes	2.0
8.4 Volcanic Landforms and Geothermal Activity	1.0

8.2 Lesson 8.1: Where Volcanoes Are Located

Key Concepts

- Volcanoes and plate tectonics
- Volcanoes at convergent and divergent plate boundaries
- Hotspot volcanoes

Lesson Objectives

- Describe how the locations of volcanoes are related to plate tectonics.
- Suggest why volcanoes are found at convergent and divergent plate boundaries.
- Describe how intraplate volcanoes can form.

Lesson Vocabulary

- **fissure:** crack in the crust at a divergent plate boundary where magma may erupt

Teaching Strategies

Introducing the Lesson

Introduce volcanoes in a dramatic fashion by showing students a short video (such as http://www.youtube.com/watch?v=xP2dreOI8gI) of the 1980 eruption of Mount St. Helens, which opens the chapter. After the video, briefly discuss the destruction caused by the Mount St. Helens eruption. You might want to share the list of facts below. Tell students they will learn more about volcanoes such as Mount St. Helens when they read this lesson.

- Mount St. Helen's 1980 eruption was the deadliest and most economically destructive volcanic eruption in U.S. history.
- The volcanic eruption killed 57 people.
- The eruption destroyed 250 homes, 47 bridges, 24 km of railways, and 298 km of highways.
- The eruption caused a 5.1 Richter magnitude earthquake, which triggered a massive avalanche of debris.
- The explosive eruption reduced the mountain's elevation by 400 m and replaced it with a 1.6 km wide crater.

Activity

Have students explore the interactive module "Volcanoes and Hot Spots" at the URL below. The module uses multimedia to cover and extend content of the Flexbook lesson. For this lesson, they should focus on the parts of the

module titled "Inside an Active Volcano," "Tracking Volcanoes," and "Above Hotspots."

http://www.mnh.si.edu/earth/main_frames.html

Differentiated Instruction

Have students make a Venn diagram comparing and contrasting volcanoes that occur at convergent plate boundaries with volcanoes that occur at hotspots.

Enrichment

Ask interested students to learn more about the 1980 eruption of Mount St. Helens, which is mentioned in the chapter. Tell them to collect photos, maps, diagrams, and statistics that show why and how the volcano erupted and the death and destruction it caused. Have students use the materials they collect to create a classroom display about Mount St. Helens.

Science Inquiry

In the inquiry activity below, students will examine the processes leading to a volcanic eruption, including mantle melting, magma formation, and magma ascent. Objectives of the activity are for students to understand how subducting plates trigger melting of mantle to form magma and how gas pressure initiates the ascent of magma into the magma chamber.

http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_one_magma_elevator.pdf

Overcoming Misconceptions

Many common misconceptions about volcanoes are listed at the following URL. Be aware that your students may hold some of these misconceptions. Discuss them with the class and point out how the misconceptions arise.

http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 8.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 8.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why are there volcanoes along the west coast of the United States?

- [There are volcanoes along the west coast of the United States because it is located at convergent plate boundaries where subducting plates sink into the mantle. The subducting plates heat up and melt, forming magma.]

2. Why does melting occur at divergent plate boundaries?

- [Melting occurs at divergent plate boundaries because hot mantle rock rises where tectonic plates move apart. This releases pressure on the mantle, which lowers its melting temperature.]

3. In the figure above, explain the geologic reason for every group of volcanoes in the diagram.

- [Volcanoes around the Pacific Ocean (Pacific Ring of Fire) occur because these areas lie along convergent plate boundaries, where one plate subducts beneath another and melts. Volcanoes at mid-ocean ridges and continental rifts occur because these areas lie along divergent plate boundaries, where tectonic plates move apart and allow hot mantle rock to rise. Other volcanoes, such as the Hawaiian Islands and Society Islands, occur within plates at hot spots, where mantle plumes carry magma up through the mantle to the crust.]

4. How did the Pacific Ring of Fire get its name? Does it deserve it?

- [The Pacific Ring of Fire got its name from all the volcanoes that form a ring around the Pacific Ocean. It deserves the name because the majority of volcanic activity on Earth occurs in this ring.]

5. What is a mantle plume?

- [A mantle plume is column of hot molten rock that rises through the mantle.]

6. Suppose a new volcano suddenly formed in the middle of the United States. How might you explain what caused this volcano?

- [*Sample answer*: I would explain the cause of this volcano as a hot spot because the middle of the United States is far from plate boundaries.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Some volcanoes are no longer active. What could cause a volcano to become extinct?

- [*Sample answer*: I think a volcano could become extinct if it is no longer over a hot spot or near a plate boundary due to movement of the plate where it is located.]

Hotspots are still poorly understood by Earth scientists. Why do you think it's hard to understand hotspots? What clues are there regarding these geological phenomena?

- [*Sample answer*: I think it's hard to understand hotspots because most of them occur in the oceans where it is difficult to investigate them. Clues about hotspots include the fact that most hotspot volcanoes occur in the oceans where the crust is relatively thin and that hotspot volcanoes on continents are caused by extremely large hotspots. These clues suggest that hotspots can form volcanoes only if the crust is thin or the hotspot is unusually large.]

Volcanoes have been found on Venus, Mars, and even Jupiter's moon Io. What do you think this indicates to planetary geologists?

- [*Sample answer*: I think this indicates that Venus, Mars, and Io have plate tectonic activity and magma.]

8.3 Lesson 8.2: Volcanic Eruptions

Key Concepts

- Composition of magma
- Types of volcanic eruptions
- Predicting volcanic eruptions

Lesson Objectives

- Explain how magma composition affects the type of eruption.
- Compare the types of volcanic eruptions.
- Distinguish between different types of lava and the rocks they form.
- Describe a method for predicting volcanic eruptions.

Lesson Vocabulary

- **active volcano:** volcano that is currently erupting or showing signs that it will erupt soon
- **dormant volcano:** volcano that is not currently erupting but has erupted in recorded history and may erupt again
- **effusive eruption:** relatively gentle, non-explosive volcanic eruption
- **eruption:** release of lava, tephra, and gases from a volcano
- **explosive eruption:** violent eruption of rock, lava, ash, and large amounts of gas from a volcano
- **extinct volcano:** volcano that has not erupted in recorded history and is unlikely to erupt again
- **lahar:** volcanic mudflow that occurs when a pyroclastic flow melts snow
- **magma chamber:** region in the crust below a volcano where magma and gases collect
- **pyroclastic flow:** hot ash, gas, and rock that race down a volcano's slopes during an explosive eruption
- **tephra:** fragments of solid material produced in an explosive volcanic eruption, which may include ash, cinders, rock fragments, and rocks
- **viscosity:** thickness of a liquid, or its resistance to flow

Teaching Strategies

Introducing the Lesson

Guide students in recalling what they know about igneous rocks from the Flexbook chapter "Rocks." Ask them to distinguish between mafic and felsic rocks. (Mafic rocks are low in silica and dark in color; felsic rocks are high in silica and light in color.) Explain that differences in the silica content of magma determine how thick the magma

is and the thickness of the magma, in turn, determines how a volcano erupts. Tell students they will learn about different types of volcanic eruptions in this lesson.

Buildings Science Skills

Students can simulate building volcanoes with different values for three variables (volume, viscosity, and volatiles) by doing the "Build a Volcano" activity at the following URL from the Smithsonian. Students will be able to observe the type of eruption that occurs with each combination of variables they select.

http://www.mnh.si.edu/earth/main_frames.html

Activity

In the activity at the following URL, students measure the volume and mass of popcorn before and after popping in an exploration of how expanding gas bubbles inflate and fragment magma during a volcanic eruption. They also study the physical characteristics of tephra using actual samples or photographs of samples.

http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_two_tephra_popcorn.pdf

Differentiated Instruction

Have students make a compare/contrast table for types of magma (mafic and felsic) and the types of volcanoes they cause (effusive and explosive, respectively).

Enrichment

Ask a small group of students who need extra challenges to do the activity at the following URL as a classroom demonstration. The students will show how gases create explosive volcanic eruptions by conducting a controlled "eruption" of baking soda/vinegar or soda water. The activity will underscore the important role of gases in providing energy for explosive volcanic eruptions. Although the activity was designed as a middle school activity, it makes a great demonstration for any grade level.

http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_one_soda_bottle_volcano.pdf

Science Inquiry

In the activity module at the URL below, students investigate the processes that build volcanoes, the factors that influence different eruption types, and the threats volcanoes pose to their surrounding environments. After exploring these characteristics, students use what they have learned to identify physical features and eruption types in some real-life documented volcanic episodes.

http://www.teachersdomain.org/resource/ess05.sci.ess.earthsys.lp_volcanoes/

Overcoming Misconceptions

Students commonly think that if a volcano doesn't erupt for a relatively short period of time, such as a century, then it must be extinct. Point out that the lifespan of a volcano may be millions of years, so a volcano that has not erupted in hundreds or even thousands of years would probably be considered dormant rather than extinct. For example, a Yellowstone volcano hasn't erupted violently for more than 600,000 years, but it recently showed signs of activity so it has just been dormant for all that time. Volcanoes become extinct when they run out of magma. However, this

is hard to detect. For example, until recently, Mount Vesuvius in Italy was thought to be extinct, but then it erupted violently showing that it too was just dormant and not extinct.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 8.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 8.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are the two basic types of volcanic eruptions?

- [The two basic types of volcanic eruptions are explosive eruptions and non-explosive, or effusive, eruptions.]

2. Several hundred years ago, a volcano erupted near the city of Pompeii, Italy (see the figure below). Archaeologists have found the remains of people embracing each other, suffocated by ash and rock that covered everything. What type of eruption must have this been?

- [This must have been an explosive volcanic eruption.]

3. What is pyroclastic material?

- [Pyroclastic material consists of ashes and rock fragments that fly out of a volcano during an explosive eruption.]

4. Name three substances that have low viscosity and three that have high viscosity.

- [*Sample answer*: Three substances that have low viscosity are water, vinegar, and milk. Three substances that have high viscosity are honey, melted wax, and molasses.]

5. Why might the addition of water make an eruption more explosive?

- [Water might make an eruption more explosive because when hot magma mixes with water, the water boils and forms gaseous water vapor. The gas increases the pressure in the magma chamber, which would make an eruption more explosive.]

6. What are three names for non-explosive lava?

- [Three names for non-explosive lava are a'a, pāhoehoe, and pillow lava.]

7. What factors are considered in predicting volcanic eruptions?

- [Factors that are considered in predicting volcanic eruptions include the volcano's history of eruptions, the occurrence of earthquakes near the volcano, ground swelling or tilting caused by the buildup of magma and gases, escape of gases from the volcano, and high-temperature spots near the volcano.]

8. Why is predicting a volcanic eruption so important?

- [Predicting a volcanic eruption is so important because it may be devastating, especially to the people who live close to the volcano. If people know that a volcano will soon erupt, they may have time to evacuate the area and stay safe.]

9. Given that astronomers are far away from the planets they study, what evidence might they look for to determine the composition of a planet on which a volcano is found?

- [*Sample answer*: They might look for evidence that shows the type of volcanic eruptions that have occurred. For example, they might look for ashes, which would indicate explosive eruptions. The type of eruption, in turn, would tell them something about the composition of magma that caused the volcanic eruptions. The composition of magma would be the same as the composition of the rocks that melted to form the magma.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What would you look for to determine if an old eruption was explosive or non-explosive?

- [*Sample answer*: You would look for the types of fragments and rocks that formed when the volcano erupted. For example, if there is evidence of ashes, that would indicate an explosive eruption. If there is evidence only of rocks formed from flowing lava, such as a'a or pillow lava, this would indicate a non-explosive eruption.]

Given the different styles of eruptions discussed above, what do you think the shapes of volcanoes are?

- [*Sample answer*: I think that explosive eruptions might create volcanoes with steeply sloping sides whereas non-explosive eruptions might create volcanoes with gently sloping sides.]

Where do you think the names a'a and pāhoehoe came from?

- [The names come from the Hawaiian language.]

Do earthquakes always indicate an imminent eruption? What factors about an earthquake might indicate a relationship to a volcanic eruption?

- [Earthquakes do not always indicate an imminent eruption, but if earthquakes become larger or more numerous they might indicate that a volcano will erupt soon. A volcano that is about to erupt may produce a sequence of earthquakes.]

8.4 Lesson 8.3: Types of Volcanoes

Key Concepts

- Composite volcanoes
- Shield volcanoes
- Cinder cones
- Supervolcanoes

Lesson Objectives

- Describe the basic shapes of volcanoes.
- Compare the features of volcanoes.
- Describe the stages in the formation of volcanoes.

Lesson Vocabulary

- **caldera:** large, circular hole formed when the top of a volcano collapses after an eruption empties the magma chamber
- **cinder cone:** small volcano composed of rock fragments piled on top of one another
- **composite volcano:** large volcano with steeply sloping sides composed of alternating layers of ash and lava flows
- **shield volcano:** broad-based volcano with gently sloping sides composed almost entirely of lava flows
- **supervolcano:** massive volcano that can produce rare but enormous eruptions

Teaching Strategies

Introducing the Lesson

Project images of a composite volcano and a shield volcano (see URLs below), and ask students to describe how the two volcanoes appear to differ. Identify the two types of volcanoes represented by the images, and tell students they will learn how the two types form when they read this lesson

- http://www.windows2universe.org/earth/interior/composite_volcanos.html
- http://www.ms-starship.com/sciencenew/images/shield_volcano.md.jpg

Activity

In the activity at the following URL, students can investigate how the viscosity of magma influences the shape of a volcano. Students will be able to relate the general viscosity of lava flows to type of volcano. They will also make some comparisons of lava flow behavior at Mount Rainier, Mount St. Helens, and Kilauea Volcano.

http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/chapter_two_lava_blocks.pdf

Building Science Skills

Students can simulate the collapse that forms a caldera with the activity at the URL below. They will use a balloon and a box of flour to model a magma chamber and overlying rock. The activity will take them through the stepwise process of predicting what they might see before and after the collapse. Students will then describe what happens with the collapse in their simulation.

http://media.up.edu/Physics/TOLE/CascadeVolcanoes/LessonPlans/FlourBoxVolcano_LessonPlan_VVP.pdf

Differentiated Instruction

Suggest that students make a compare/contrast table for composite and shield volcanoes. They should compare such features as shape of volcano, type of eruption, and type of magma. Tell them to add a simple sketch of each type of volcano to their table.

Enrichment

Volcanic eruptions obviously can have devastating impacts on people and the environment. However, unlike earthquakes, volcanoes can also have positive impacts, which may help explain why people choose to live near volcanoes. Ask a few students to debate whether they think volcanic eruptions have an overall more positive or more negative effect. They can learn more at the URL below. Set aside class time for their debate.

http://www.bbc.co.uk/schools/gcsebitesize/geography/natural_hazards/volcanoes_rev5.shtml

Science Inquiry

Have students do the activity "Piles of Fire" at the URL below. They will use simple materials to simulate a volcanic eruption in order to investigate how particle size affects the angle of a volcano's slope.

http://www.spacegrant.hawaii.edu/class_acts/PilesFireTe.html

Creative Writing Connection

In the writing assignment described at the following URL, students create an original work of fiction pertaining to the geology of composite volcanoes and the dangers of their eruptions.

http://serc.carleton.edu/NAGTWorkshops/intro/activities/25036.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 8.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 8.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Rank, in order, the four types of volcanoes from smallest to largest in diameter.

   - [From smallest to largest in diameter, the four types of volcanoes are cinder cones, composite volcanoes, shield volcanoes, and supervolcanoes.]

2. What factor best determines what type of volcano will form in a given area?

   - [The composition and thickness of magma best determines what type of volcano will form in a given area.]

3. Which type of volcano is most common?

   - [Cinder cone volcanoes are most common.]

4. Why do pāhoehoe and a'a lava erupt from shield volcanoes? Why don't they erupt from composite volcanoes?

   - [Pāhoehoe and a'a lava are forms of thin lava that can flow easily. Thin lava erupts from shield volcanoes, which have a shield shape because the lava flows quickly and can flow far from the vent before it cools and hardens. Thick lava erupts from composite volcanoes, which are formed by explosive eruptions due to the thickness of the magma and the buildup of gas pressure. Thick lava cannot flow very far from the vent before it cools and hardens because it flows slowly or even explodes out of the vent and up into the air.]

5. Why are cinder cones short-lived?

   - [Cinder cones are short-lived because they usually have a single eruption cycle.]

6. If supervolcanoes are so big, why did it take so long for scientists to discover them?

   - [Sample answer: It took scientists so long to discover supervolcanoes because they are extremely rare. Most supervolcano eruptions occurred hundreds of thousands or even millions of years ago.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Composite volcanoes and volcanic cones usually have craters on the top. Why are the craters sometimes U- or horseshoe-shaped?

- [*Sample answer*: The craters of composite volcanoes are sometimes U- or horseshoe-shaped because lava builds up in the center of the caldera after it forms and then flowing lava or landslides break down one end of the caldera, forming the open end.]

Think about plate boundaries again. What type of volcanoes do you think are found at convergent, divergent, and transform boundaries? How about at intraplate sites?

- [*Sample answer*: I think that composite volcanoes are found at convergent boundaries and that shield volcanoes are found at divergent boundaries and intraplate sites. I think that transform plate boundaries do not usually have volcanoes.]

Some people have theorized that if a huge asteroid hits Earth, the results would be catastrophic. How might an asteroid impact and a supervolcano eruption be similar?

- [Both an asteroid impact and a supervolcano eruption might produce a huge cloud of debris that blankets the planet and blocks the sun.]

8.5 Lesson 8.4: Volcanic Landforms and Geothermal Activity

Key Concepts

- Landforms from lava
- Landforms from magma
- Hot springs and geysers

Lesson Objectives

- List and describe landforms created by lava.
- Explain how magma creates different landforms.
- Describe the processes that create hot springs and geysers.

Lesson Vocabulary

- **geyser:** fountain of hot groundwater and steam that erupts under pressure onto the surface
- **hot spring:** place where hot water bubbles or flows continuously out of the ground
- **lava dome:** dome-shaped landform of igneous rock that forms when viscous lava cools near the vent of a volcano
- **lava plateau:** large, flat landform of igneous rock that forms when large amounts of non-viscous lava flow quickly over the ground

Teaching Strategies

Introducing the Lesson

As an introduction to geothermal activity, show students a short video of Old Faithful erupting. The video at the URL is a good example because it includes basic information about the geyser and its eruption cycle. Tell students they will read in this lesson about geysers like Old Faithful as well as other interesting features related to volcanic activity.

http://www.youtube.com/watch?v=dStibCCOOyE

Activity

Use Activity I at the URL below to teach students about volcanic landforms, using the volcanic landforms of Alaska as an example. In the activity, students will develop an understanding of the volcanic landforms in Alaska using photographs and worksheets. The activity concludes with student papers, presentations, and/or posters. The PDF

document includes the photographs and worksheets as well as a teaching strategy, extension activities, a glossary, and other useful materials.

http://pubs.usgs.gov/gip/99/pdf/gip99_chapter4.pdf

Differentiated Instruction

Have students outline the lesson as good way to organize and remember the most important content. Show them how to use the heading structure in the lesson to frame the basic outline. Then tell them to add important details under the relevant headings after they read the lesson.

Enrichment

Ask a small group of students to discuss how groundwater that has been heated by magma might be used to generate electricity. After they have come up with their own ideas, they can find out three different ways it can be done at the following URLs. Ask the students to describe one or more of the methods to the rest of the class.

- http://www.powerscorecard.org/tech_detail.cfm?resource_id=3
- http://www.renewableenergyworld.com/rea/tech/geoelectricity
- http://geo-energy.org/basics.aspx#how_plant_work

Science Inquiry

With the guided inquiry activity at the following URL, students can create a model of a geyser and use it to learn more about these geothermal features. For example, they will observe that there are three main phases in a geyser's cycle (heating, erupting, and refilling).

http://www.exploratorium.edu/snacks/geyser/index.html

Biology Connection

Tell students about thermophile ("heat-loving") bacteria that are able to survive at very high temperatures in hot springs. These bacteria are important because they provide clues about what early life forms on Earth might have been like. They have also proven useful in biotechnology because their enzymes remain active at high temperatures. You (or your students) can learn more at the following URLs.

- http://bioinfo.bact.wisc.edu/themicrobialworld/LAHT/b27.html
- http://serc.carleton.edu/microbelife/extreme/extremeheat/index.html
- http://whyfiles.org/2011/biology-critters-that-should-not-exist/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 8.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 8.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are four different landforms created by lava?

- [Four different landforms created by lava are volcanic mountains, lava domes, lava plateaus, and volcanic islands.]

2. What is the major difference between hot springs and geysers?

- [The major difference between hot springs and geysers is that the water in a hot spring bubbles out of the ground whereas the water in a geyser erupts out of the ground because it is under pressure in a narrow underground passageway.]

3. The geyser called Old Faithful has been erupting for perhaps hundreds of years. One day, it could stop. Why might geysers completely stop erupting?

- [*Sample answer*: A geyser over a hotspot in a tectonic plate, such as Old Faithful, might stop erupting if it is no longer over the hotspot due to plate movement. Without the hotspot, the groundwater that creates the geyser may no longer be heated by magma.]

4. After earthquakes, hot springs sometimes stop bubbling, and new hot springs form. Why might this be?

- [*Sample answer*: This might happen if rocks shift during the earthquake so the cracks through which hot groundwater rises to the surface close up in one place and open up in another place.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What might Earth look like if there were no tectonic plates? Are there any planets or satellites (moons) that may not have tectonic plates? How is their surface different from that of Earth?

- [*Sample answer*: If Earth had no tectonic plates, most volcanic activity would cease. Without volcanic activity, Earth's surface might have more impact craters from meteorites striking the planet. Planets and moons that do not have tectonic activity are generally covered by craters, partly because the surface is not recycled by volcanic activity.]

The largest volcano in the solar system is Olympus Mons on Mars. How could this volcano have formed?

- [Olympus Mons is a shield volcano that formed over a hotspot. The crust of Mars does not have tectonic plates that move, so the volcano remained over a hotspot and continued to erupt for a long period of time.]

What kind of land formations are the result of volcanic activity? Are all of these created by extrusive igneous rocks?

- [Landforms created by extrusive igneous rock are those that formed from lava on the surface. They include volcanoes, lava domes, lava plateaus, and volcanic islands. The entire ocean floor was also created by lava flowing to the surface through fissures. Landforms creates by intrusive igneous rock are those that formed from magma beneath the surface and were later exposed by erosion. For example, Shiprock in New Mexico is the neck of an old volcano that eroded away.]

How are hydrothermal vents at mid-ocean ridges like the geysers of Yellowstone?

- [At both hydrothermal vents and geysers, hot water erupts out of cracks onto the surface.]

CHAPTER 9 HS TE Weathering and Formation of Soil

Chapter Outline

9.1 Chapter 9: Weathering and Formation of Soil

Chapter Overview

This chapter describes mechanical and chemical weathering of rock. It also explains how soil forms, identifies soil horizons, and relates soil type to climate.

Online Resources

See the following Web sites for appropriate laboratory activities:

Have students do the real-world weathering project described at the following URL. They will photograph and document examples of different types of weathering around their community. (The lab was written for a community in Virginia, so you will have to substitute the correct place names for your community.) Students will also investigate specifically the effects of exposure (north, south, east, or west) on rate of weathering. Finally, they will do library research on weathering and conclude the activity with a written report.

- http://www.earth2class.org/docs/tchrlessonplans/Stallard_weathering.php

In the soil lab described at the URL below, students will test a soil sample for levels of three major soil elements and for pH. The experiment leads to a soil analysis in which students answer questions about optimum growing conditions with their soil, including preferred fertilizer and plants.

- http://bostonteachnet.org/Quinones/QuinonesSp3/

These Web sites may also be helpful:

The National Geographic article below has excellent images of weathering. It is also a good alternative presentation of the content of the first lesson in this chapter ("Weathering").

- http://education.nationalgeographic.com/education/encyclopedia/weathering/?ar_a=1

At the following URL, you can find 18 short, narrated video clips on different types of soil organisms.

- http://www.agron.iastate.edu/ loynachan/mov/

The USDA provides many soil resources for teachers and students at this URL:

- http://soils.usda.gov/education/index.html

You can find an entire multimedia library devoted to soils at the following URL.

- http://forces.si.edu/soils/04_00_00.html

Pacing the Lessons

TABLE 9.1: short caption

Lesson	Class Period(s) (60 min)
9.1 Weathering	2.0
9.2 Soils	2.0

9.2 Lesson 9.1: Weathering

Key Concepts

- Definition of weathering
- Mechanical weathering
- Chemical weathering
- Factors that affect rates of weathering

Lesson Objectives

- Define mechanical and chemical weathering.
- Discuss agents of weathering.
- Give examples of each type of weathering.

Lesson Vocabulary

- **abrasion:** form of mechanical weathering that occurs when rocks and rock particles scrape against other rocks
- **chemical weathering:** type of weathering that changes the mineral composition of rocks
- **climate:** average weather of a location over a long period of time
- **hydrolysis:** chemical change in which hydrogen or hydrogen ions replace positive ions in a mineral
- **ice wedging:** form of mechanical weathering that occurs when water enters a crack in rock, expands as it freezes, and wedges the rock apart
- **leaching:** process in which minerals in soil are dissolved and carried to lower layers of soil
- **mechanical weathering:** type of weathering that breaks rocks into smaller pieces without changing their mineral composition
- **oxidation:** chemical change in which oxygen reacts with another element to create a metal oxide

Teaching Strategies

Introducing the Lesson

Project the photo at the URL below. It shows an astronaut on the moon. Point out the astronaut's footprints in the dust on the moon's surface. Tell the class that the footprints were made in the early 1970s but they remain virtually unchanged decades later. Similar footprints left in most places on Earth would quickly be disturbed. That's because on Earth, unlike the moon, forces of weathering are continuously changing the surface. Tell students they will learn about weathering when they read this lesson.

http://www.nasa.gov/images/content/371255main_Seismic_full.jpg

Demonstration

Use a simple demonstration to make clear the differences between mechanical and chemical weathering. Demonstrate mechanical weathering by placing an effervescent antacid tablet on a table and breaking it with a hammer. Explain that this is a form of mechanical weathering, in which rocks are physically broken into smaller fragments without changing their chemical composition. Ask students what natural processes break rocks into fragments in this way. (ice wedging, abrasion, and actions of living things) Demonstrate chemical weathering by dropping an effervescent antacid tablet into a beaker of water. As the tablet dissolves, explain that it contains sodium bicarbonate, which dissolves in water similar to the way that carbonate rocks dissolve in water.

Differentiated Instruction

Suggest that less proficient readers make a concept map of lesson concepts. It should include the following concepts: weathering, agents of weathering (water, wind, glaciers, and gravity), mechanical weathering (by ice wedging, abrasion, and plants and animals), chemical weathering (by water, carbon dioxide, and oxygen), and influences on weathering (rock types and climate).

Enrichment

Challenge students to compute how much the surface area of a cube increases if it is cut into two equal pieces. (Its surface area will increase by 25 percent.) Ask them to demonstrate their solution to the class and explain how it relates to the weathering of rock.

Science Inquiry

Obtain permission to visit a nearby cemetery with your class. The cemetery should have tombstones made from different types of rock, including marble, slate, and granite. Help students identify the different types of rock, and tell them to look for evidence of weathering on tombstones of each rock type. They should look for cracks or missing pieces of rock, legibility of the inscription, surface texture of the tombstone, and biological alterations such as mildew, mold, or lichen Be sure to have students make note of the year the tombstone was put in place (assumed to be the date of death) so they will be able to factor in the amount of time the tombstone has been weathering. As a class, have students create a rubric that assigns a numeric value for the extent of weathering observed. Have students graph their results to show which type of rock weathers most quickly in their climate. Discuss the particular climate factors that contribute to weathering in their area.

Overcoming Misconceptions

Listed below are several misconceptions about weathering, each of which is held by at least a third of high school students (AAAS Project 2061). Use the list as a true/false quiz to identify which misconceptions are held by your own students. Discuss these misconceptions with the class and show students examples that disprove the misconceptions.

1. Wind cannot break grains of sand.
2. Wind cannot break solid rock.
3. The growth of plant roots cannot break rock.
4. Wind can carry small rocks (e.g., sand) but never carries large rocks (e.g., fist-sized).
5. A small stream cannot wear away the solid rock of a cliff over time.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 9.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 9.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are the four forces of erosion and which is responsible for the most erosion?

   - [The four forces of erosion are wind, water, glaciers, and gravity. Water is responsible for the most erosion.]

2. Name two types of mechanical weathering. Explain how each works to break apart rock.

   - [*Sample answer*: Two types of mechanical weathering are abrasion and ice wedging. In abrasion, rocks and rock particles break apart other rocks by scraping against them. In ice wedging, water enters a crack in rock, expands as it freezes, and wedges the rock apart.]

3. What are three agents of chemical weathering? Give an example of each.

   - [*Sample answer*: Three agents of chemical weathering are water, carbon dioxide, and oxygen. Water can completely dissolve some minerals, such as salt. Carbon dioxide combines with raindrops and forms a weak acid, called carbonic acid, which works to dissolve rocks. Oxygen strongly reacts with elements at Earth's surface. For example, it reacts with iron to form iron oxide.]

4. What type of climate would likely produce the greatest degree of weathering? Explain.

   - [A warm, wet climate would likely produce the greatest degree of weathering. Chemical weathering occurs more quickly in a hot climate because chemical reactions proceed more rapidly at higher temperatures. In addition, more plants grow in a warm, wet climate, so there would be a greater rate of biological weathering. More water also allows more chemical reactions. If the water is moving, it causes more mechanical weathering as well.]

5. What causes differential weathering in a rock?

   - [Differential weathering in a rock is caused by different minerals that weather at different rates. For example, some minerals in a rock might completely dissolve in water and leave behind the minerals that do not dissolve as readily in water.]

6. Would a smooth, even surface weather faster than an uneven, broken surface?

   - [*Sample answer*: I think that an uneven, broken surface would weather faster than a smooth surface because the uneven, broken surface has greater surface area. With more surface exposed, there are more places for weathering to occur. The broken surface also might let water enter into cracks to dissolve minerals. In a cold climate, water seeping into cracks would allow ice wedging to take place.]

7. What type of rocks would be best suited to making monuments?

- [Igneous rocks, especially intrusive igneous rocks such as granite, would be best suited to making monuments because it is difficult for water to penetrate them and this would cause them to weather slowly.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What types of surfaces are affected by weathering other than rock?

- [Many surfaces are affected by weathering, including wood, asphalt, concrete, and metal.]

What might the surface of Earth look like if there was no weathering? Think about the Moon or other planets.

- [*Sample answer*: If weathering did not occur, Earth's surface would be covered with large masses of rock and there would be fewer small rocks and no soil. There would also be more craters from the impact of meteorites.]

Do you think that you would be alive today if water did not dissolve elements?

- [*Sample answer*: If water did not dissolve elements, plants would not be able to take in dissolved nutrients from soil. Without plants, animalspeoplenot be alive today. Most living things also depend on water to dissolve elements within their cells, so normal cell functions would not occur without the ability of water to dissolve elements.]

Would the same composition of rock weather the same way in three very different climates?

- [No, probably not. In a cold climate, for example, rock might weather mainly by ice wedging. In a hot climate, the rock might weather mainly by chemical weathering.]

9.3 Lesson 9.2: Soils

Key Concepts

- Characteristics of soil
- Soil texture and composition
- Soil horizons and profiles
- Types of soils
- Factors that determine soil type
- Soil conservation

Lesson Objectives

- Discuss why soil is an important resource.
- Describe how soil forms from existing rocks.
- Describe the different textures and components of soil.
- Draw and describe a soil profile.
- Define three climate related soils: pedalfer, pedocal, and laterite.

Lesson Vocabulary

- **B-horizon:** layer of a soil profile beneath the topsoil where ion oxides and clay minerals accumulate; also called subsoil
- **C-horizon:** lowest layer of a soil profile consisting of partially altered bedrock
- **humus:** organic portion of soil that consists of partially decayed remains of plants and animals
- **inorganic:** not related to life or living organisms; not organic
- **laterite:** nutrient-poor, red soil that forms in tropical rainforests
- **loam:** type of soil that contains about equal proportions of sand, silt, and clay
- **pedalfer:** very fertile, dark soil that forms in mid-latitude deciduous forests
- **pedocal:** moderately fertile soil that forms in grasslands
- **permeable:** material with tiny holes that water can pass through easily
- **residual soil:** soil that forms from the bedrock upon which it is found
- **soil:** top layer of Earth's surface containing weathered rocks and minerals and organic materials
- **soil horizon:** individual layer of a soil profile; A-, B-, or C-horizon
- **soil profile:** entire set of soil layers, or horizons, for a particular soil
- **subsoil:** B-horizon of a soil profile, which lies beneath the topsoil
- **topsoil:** A-horizon of a soil profile, which is the uppermost and most fertile layer of soil, containing humus, plant roots, and living organisms
- **transported soil:** soil that forms from weathered components that have been transported from a different area

Teaching Strategies

Introducing the Lesson

Introduce soil with the beautiful Smithsonian video, "Soil: the Secret Ingredient," at the following URL. The brief video will show students some of the many ways that soil affects our lives.

http://forces.si.edu/soils/04_00_00.html

Activity

Healthy soils are held together by "soil glue," or glomalin, that is produced by fungi. Soils rich in soil organisms hold together well, whereas soils lacking soil organisms fall apart easily. These differences have implications for water retention by soils, the ability of soils to support plant growth, and how easily soils erode. Help students understand this important property of soils by having them do the activity at the URL below. The activity will demonstrate that less disturbed soils contain more "soil glue" and hold together better than more disturbed soils. It will show why it is important to protect soils from disturbance.

http://soils.usda.gov/sqi/publications/files/soil_glue_lesson_plan.pdf

Differentiated Instruction

Have students make a compare/contrast table for the three types of soils described in the lesson (pedalfer, pedocal, and laterite). They should include distinguishing features of the soils and where they form.

Enrichment

Ask a small group of students to demonstrate how the amount of organic matter in soil influences the extent to which the soil can be eroded by flowing water. They can follow the procedure at the URL below. It uses only readily available materials.

http://soils.usda.gov/education/resources/lessons/experiments/erosion/

Science Inquiry

Students can analyze a soil sample with the activity at the URL below. In the activity, students will collect a local soil sample and use a simple procedure to determine what type of soil it is by its proportion of particles of different sizes. They will also decide on the soil's potential for supporting plant growth.

http://ia700204.us.archive.org/20/items/AP_Environmental_Sci_Lab_11/chapter11extralab1.html

Real-World Connection

The use of geological materials such as soils to solve criminal cases began with the great fictional detective Sherlock Holmes. Today, it is commonplace. At the URLs below, students can read about several criminal cases that were solved with the help of soil forensics.

http://www.forensicgeology.net/science.htm

http://www.csiro.au/Outcomes/Environment/Australian-Landscapes/soil-evidence-murder-case.aspx

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 9.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 9.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why is soil sometimes described as a living resource?

- [Soil is sometimes described as a living resource because it forms an ecosystem unto itself. In the spaces in soil, there are thousands or even millions of living organisms, including earthworms, ants, and fungi. Plants also send their roots down into soil.]

2. Name two factors that influence soil formation and explain how they do so.

- [*Sample answer*: Two factors that influence soil formation are climate and original rock type. Climate is the most important factor influencing soil type. Climate factors that influence weathering also influence the rate at which soil forms. For example, increased temperature increases the rate of chemical weathering, which increases the rate of soil formation. The original rock is the source of the inorganic part of soil. The minerals that are present in the rock influence the mineral composition of the soil that forms from the rock.]

3. Which region of a soil profile reacts the most?

- [The A-horizon, or topsoil, of a soil profile reacts the most because this is where most of the contact with air and water occur.]

4. Is the soil in your backyard more likely a residual soil or a transported soil? How could you check?

- [*Sample answer*: Only about one-third of the soils in the United States are residual soils, so the soil in your backyard is more likely to be a transported soil. You could check by comparing the mineral composition of the soil with the mineral composition of the underlying bedrock. The mineral composition would be the same for a residual soil but might be different for a transported soil.]

5. Name several advantages to adding humus to the soil.

- [Adding humus to the soil improves the soil's ability to hold onto water by increasing the soil's porosity. This helps to buffer rapid changes in soil acidity. Humus also coats the mineral grains in soil, binding them together into clumps that hold the soil together. In addition, humus increases the soil's ability to hold onto nutrients, thus increasing the fertility of the soil.]

6. What are three soil horizons? Describe the characteristics of each.

- [Three soil horizons are the A-, B-, and C-horizons. The A horizon is the uppermost layer of soil, also called topsoil It is usually the darkest layer and contains the most organic material. This is also where most soil organisms live and where plant roots grow. Dissolved minerals and tiny mineral particles such as clay are

generally carried from the topsoil down to lower soil layers. The B-horizon, or subsoil, is the horizon that lies beneath the A-horizon. This is where soluble minerals and clay particles accumulate. The presence of iron and clay minerals causes subsoil to hold more water than topsoil. Subsoil is also lighter in color than topsoil and contains less organic matter. The C-horizon is a layer of partially altered bedrock without organic material. There is some evidence of weathering in this layer, but pieces of the original rock can be seen and identified.]

7. Name three climate related soils. Describe the climate and vegetation that occurs in the area where each forms.

- [Three climate-related soils are pedalfer, pedocal, and laterite. Pedalfer forms in temperate deciduous forests that receive at least 65 cm of rain per year. Pedocal forms in drier temperate areas where grasslands and brush are the usual types of vegetation. These areas receive less than 65 cm of rain per year. Laterite forms in tropical rainforests, where the climate is hot year-round and it rains every day.]

8. Where would you choose to buy land for a farm if you wanted fertile soil and did not want to have to irrigate your crops?

- [*Sample answer*: I would choose to buy land for a farm where there is pedalfer soil. This is dark brown or black soil that forms in a deciduous forest. This soil is very fertile because of all the dead leaves that fall to the ground each year and turn to humus. Deciduous forests also require plenty of rainfall, so the soil would be moist and not require irrigation.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why is soil such an important resource?

- [Soil is such an important resource because people and most organisms could not survive without soil. Most plants need soil to grow, and most other organisms depend on plants, either directly or indirectly, for food.]

Would soil mature faster from unaltered bedrock or from transported materials?

- [Soil would mature faster from transported materials than from unaltered bedrock because the transported materials are already weathered.]

If soil erosion is happening at a greater rate than new soil can form, what will eventually happen to the soil in that region?

- [The soil in that region will eventually be depleted.]

Do you think there are pollutants that could not easily be removed from soil?

- [Pollutants that cannot easily be removed from soil include heavy metals, such as lead and mercury; hydrocarbons from coal burning and vehicle emissions; and residues from certain pesticides and herbicides.]

CHAPTER 10 HS TE Erosion and Deposition

Chapter Outline

10.1 Chapter 10: Erosion and Deposition

Chapter Overview

This chapter explains how erosion and deposition shape Earth's surface through the action of streams, groundwater, waves, wind, glaciers, and gravity.

Online Resources

See the following Web sites for appropriate laboratory activities:

The first three stream table labs accessible at the following URL allow students to investigate erosion and deposition by flowing water. Students will learn how a stream forms; how the processes of erosion and deposition occur in a stream, including where they occur on both a large and a small scale; how stream velocity relates to the rate of erosion and deposition; and how sorting of sediments occurs in streams and its relationship to water velocity. Students will also learn how to make good observations, how to apply the different parts of the scientific method, and how to design a simple experiment with provided materials.

- http://csip.cornell.edu/Curriculum_Resources/CEIRP/streamtable.html

In the investigation at the URL below, students will model glacial dynamics with flubber (glue, water, and detergent). They will run several tests with different values for valley slope, flubber temperature, and basal conditions; and they will calculate the "glacier's" velocity for each scenario. Students will also compare their glacier models to the dynamics of real glaciers and discuss how and why glaciers might be changing over time.

- http://nagt.org/nagt/programs/teachingmaterials/11337.html

These Web sites may also be helpful:

Visit the URL below for information on building and using a stream table to simulate erosion and other processes involving sediment transport by water.

- http://www.mostreamteam.org/pdfs/bldusng.pdf

The following URL is a database of incredible photos for many glacier education topics including glacier hazards, how glaciers shape the landscape, and benefits of glaciers.

- http://www.swisseduc.ch/glaciers/earth_icy_planet/glaciers16-en.html

This URL contains common questions and myths about glaciers.

- http://ak.water.usgs.gov/glaciology/FAQ.htm

At the URL below, you can download a free handbook on landslides titled "The Landslide HandbookGuide to Understanding Landslides." The handbook answers questions such as: What are landslides? Where do they occur? What causes them? How are they monitored? How can they be prevented? What safety measures can you follow if you live near steep hills? Written for a general audience, the handbook is heavily illustrated with diagrams and photographs taken at locations around the globe.

- http://pubs.usgs.gov/circ/1325/

Pacing the Lessons

TABLE 10.1: short caption

Lesson	Class Period(s) (60 min)
10.1 Water Erosion and Deposition	1.5
10.2 Wave Erosion and Deposition	1.5
10.3 Wind Erosion and Deposition	1.5
10.4 Glacial Erosion and Deposition	1.5
10.5 Erosion and Deposition by Gravity	1.5

10.2 Lesson 10.1: Water Erosion and Deposition

Key Concepts

- Erosion and deposition by streams
- Groundwater erosion and deposition

Lesson Objectives

- Describe how surface streams produce erosion.
- Describe the types of deposits left behind by streams.
- Describe landforms that are produced as groundwater flows.

Lesson Vocabulary

- **alluvial fan:** fan-shaped landform created where a stream goes from a steep slope to flat ground and deposits its sediments
- **base level:** elevation of the mouth of a stream where it enters a large body of standing water such as the ocean
- **bed load:** sediments that move by rolling or bumping along a streambed
- **column:** cave deposit formed when a stalactite and stalagmite merge
- **competence:** measure of the largest particle size that a stream can transport
- **delta:** triangular landform created where a river flows into a body of standing water and deposits its sediments
- **dissolved load:** elements carried in solution by flowing water
- **floodplain:** flat area on both sides of a stream channel that is covered with water when the stream floods its banks
- **gradient:** slope of a stream
- **groundwater:** fresh water that moves through pores and fractures in soil and rock beneath Earth's surface
- **headwaters:** location where a stream forms, often high in the mountains
- **meander:** large curve in a stream caused by erosion of the outside of a curve and deposition on the inside of a curve
- **natural levee:** raised strip of coarse-grained sediments that are deposited on a stream's banks when it floods its channel
- **saltation:** transport of bed load along a stream bed in little jumps
- **sinkhole:** circular hole in the surface of the ground that forms when the roof of a cave collapses
- **stalactite:** icicle-like formation of calcium carbonate that comes out of solution when water drips from the ceiling of a cave
- **stalagmite:** deposit of calcium carbonate on the floor of a cave that comes out of solution when water drips onto the cave floor
- **suspended load:** very small particles such as clay that are carried by the main stream flow but are not dissolved by water

- **travertine:** type of deposit of calcium carbonate that forms from mineral spring water and is valued for its beauty

Teaching Strategies

Introducing the Lesson

Introduce water erosion and deposition by referring students to the chapter opener photo and accompanying description in their FlexBook® resource.

Question: Why did astronauts say that Madagascar is "bleeding into the ocean"?
Answer: The river in the photo is carrying huge amounts of soil from Madagascar's land into the ocean.
Question: What conditions cause the river to carry more soil from the land into the ocean?
Answer: The river carries more soil because the forest has been cleared by logging. The river also carries more soil during tropical storms.

Tell students they will learn in this lesson why factors such as these cause flowing water to wash away so much soil.

Activity

Students can learn more about groundwater erosion and deposition with the interactive "Virtual Cave" activity at the following URL. They can click on a wide variety of cave features to see photographs and read descriptions. The Web site includes a background essay and discussion questions.

http://www.teachersdomain.org/resource/ess05.sci.ess.earthsys.virtmap/

Differentiated Instruction

Have students who need extra help make a main ideas/details chart for the lesson. This will help them focus on the most important ideas and supporting information. To start the chart, they can divide a sheet of paper down the middle and use the left column for the main ideas, each separated by several lines to make room for adding details to the right column. Suggest that students include at least one main idea for each heading and subheading in the lesson. Advise them to keep the details brief and to the point.

Enrichment

Tell students that sinkholes are especially common in Florida. Shows them pictures of Florida sinkholes at the first URL below. Then challenge a few students to find out why sinkholes are so common in Florida and to report back to the class with the explanation. The second URL below is a good place for them to learn more.

http://www.weather.com/news/florida-sinkhole-photos-20130301

http://www.dep.state.fl.us/geology/geologictopics/hazards/sinkholes.htm

Science Inquiry

In the inquiry activity at the following URL, students will model stream erosion and deposition. Using their model, they will observe the effects of changes in water velocity on erosion and deposition of sediments of different sizes.

http://www.mysciencebox.org/book/export/html/209

Science Inquiry

If possible, take your class on a fieldtrip to investigate erosional and depositional features of a stream in your area. You can follow the guidelines in the URL below, which incorporates technology including Internet research, GPS mapping, and PowerPoint presentations. Students will learn about four types of features created by stream erosion and four types created by stream deposition. Then they will find likely locations for the features on their trip. In the field, they will use a mobile device to document and explain how each of the features formed. Finally, they will use GPS to make a map showing the locations of the features and create a PowerPoint presentation with their documentation.

http://edtech2.boisestate.edu/hyattb/502/mobile.html

Overcoming Misconceptions

More than half of high school students questioned think that it takes flowing water millions of years to wear away just a few inches or feet of rock (AAAS Project 2061). Use the following multiple choice questions to check for this misconception in your students. (For both questions, the correct choice is 'a.') Then make sure students are aware of the correct facts.

1. Which of the following statements describes how water can change mountains?
   a. Water can gradually wear away the solid rock of mountains as much as thousands of feet over many millions of years.
   b. Water can wear away the solid rock of mountains no more than several feet over many millions of years.
   c. Water can wear away the solid rock of mountains no more than several inches over many millions of years.
   d. Water cannot wear away the solid rock of mountains, even over many millions of years.
2. Which of the following statements describes how water can change river valleys?
   a. Water can gradually wear away the solid rock of river valleys as much as thousands of feet over millions of years.
   b. Water can wear away the solid rock of river valleys no more than several feet over many millions of years.
   c. Water can wear away the solid rock of river valleys no more than several inches over many millions of years.
   d. Water cannot wear away the solid rock of river valleys, even over many millions of years.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 10.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 10.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Define the three kinds of load that make up the particles a stream carries.

- [Three kinds of load that make up the particles a stream carries are dissolved load, suspended load, and bed load. Dissolved load is composed of ions in solution. Suspended load consists of small solid sediments carried by the main stream flow but not dissolved in the water. Bed load consists of

particles that are too large to be carried as suspended load. They are bumped and pushed along the stream bed.]

2. What is a stream's gradient? What effect does it have on the work of a stream?

- [A stream's gradient is the slope of the stream bed. The greater the slope is, the greater is the velocity of the flowing water. Water that is flowing more rapidly has more energy and can do more work. It can cause more erosion and transport more and larger sediments.]

3. How do streams erode their beds?

- [Streams erode their beds downward where they have a relatively great velocity. This generally occurs at a stream's headwaters, often high in the mountains.]

4. How does a stream produce a wide, flat floodplain?

- [A stream produces a wide, flat floodplain where it flows over ground with a very gentle slope. It carves a floodplain by eroding the outer edges of its banks.]

5. What type of gradient would a river have when it is actively eroding its stream bed?

- [A river would have a steep gradient when it is actively eroding its stream bed.]

6. When would a river form an alluvial fan and when would it form a delta? Describe the characteristics of each type of deposit.

- [A river would form an alluvial fan when it flows from a steep slope to nearly level land. It would form a delta when it flows into a large body of still water such as the ocean. An alluvial fan has a fan shape, and a delta has a triangular shape.]

7. What are two formations that form inside caves?

- [Two formations that form inside caves are stalactites, which form on the ceilings of caves, and stalagmites, which form on the floors of caves.]

8. What erosional feature formed by groundwater could swallow up your house?

- [A sink hole could swallow up your house. This is a circular hole in the surface of the ground that forms when the roof of a cave collapses.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Would a stream at higher elevations erode more than a stream at lower elevations?

- [A stream at higher elevations would erode more than a stream at lower elevations because the higher elevation stream is likely to have steeper channel and greater velocity. A stream with greater velocity can cause more erosion. It can carry more sediments and larger sediments.]

How would Earth's surface look without streams?

- [Without streams, there would be no features that are formed from erosion or deposition by flowing water. There would be no stream valleys, floodplains, alluvial fans, or deltas. For example, the Grand Canyon would not exist without stream erosion.]

Would a flash flood along a normally dry river valley be a dangerous event?

- [*Sample answer*: Yes; it would be a dangerous event because the river would overflow its banks and flood land that rarely floods. It might flood homes and wash out bridges.]

Do you think caves could form in your neighborhood?

- [Answers may vary. Students who live in areas known for caves or in high-rainfall climates might say that they think caves could form in their neighborhood.]

10.3 Lesson 10.2: Wave Erosion and Deposition

Key Concepts

- Wave action and erosion
- Wave deposition
- Protecting shorelines

Lesson Objectives

- Describe how the action of waves produces different shoreline features.
- Discuss how areas of quiet water produce deposits of sand and sediment.
- Discuss some of the structures humans build to help defend against wave erosion.

Lesson Vocabulary

- **arch:** landform created when waves erode through a cliff from opposite sides
- **barrier island:** long, narrow island of sand parallel to shore that is deposited by waves
- **beach:** sediments deposited in a relatively quiet area on shore, consisting mainly of sand
- **breakwater:** artificial barrier built in the water parallel to shore to protect the shore from erosion by strong incoming waves
- **groin:** artificial barrier built in the water perpendicular to shore to trap sand carried along the shore by longshore drift
- **refraction:** change in direction of a wave caused by a change in wave speed, which occurs when a wave strikes the shore at an angle
- **sea stack:** isolated tower of rock created when the top of a sea arch erodes and collapses
- **sea wall:** artificial barrier built on a beach parallel to the shoreline to protect the beach from erosion by strong waves
- **spit:** ridge of sand extending out from shore that is deposited by longshore drift
- **wave-cut cliff:** sea cliff created by wave erosion
- **wave-cut platform:** level area created by wave erosion as waves undercut a cliff

Teaching Strategies

Introducing the Lesson

Grab students' attention by showing a short video of surfers riding waves to shore (see URLs below). Ask students if they know what causes the waves that make surfing possible. (wind) Tell them they will learn how waves form and also how they cause erosion and deposition when they read this lesson.

http://mpora.com/surfing/videos

http://www.dailysurfvideos.com/

Building Science Skills

If you use the lesson plan "Who Moved the Beach?" at the following URL, students can investigate the primary causes and impacts of wave erosion and how human communities should respond to this process.

http://oceanservice.noaa.gov/education/classroom/lessons/09_coastmanag_erosion.pdf

Differentiated Instruction

Have students make a KWL chart for wave erosion and deposition. Before they read the lesson, they should list what they already know (K) in the first column of the chart and what they want to know (W) in the second column of the chart. Then, after they finish reading the lesson, they should list what they learned (L) in the last column of the chart.

Enrichment

Point out that barrier islands are some of the most highly developed, urbanized coastal areas. Cities built at least partially on barrier islands include Miami Beach, Florida; Atlantic City, New Jersey; and Long Beach, New York. Ask a few students to learn about the effects of urbanization on barrier islands and their subsequent ability to protect coasts from erosion. Students should also identify pros and cons of barrier-island living for residents and businesses. Then ask the students to present a debate to the class in which they argue for or against development on barrier islands.

Science Inquiry

With the inquiry activity at the following URL, students investigate how wave erosion and deposition can change the shape of coastlines. They model how waves cause longshore drift and how wave speed relates to deposition. They also model how groins and boulders placed at the foot of cliffs can slow down erosion.

http://www.earthlearningidea.com/PDF/73_Coastal_crumble.pdf

Overcoming Misconceptions

Students may erroneously think that wave erosion is a problem only along the shorelines of the oceans. Make sure students are aware that waves can also cause erosion along the shorelines of lakes. Very large lakes, such as the Great Lakes of North America, may have very high waves and serious wave erosion. For example, waves greater than 30 feet in height have been recorded in Lake Superior. Homes built close to a lake may be threatened by the continuous nibbling away of land along the shore by waves.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 10.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 10.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Name three structures that people build to try to prevent wave erosion. How well do they work?

- [Three structures that people build to try to prevent wave erosion include groins, breakwaters, and sea walls. Groins trap and hold sand that would otherwise be carried along the shore by longshore drift. Breakwaters act like natural barrier islands to block strong incoming waves before they strike the shore and cause erosion. Sea walls protect the beach behind them from erosion by strong waves.]

2. Name three natural landforms that are produced by wave erosion.

- [Three natural landforms that are produced by wave erosion include (any three): wave-cut cliffs, wave-cut platforms, sea arches, and/or sea stacks.]

3. What are the names of the parts of a waveform?

- [Parts of a waveform include the crest, trough, and wavelength.]

4. Describe the process that produces wave refraction.

- [Wave refraction is produced when waves approach the shore at some angle so the inshore part of the wave reaches shallow water sooner that the part that is farther offshore. The shallow part of the wave "feels" the bottom first. This slows down the inshore part of the wave and makes the wave "bend.']

5. If you were to visit a beach surrounded by coral reefs, what would the beach be made of?

- [The beach would be made mainly of pieces of coral, probably along with rock fragments, pieces of shell, and mineral grains like quartz.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What situations would increase the rate of erosion by waves?

- [Situations that would increase the rate of erosion by waves could include storms and building homes and other structures right on the beach.]

If barrier islands are nature's first line of defense against ocean storms, why do people build on them?

- [People may not realize how important barrier islands are in protecting shores from erosion. They may build on them in order to be as close to the ocean as possible.]

Could a seawall ever increase the amount of damage done by waves?

- [A seawall could increase the amount of damage done by waves if it leads people to build right up to the shoreline because they feel protected by the seawall. Then, if unusually high waves wash over the seawall, the damage done by the waves would be greater.]

10.4 Lesson 10.3: Wind Erosion and Deposition

Key Concepts

- Transport of particles by wind
- Wind erosion
- Wind deposition

Lesson Objectives

- Describe the ways particles are carried by wind.
- Discuss several ways that wind erosion changes land surfaces.
- Describe how sand dunes form.
- Describe the type of deposits formed by windborne silts and clays.

Lesson Vocabulary

- **deflation:** process in which wind erodes silt and clay, causing the ground surface to subside
- **desert pavement:** rocky, pebbled surface created when silt and clay are eroded from the surface of a desert by wind
- **desert varnish:** dark mineral coating that forms on exposed rock surfaces when windborne clay particles are deposited on them
- **loess:** type of deposit that forms when wind drops layers of silt and clay in nearly vertical cliffs
- **sand dune:** small hill of sand deposited by wind in a region with abundant sand and steady winds
- **slip face:** steeper, downwind side of a sand dune where grains of sand fall down from the crest of the dune because of gravity
- **ventifact:** polished, faceted stone formed through abrasion by windborne sand

Teaching Strategies

Introducing the Lesson

Introduce wind erosion with the short video on wind erosion of soil at the URL below. Tell students they will learn more about wind erosion when they read this lesson.

http://www.youtube.com/watch?v=PQmon7Rj6ns

Discussion

Discuss factors that result in the formation of the different types of sand dunes pictured in the link below. (You can share the figure with your students by making a transparency or copies to handout). The arrows in the sketch show the direction of the wind, which is one of the factors that determines dune type. The other factor is the amount of sand. Explain that transverse dunes form where there is a lot of sand, whereas barchans (small, crescent-shaped dunes) form where there is little sand. Transverse, parabolic, and longitudinal dunes form where wind blows steadily from a single direction. Over time, a transverse dune may change to a parabolic dune, which in turn may change to a longitudinal dune. Finally, a star-shaped dune forms where wind keeps changing from one direction to another.

http://www.uwgb.edu/dutchs/EarthSC202Notes/WINDeros.HTM

Differentiated Instruction

Have students make a Venn diagram comparing and contrasting the formation of a sand dune with the formation of loess. This will help them appreciate the role of particle size in deposition by wind.

Enrichment

Ask one or more interested students to create a Web page about the Dust Bowl, which has been called our nation's worst ecological disaster. It occurred during the 1930s in Oklahoma and neighboring states when huge amounts of precious topsoil were lost to wind erosion following a prolonged drought and mismanagement of soil by farmers. Students can learn more about the Dust Bowl at the first two URLs below. Other resources they might consider using for their Web page include a map of the Dust Bowl area and some of the iconic photos of the Dust Bowl, all of which can be found at the last URL below. Encourage other students in the class to visit the completed Web page.

- http://www.kshs.org/kansapedia/dust-bowl/12040
- http://drought.unl.edu/DroughtBasics/DustBowl.aspx
- http://www.weru.ksu.edu/new_weru/multimedia/dustbowl/dustbowlpics.html

Science Inquiry

Use the simple activity at the following URL to allow students to model how wind erodes sand. Students will also build different types of barriers to see which design is most effective in stopping erosion by the wind.

http://www.spacegrant.hawaii.edu/class_acts/Wind.html

Overcoming Misconceptions

A common misconception is that wind is the major agent of erosion in deserts. Ironically, flowing water is responsible for more erosion in deserts. Explain to students that when it rains in a desert, the runoff is very fast and often causes flash floods. With little or no vegetation, there are few if any plant roots to help hold the soil and sand in place and prevent erosion by the running water. Another common misconception about deserts is that they are mostly covered with sand dunes. Tell students that only about 10 percent of deserts are covered with sand dunes.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 10.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 10.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents. 1. Discuss suspended load and bed load transport by wind.

- [Suspended load transported by wind consists of very small particles of silt and clay. These particles may travel high above the ground, remain suspended for days, and be transported great distances. Bed load transported by wind consists of sand-sized particles, many of which move by saltation in short hops. These particles usually remain within a meter of the ground.]

2. Describe how desert pavement forms.

- [Desert pavement is a rocky, pebbled surface that forms when silt and clay are eroded from the surface by the wind.]

3. Discuss the factors necessary for sand dunes to form.

- [For sand dunes to form, there must be an abundant supply of sand and steady winds. Some type of obstacle is needed to slow down the wind so it drops its load of sand and begins to form a dune.]

4. Name four types of sand dunes that form in desert areas.

- [Four types of sand dunes that form in desert areas are crescent-shaped dunes, star-shaped dunes, parabolic dunes, and linear dunes.]

5. Name one type of wind deposition.

- [*Sample answer*: One type of wind deposition is loess. This type of deposit forms when wind drops layers of silt and clay in nearly vertical cliffs.]

6. Why is wind erosion more important in arid regions than humid areas?

- [Wind erosion is more important in arid regions than humid areas because dry soils are easier to pick up. In humid areas, in contrast, water and vegetation bind the soil so it is harder to pick up. Winds tend to be stronger in arid regions as well.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Would hurricane-force winds along a coastline produce wind-related erosion?

- [Yes; hurricane-force winds along a coastline would produce wind-related erosion. The wind could blow away sand and soil along the coastline. It also might blow over trees and other plants that help to hold soil in place, leading to even greater wind-related erosion.]

What would be needed to convert a desert area back to a productive region for farming?

- [Water and fertile soil would both be needed to convert a desert area back to a productive region for farming.]

Do you think wind could sculpt exposed rocks? Explain how this might happen.

- [Yes; wind could sculpt exposed rocks. Wind-blown sediments abrade the rocks and wears them away.]

10.5 Lesson 10.4: Glacial Erosion and Deposition

Key Concepts

- Formation and movement of glaciers
- Glacial erosion
- Glacial deposition

Lesson Objectives

- Discuss the different erosional features formed by alpine glaciers.
- Describe the processes by which glaciers change the underlying rocks.
- Discuss the particles deposited by glaciers as they advance and recede.
- Describe the landforms created by glacial deposits.

Lesson Vocabulary

- **alpine (valley) glacier:** mass of ice that flows downhill through a mountain valley
- **continental glacier:** mass of flowing ice that covers a large area and is not confined to a valley
- **end moraine:** ridge of glacial till deposited by a glacier where it paused while receding
- **glacial erratic:** large rock deposited by a glacier that is different from surrounding bedrock
- **glacial striation:** long, deep groove scratched in underlying bedrock by sediment carried on the bottom of a glacier
- **glacial till:** mixture of particles and rocks of different sizes deposited by a glacier
- **glacier:** large mass of flowing ice
- **ground moraine:** thick layer of sediment deposited under a glacier
- **hanging valley:** cliff formed where a large alpine glacier cut off the U-shaped valley of a tributary glacier
- **lateral moraine:** linear deposit of glacial till at the edge of an alpine glacier
- **medial moraine:** linear deposit of glacial till in the middle of an alpine glacier where lateral moraines of two tributary glaciers merge
- **moraine:** any linear deposit of unsorted sediments that have been dropped by a glacier
- **plucking:** process in which a glacier picks up sediments as it flows over the ground and the sediments freeze to the bottom of the glacier
- **terminal moraine:** ridge of glacial till deposited by a glacier at the farthest point it reached
- **varve:** paired layers of alternately finer and coarser sediments deposited in a glacial lake and representing an annual cycle

Teaching Strategies

Introducing the Lesson

Introduce glaciers by having students do the interactive activity at the URL below. This activity provides a comprehensive introduction to glaciers. By exploring the different sections, students will learn where and why glaciers form, what influences their growth and decline, and how an apparently solid mass of ice can flow like a river.

http://www.teachersdomain.org/resource/ess05.sci.ess.earthsys.glaciers/

Activity

Students will have a more detailed understanding of how a glacier forms and melts if they do the interactive "Life Cycle of a Glacier" at the following URL.

http://www.pbs.org/wgbh/nova/vinson/glacier.html

Differentiated Instruction

Have students make a flow chart to show how a snowflake that falls on a glacier becomes part of the ice of the glacier, is transported by the glacier, and ultimately melts to become part of glacial meltwater. Suggest that they add sketches to illustrate their flow chart.

Enrichment

Ask students to predict how global warming is affecting glaciers around the world. Then have a few students find photos of the same glaciers at different time periods over the past several decades to see how they have changed as global temperature has increased. Ask the students to prepare a display with the photos and explain them to the rest of the class.

Science Inquiry

When you teach this lesson, use the gold-star glacier simulation activity at the URL below. In the activity, students will use a simulation program to determine factors that affect the motion of glaciers, calculate the speed of glacier movement, and discover what a glacier budget means for the growth and destruction of a glacier.

http://phet.colorado.edu/en/contributions/view/3133

Overcoming Misconceptions

Students commonly have the misconception that a melting glacier "retreats," or reverses direction. Explain that a glacier can only move downhill because of gravity. When a glacier recedes, it continues to move in the same direction, but its leading edge melts, giving it the appearance of moving in the opposite direction.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 10.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 10.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. How much of Earth's land surface is covered by glaciers today? Where are they found?

- [About 10 percent of Earth's land surface is covered by glaciers today. They are found near Earth's poles and in high mountains.]

2. What are the two types of glaciers and how are they different from each other?

- [The two types of glaciers are alpine (valley) and continental glaciers. Alpine glaciers flow downhill through mountain river valleys, whereas continental glaciers cover large areas, even entire continents, and are not confined to valleys.]

3. What is the shape of a valley that has been eroded by a river? How does a glacier change that shape and what does it become?

- [A mountain river valley is V-shaped. A glacier changes the shape of a river valley by erosion to a U-shaped valley with nearly vertical sides.]

4. What two different features form as smaller side glaciers join the central main glacier?

- [As smaller side glaciers join a central main glacier, they form hanging walls, where the main glacier cuts off the valleys of the side glaciers and creates cliffs. They also form medial moraines, where the lateral moraines of the two side glaciers join together in the middle of the main glacier.]

5. How do glaciers erode the surrounding rocks?

- [Glaciers erode surrounding rocks in two main ways: plucking and abrasion. Plucking occurs when a glacier flows over rocks and the rocks freeze to the bottom of the glacier. Abrasion occurs when rocks and other sediments embedded in the bottom of a glacier scrape over underlying bedrock. They may leave long, parallel grooves in the bedrock, called glacial striations.]

6. Name the erosional features that are formed by glaciers high in the mountains and describe how they form.

- [Erosional features formed by glaciers high in the mountains include U-shaped valleys, hanging valleys, cirques, tarns, arêtes, and horns. When a glacier cuts through a V-shaped river valley, it plucks rocks from the sides and bottom. This widens the valley and steepens the walls, changing it to a U-shaped valley. A hanging valley forms where a main glacier cuts off a tributary glacier and creates a cliff. A cirque is a bowl-shaped feature scooped out of the side of a mountain by an alpine glacier. A tarn is a lake that forms from meltwater trapped in a cirque. An arête is a sharp-edged ridge that forms when two alpine glaciers move down opposite sides of a mountain from the peak. A horn is a sharp-sided point that forms when several alpine glaciers move down all sides of a mountain from the peak.]

7. Describe the different types of moraines formed by glaciers.

- [Moraines are linear deposits of glacial till. Lateral moraines form at the edges of a glacier from material that drops onto the glacier from the erosion of valley walls. A medial moraine forms where the lateral moraines of two tributary glaciers join together in the middle of a larger glacier. Ground moraine forms when sediments on the bottom of a glacier are deposited. A terminal moraine is a long ridge of till left at the farthest point that a glacier reached. An end moraine is deposited where a glacier stopped long enough to create a rocky ridge as it retreated.]

8. Describe the difference between glacial till and stratified drift. Give an example of how each type of deposit forms.

- [Glacial till is an unsorted deposit of sediments and rocks of all sizes. Stratified drift is a sorted deposit of sand and smaller particles. Glacial till forms when the ice of a glacier melts and drops the sediments and rocks it was carrying. When glacial meltwater moves through unsorted glacial till, it picks up the smaller sediments and leaves behind the larger particles. When the water deposits the smaller sediments, it forms a stratified drift.]

9. Name and describe the two asymmetrical hill-shaped landforms created by glaciers.

- [The two asymmetrical hill-shaped landforms created by glaciers are eskers and drumlins. An esker is a winding ridge of sand and gravel deposited under a glacier by a stream of meltwater. A drumlin is an asymmetrical hill made of sediments that points in the direction the ice moved.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What features would you look for to determine if glaciers had ever been present?

- [Features you would look for include erosional and depositional features created by glaciers. Erosional features might include glacial striations on rocks and U-shaped valleys in mountains. Depositional features might include glacial erratics and drumlins.]

If glaciers had never formed, how would soil in Midwestern North America be different?

- [If glaciers had never formed, the soil in Midwestern North America would not be as fertile because it has been enhanced by glacial deposition. Some of the soil was deposited directly by glaciers as glacial till. Some was deposited as loess by winds that transported sorted glacial drift.]

Can the process of erosion produce landforms that are beautiful?

- [Yes, it can. For example, erosion by wind in dry regions can produce beautiful "sculptures" from rocks.]

10.6 Lesson 10.5: Erosion and Deposition by Gravity

Key Concepts

- Types of movement caused by gravity
- Landslides and avalanches
- Mudflows and lahars
- Slump and creep
- Factors contributing to mass movement

Lesson Objectives

- Describe the ways that material can move downhill by gravity.
- Discuss the factors that increase the likelihood of landslides.
- Describe the different types of gravity-driven movement of rock and soil.
- Describe ways to prevent and be aware of potential landslides or mudflows.

Lesson Vocabulary

- **avalanche:** sudden movement of a mass of snow down a slope due to gravity
- **creep:** extremely slow movement of rock and soil downhill because of gravity
- **landslide:** rapid movement of soil, loose rock, and debris downhill under the influence of gravity
- **mass movement:** any erosion in which soil, rock, debris, and/or mud move down a slope due to gravity; also called mass wasting
- **mass wasting:** any erosion in which soil, rock, debris, and/or mud move down a slope due to gravity; also called mass movement
- **mudflow:** movement of saturated, slippery soil downhill under the influence of gravity
- **slump:** movement of a large block of rock and soil as a single unit down a slope due to gravity
- **talus slope:** pile of angular rock fragments that have fallen down a cliff because of gravity and accumulated at the bottom

Teaching Strategies

Introducing the Lesson

Introduce mass movement with the 11-minute trailer for the USGS video "Riding the Storm: Landslide Danger in the San Francisco Bay Area" (see URL below). The trailer shows the incredible destruction that can be caused by a landslide from the point of view of people who have experienced one. It also explains why landslides are common in the San Francisco Bay area. Tell students they will learn more about landslides in this lesson.

http://pubs.usgs.gov/gip/2007/48/

Discussion

Discuss how gravity compares with other agents of erosion and deposition. For example, gravity can move materials only down a slope; and certain other conditions, such as saturated soil or an earthquake, may also be needed for mass movement to occur. On the other hand, gravity can move materials more quickly than other agents of erosion. In fact, gravity can move tons of material in a few seconds. For running water or wind to move that much material might take millions of years.

Differentiated Instruction

Pair students with differing abilities and have partners make a cluster diagram for mass movement. The center circle should be labeled "mass movement" and include a definition of the term. The surrounding circles should be labeled with the different types of mass movement and include brief descriptions of each type.

Enrichment

Ask interested students to learn more about avalanches, such as what factors suggest that an avalanche is likely to occur and what snow enthusiasts can do to avoid avalanches. Suggest that they start with the URLs below. Have them share what they learn with the rest of the class in a PowerPoint presentation.

- http://www.pbs.org/wgbh/nova/avalanche/textindex.html
- http://www.avalanche.org/tutorial/tutorial.html
- http://www.pbs.org/wnet/savageplanet/04extremes/01avalanche/indexmid.html

Science Inquiry

Have students explore the "Landslide Overview Map of the Coterminous United States" at the URL below. Tell them to identify where in the United States the risk of landslides is greatest. Then challenge students to explain what physical features of these areas predispose these areas to landslides.

http://landslides.usgs.gov/learning/nationalmap/

Real-World Connection

Tell students that landslides and mudflows can do billions of dollars' worth of damage but the costs are difficult to estimate because there are both direct and indirect costs. Direct costs include damage to structures and roads. Indirect costs include decreased property values, lost productivity, and the cost of driving longer distances because roads are blocked.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 10.5 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 10.5 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe three ways that gravity moves materials.

   - [*Sample answer*: Three ways that gravity moves materials are landslides, mudflows, and creep. Landslides are sudden falls of rocks and other materials downhill because of gravity. They are generally very destructive and may bury entire villages. Mudflows are the movement of wet soils rich in clay downhill because of gravity. Mudflows follow river channels and may wash out bridges, trees, and homes that are in their path. Creep is the extremely gradual movement of rock and soil downhill due to gravity. Creep causes tree trunks to bend and power poles to tilt downhill.]

2. What natural events and human actions can trigger a landslide or avalanche?

   - [Natural events that can trigger a landslide or avalanche include earthquakes and volcanic eruptions because they shake the ground. A landslide may also be triggered by heavy rains that saturate the soil, especially if the soil is high in clay so it becomes slippery when wet. Human actions that can trigger a landslide include undercutting a hillside to create roads or building sites. Blasting or heavy trucks may shake the ground and trigger a landslide or avalanche. Skiers or hikers who disturb the snow they travel over may also set off an avalanche.]

3. What makes landslides and avalanches move at such great speeds?

   - [Landslides and avalanches move at such great speeds because air becomes trapped and compressed under the falling material and keeps it from slowing down. As a result, landslides and avalanches can move as fast as 200 to 300 km/hour.]

4. Compare and contrast a mudflow and a lahar.

   - [Both a mudflow and a lahar are the movement of mud or other fluid material down a slope because of gravity. A mudflow occurs when clay-rich soil becomes saturated by rain and flows downhill through a river channel. A lahar occurs when a composite volcano erupts, ash melts snow and ice, and the resulting material flows down the side of the volcano.]

5. Name two ways that soil can move slowly down a slope.

   - [Two ways that soil can move slowly down a slope are slump and creep.]

6. What can people do to help prevent landslides or mudflows?

   - [To help prevent landslides or mudflows, people can avoid undercutting slopes. If slopes must be cut into, they can be stabilized to help prevent a landslide or mudflow. For example, slopes can be planted with trees and other vegetation to hold the soil in place. Providing drainage so the slope does not become saturated with water may also help prevent these forms of mass movement.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.5 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why might someone build a home on top of land where a landslide has happened before?

- [Someone might build a home on land where a landslide has already occurred because it is located on a high hill that provides a good view of the surrounding landscape. They also might not realize that the location is at risk for landslides to occur again.]

What factors make it likely or unlikely that a landslide could happen in your area?

- [Answers may vary. A landslide might be likely in an area that has steep slopes, a dry climate with periodic heavy rains, soil rich in clay, and a risk of earthquakes or volcanoes. An area without any of these factors might be unlikely to experience a landslide.]

What new technologies might help people to know when a landslide will occur?

- [*Sample answer*: Technologies that might help people know when a landslide will occur are devices that measure changes in soil moisture and devices that can detect when an earthquake is likely to occur.]

CHAPTER 11 HS TE Evidence About Earth's Past

Chapter Outline

11.1 Chapter 11: Evidence about Earth's Past

Chapter Overview

This chapter explains ways that fossils form and the methods of relative and absolute dating of rocks.

Online Resources

See the following Web sites for appropriate laboratory activities:

The lab at the following URL guides students through an inquiry-based study of absolute and relative dating methods. In the lab, students are asked to interpret an archaeological site and decide on appropriate dating methods. They will apply knowledge in a way that is similar to how scientists approach the dating of sites.

- http://gk12.asu.edu/absoluteandrelativedating

Another lab on relative and absolute dating is available in the PDF document below. It is a two-part lab titled "It's Not Your Average Friday Night; Relative and Absolute Dating of Geological Materials" (Lesson #4, pages 15–18). In the lab, students will gain an understanding of the differences between relative and absolute dating techniques and how they may be used in Carlsbad Caverns National Park or a local national park.

- http://www.nps.gov/cave/forteachers/upload/geology_curriculum_high_school_pdf.pdf

In the gold-star simulation lab at the following URL, students will identify isotopes that are commonly used to determine how old matter might be. They will also be able to explain how radiometric dating works and why different elements are used for dating different objects. They will use the percent of an isotope measured in an object to estimate its age.

- http://phet.colorado.edu/en/contributions/view/3636

These Web sites may also be helpful:

This highly recommended Web site has detailed descriptions of different types of fossils and how they form.

- http://www.ucmp.berkeley.edu/paleo/fossils/

At the URL below, you can find detailed information about fossilization that goes beyond lesson content.

- http://www.fossilmuseum.net/fossilrecord/fossilization/fossilization.htm

This Web site is all about fossils. It includes fossil lesson plans, activities, articles, and extreme fossil facts.

- http://www.fossils-facts-and-finds.com/

You can find a fossil image gallery at this URL: http://www.fossilmuseum.net/FossilGalleries.htm.

For more in-depth coverage of methods of dating fossils and rocks, go to this URL: http://paleobiology.si.edu/geotime/main/foundation_dating1.html.

At the following URL, you can find a much more detailed geologic time scale.

- http://paleobiology.si.edu/geotime/main/pdf/timescale_isc_american.pdf

Pacing the Lessons

TABLE 11.1: short caption

Lesson	Class Period(s) (60 min)
11.1 Fossils	2.0
11.2 Relative Ages of Rocks	2.5
11.3 Absolute Ages of Rocks	1.5

11.2 Lesson 11.1: Fossils

Key Concepts

- How fossils form
- Types of fossils
- Clues from fossils

Lesson Objectives

- Explain why it is rare for an organism to be preserved as a fossil.
- Distinguish between body fossils and trace fossils.
- Describe five types of fossilization.
- Explain the importance of index fossils, and give several examples.

Lesson Vocabulary

- **amber:** fossilized tree sap
- **body fossil:** fossilized remains of a long-dead organism
- **cast:** mold filled with sediment that has hardened to create a replica of the original fossil
- **fossilization:** any process by which remains or traces of once-living organisms become fossils
- **index fossil:** fossil of a species that was widespread but short-lived and can be used to determine the age of rock layers in different places
- **microfossil:** fossil that is so small that it must be observed with the aid of a microscope
- **mold:** impression made in sediments by the hard parts of an organism
- **permineralization:** fossilization process in which water deposits minerals into empty spaces in the remains of a dead organism
- **trace fossil:** evidence of the activity of an ancient organism, such as tracks, burrows, or feces

Teaching Strategies

Introducing the Lesson

Tell the class that on a recent hike in high mountains, a hiker found fossil shells of a marine organism embedded in a massive rock. Challenge students to explain the situation. Accept all reasonable responses at this point, and tell students they will learn the correct explanation when they read this lesson.

Activity

With level 2 of the interactive activity at the URL below, students will gain a basic understanding of what a fossil is and how fossilization occurs. The URL includes a suggested lesson plan, classroom handouts, and assessments.

http://www.ucmp.berkeley.edu/education/explorations/tours/fossil/index.html

Collaborative Learning

Divide the class into five groups and assign each group one of the types of fossilization described in the lesson: preserved remains, permineralization, molds and casts, replacement, or compression. Students in each group should work together to learn more about their assigned type of fossilization, including where fossils formed this way have been found and the conditions under which this type of fossilization occurs. Students should prepare a 5–10 minute presentation about their type of fossilization. During the presentations, other students in the class should take notes.

Differentiated Instruction

Have students make a cluster diagram for different types of fossilization. A central circle should be labeled "Fossilization" and include a general definition of the term. Five surrounding circles should each be labeled with one of the five types of fossilization covered in the lesson, with definitions or brief descriptions of each type.

Enrichment

Ask a small group of students to create a Jeopardy-style game for the whole class to play based on the content of this lesson. At the URL below, students can learn how to create a Jeopardy-style game using PowerPoint. Schedule time for the students to lead the class in playing the game.

http://www.joe.org/joe/2003april/tt2.php

Science Inquiry

In the activity at the following URL, students take part in an imaginary fossil hunt. Following a script read by the teacher, students "find" (remove from an envelope) paper "fossils" of some unknown creature, only a few at a time. Each time they find new fossils, they must attempt to reconstruct the creature, and their interpretation will keep changing as new pieces are "found." From the activity, students will realize that science is uncertain; as new evidence is revealed, ideas may change.

[http://www.indiana.edu/ ensiweb/lessons/gr.fs.fd.html http://www.indiana.edu/ ensiweb/lessons/gr.fs.fd.html

Overcoming Misconceptions

Because the chances of an individual organism becoming a fossil are very small, students may hold the misconception that fossils are very rare. Make sure they realize that billions of fossils have been found and that the fossil record is actually very rich. You may want to share the following facts with your class (http://www.redundancydept.com/fiction.htm).

- A half-mile layer of rock in Wyoming contains some 12 billion fish fossils.
- Under each square mile of soil in Nebraska, there are an estimated 3000 mammoth fossils.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 11.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 11.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What factors make it more likely that an animal will be preserved as a fossil?

- [Factors that increase the chances that an animal will be preserved as a fossil include the presence of hard parts such as teeth, bones, or shells; and quick burial, which is more common for marine than land animals.]

2. What are the five main processes of fossilization?

- [The five main processes of fossilization are complete preservation (as in amber or ice), permineralization, the formation of molds and casts, replacement, and compression.]

3. A scientist wants to determine the age of a rock. The rock contains an index fossil and an ancient relative of a living organism. Which is more useful for dating the rock, and why?

- [The index fossil is more useful for dating the rock. Index fossils come from organisms that lived for a relatively short period of time but were very widespread. If you find a rock with an index fossil, then the rock must have formed during the short period of time that the animal existed. In contrast, the ancestor of a living organism may have existed for a very long period of time, so it might not provide any clues about the age of the rock.]

4. The island of Spitzbergen is in the Arctic Ocean near the North Pole. Fossils of tropical fruits have been found in coal deposits in Spitzbergen. What does this indicate?

- [The finding of fossils of tropical fruits in the Arctic indicates that the climate of Spitzbergen must have been much warmer when the coal formed. This could be because Spitzbergen was once located in the tropics or because Earth's overall climate was much warmer at that time]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What are some other examples of mythical creatures that may be based on fossils?

- [Some other examples of mythical creatures that may be based on fossils include unicorns and mermaids.]

Why is it so rare for an animal to be preserved as a fossil?

- [It is so rare for an animal to be preserved as a fossil because most remains are consumed, scattered, or weathered before they can be buried by sediments and preserved as fossils.]

Some organisms are more easily preserved than others. Why is this a problem for scientists who are studying ancient ecosystems?

- [The fact that some organisms are more easily preserved than others is a problem because it gives a biased picture of ancient ecosystems. Some organisms may be represented in relatively great numbers while other organisms may not be represented at all.]

Why are examples of amazing fossil preservation so valuable for scientists?

- [Examples of amazing fossil preservation are so valuable for scientists because they include soft tissues and other parts that are not normally preserved, such as skin, hair, and organs. Some organisms are so well preserved that scientists can even study their DNA.]

Many fossils of marine organisms have been found in the middle of continents, far from any ocean. What conclusion can you draw from this?

- [From fossils of marine organisms found in the middle of continents, you can draw the conclusion that the region where the fossils were found was once the floor of an ancient sea.]

11.3 Lesson 11.2: Relative Ages of Rocks

Key Concepts

- Steno's laws of superposition, original horizontality, and lateral continuity
- Smith's principle of faunal succession
- Hutton's principles of cross-cutting relationships, uniformitarianism, and unconformity
- Determining the relative ages of rocks
- Matching up rock layers in different places
- The geologic time scale

Lesson Objectives

- Explain Steno's laws of superposition and original horizontality.
- Based on a geological cross-section, identify the oldest and youngest formations.
- Explain what an unconformity represents.
- Know how to use fossils to correlate rock layers.

Lesson Vocabulary

- **biozone:** rock unit that is defined by a characteristic index fossil or fossil assemblage
- **cross-cutting relationships:** principle stating that an intrusion or fault is younger than the rocks across which it cuts
- **geologic time scale:** division of Earth's history into blocks of time distinguished by major geologic and evolutionary events
- **key bed:** thin rock layer that is unique and widespread so it can be used to match rock layers by age in different areas
- **lateral continuity:** principle that sedimentary tock layers extend as wide as the basin in which they form
- **microfossil:** fossil that is so small that it must be observed with the aid of a microscope
- **original horizontality:** principle that the sediments that form sedimentary rocks are deposited in horizontal layers
- **relative age:** the age of an object (younger or older) in comparison with the ages of other objects
- **superposition:** law stating that younger layers of sedimentary rock are deposited on top of older layers of sedimentary rock
- **unconformity:** gap in a sequence of rock layers
- **uniformitarianism:** principle that natural processes have operated in the same way throughout Earth's history as they do today

Teaching Strategies

Introducing the Lesson

Introduce stratigraphy as the basis of relative dating by asking students to recall what they already know about sedimentary rocks. For example, ask them to explain how sedimentary rocks differ from other types of rocks and how sedimentary rocks form. Tell students that this knowledge will help them understand how scientists know which fossils or rock layers are older or younger than others.

Building Science Skills

The activity below is a great way to introduce relative dating. Students will work to decide the sequence in which certain events occurred, using their powers of observation and logic. Pairs of students will be given a block of wood that has been painted, nailed, and gouged. Then then they will be instructed to deduce the order of events and to justify their answers. Relate the activity to the process in which rock layers are assigned relative ages.

http://serc.carleton.edu/sp/mnstep/activities/35609.html

Activity

Have students explore geologic time with the interactive time scale at the following URL. The time scale shows geologic subdivisions of time to scale so students can easily see their relative lengths. They can also click on specific blocks of geologic time to see them in greater detail and read about their major evolutionary events.

http://www2.nature.nps.gov/geology/usgsnps/gtime/gtime2.html

Differentiated Instruction

Give kinesthetic learners and students with limited English proficiency hands-on experience creating "sedimentary rock layers" and "fossils." Provide them with a clear glass jar, samples of different colors of sand or other similar materials (e.g., colored sugar), and small plastic animals to represent fossils. Then have students use the materials to make a multi-layered "sedimentary rock" containing "fossils" at different layers. Discuss how the activity relates to the actual formation of sedimentary rocks and fossils.

Enrichment

Challenge students to relate the significance of uniformitarianism to Darwin's development of evolutionary theory. They should express their ideas in a concise paragraph. (For more information, suggest that they start with the URL below.) Ask each student to read his or her paragraph to the class. Then hold a general discussion of how advances in one area of science often lead to new developments in other areas of science, as this example illustrates.

http://evolution.berkeley.edu/evolibrary/article/history_12

Science Inquiry

With the inquiry activity "Who's on First?" at the URL below, students will sequence information using items that overlap specific sets. They will also relate sequencing to the law of superposition and show how fossils can be used to give relative dates to rock layers.

http://www.ucmp.berkeley.edu/fosrec/BarBar.html#topbar

History Connection

Understanding how scientific knowledge accumulates and develops helps students understand the nature of the scientific endeavor. Suggest that they learn how and why the geologic time scale was developed. The two URLs below are good sources for this purpose.

http://www.ucmp.berkeley.edu/exhibit/histgeoscale.html

http://www2.nature.nps.gov/geology/usgsnps/gtime/gtime1.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 11.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

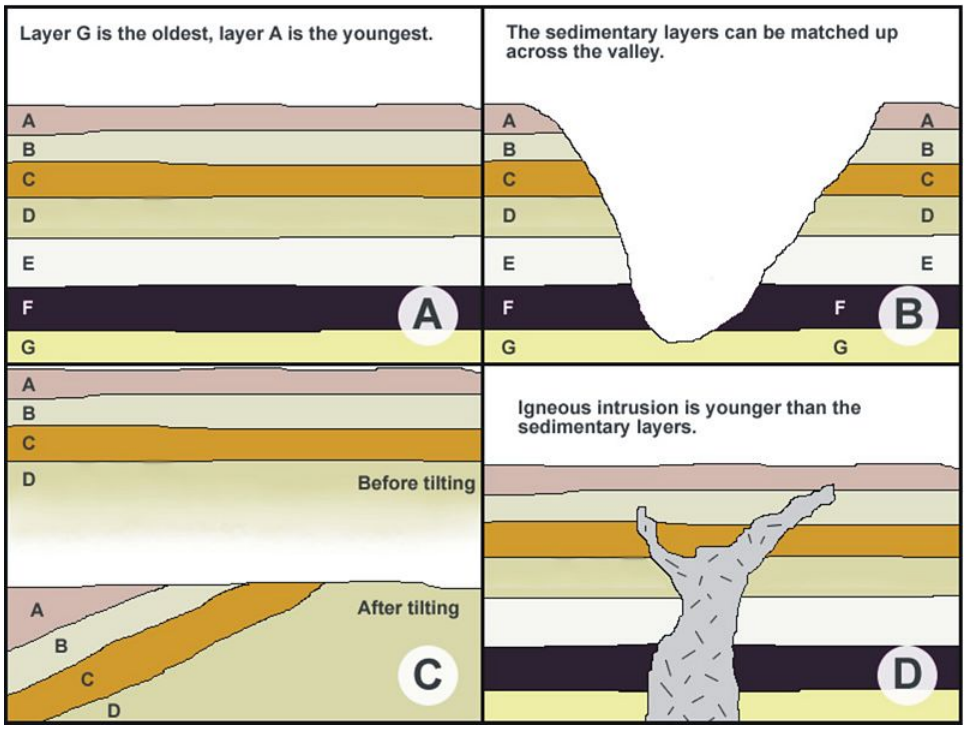
Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 11.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. A 15th century farmer finds a rock that looks exactly like a clamshell. What did he likely conclude about how the fossil got there?

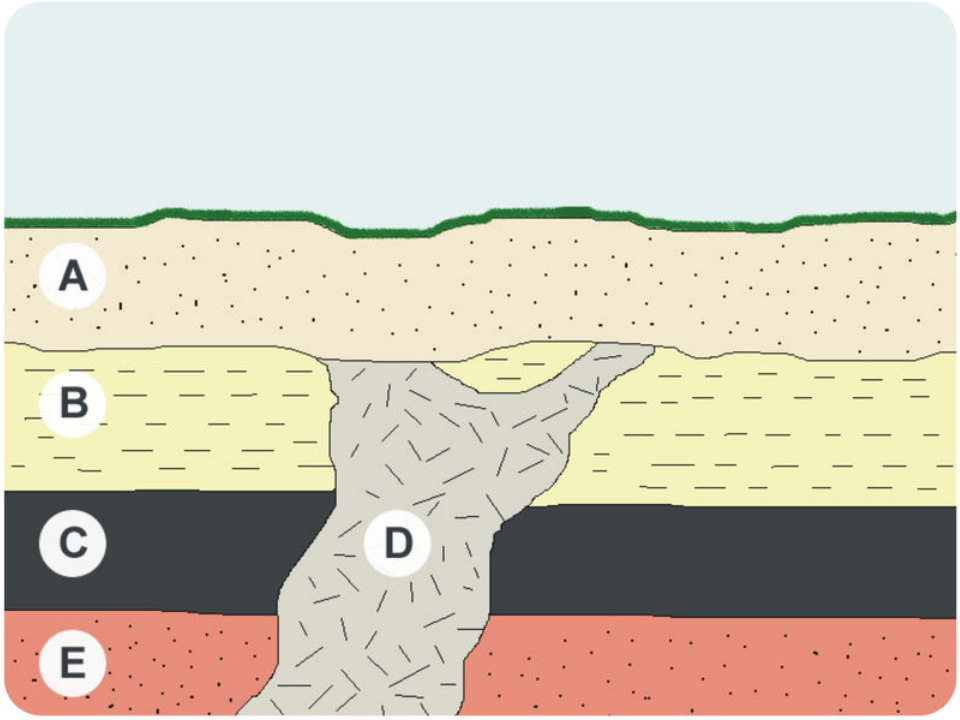
- [Answers will vary. Prior to Nicholas Steno, people believed either that fossils were thrown up on the land by Noah's flood or that they formed within the rocks themselves and never were parts of living organisms.]

2. Which of Steno's Laws is illustrated by each of the images in the figure below?



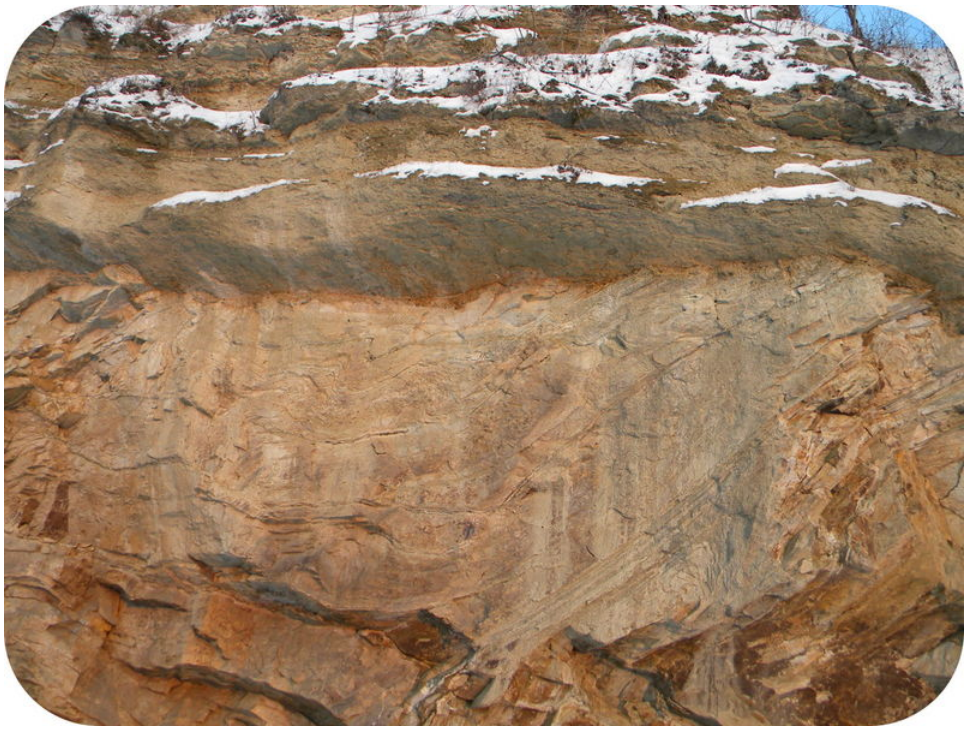
- [Image A illustrates the law of superposition; the youngest layers are at the top of the sequence, and the oldest layers are at the bottom. Image B illustrates the law of lateral continuity; the rock layers continue on the other side of the valley because they were originally deposited in large flat sheets. Image C illustrates the law of original horizontality; tilted sedimentary rocks were originally deposited in flat layers and were tilted later. Image D illustrates the law of cross-cutting relationships; the intrusion cuts through the sedimentary layers, so it must be younger than the sedimentary rocks.]

3. What is the sequence of rock units in the figure below, from oldest to youngest?



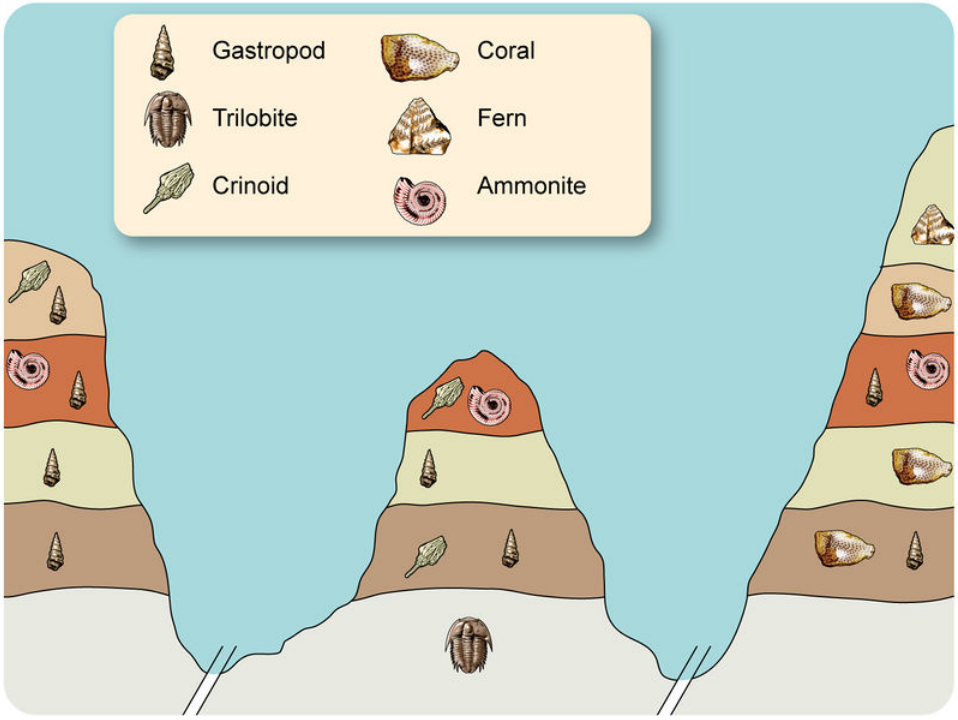
- [From oldest to youngest, the sequence of rock units is E, C, B, D, and A. Layer A lies on top of an erosional surface that cuts through intrusion D, so A is younger than D. Intrusion D cuts through layers B, C, and E, so D is younger than B, C, and D. Of the remaining three layers, B is youngest because it is on top, and E is oldest because it is on the bottom.]

4. What kind of geological formation is shown in the outcrop in the figure below, and what sequence of events does it represent?



- [The figure shows an unconformity. The layers at the bottom were deposited, hardened into a rock, uplifted, and then eroded. After that, water covered the region and new sedimentary layers were deposited on top. This was followed by another episode of uplift and erosion.]

5. The three outcrops in the figure below are very far apart. Based on what you see, which fossil is an index fossil, and why?



- [Based on this diagram, the ammonite fossil is an index fossil. An index fossil is a fossil that is widespread but appears for a relatively short period of time. There are two fossils that appear in all three outcrops,

the gastropod and the ammonite. The ammonite only appears in one rock layer in each outcrop, while the gastropod appears in many layers in each outcrop. Therefore the ammonite best fits the definition of an index fossil.]

6. Why didn't the early geologic time scale include the number of years ago that events happened?

- [The early geologic time scale did not include the number of years ago that events happened because the early scale was created before the discovery of radioactivity. Knowledge of radioactive isotopes allowed scientists to determine the ages of rocks in years with radiometric dating.]

7. Dinosaurs went extinct about 66 million years ago. Which period of geologic time was the last in which dinosaurs lived?

- [The last period of geologic time in which dinosaurs lived was the Cretaceous period.]

8. Suppose that while you're hiking in the mountains of Utah, you find a fossil of an animal that lived on the ocean floor. You learn that the fossil is from the Mississippian period. What was the environment like during the Mississippian in Utah?

- [During the Mississippian period in Utah, the land must have been covered by a sea. The mountains formed later when the seafloor was uplifted.]

9. Why are sedimentary rocks more useful than metamorphic or igneous rocks in establishing the relative ages of rock?

- [Sedimentary rocks are more useful than other types of rocks in establishing the relative ages of rocks because they are always laid down in horizontal layers with newer rocks on top of older rocks. Any fossils in metamorphic rocks would be likely to be destroyed by heat or pressure. Fossils would almost never be found in an igneous rock, because they form from molten magma or lava. Very few organisms would be trapped there, and any that were trapped would likely be destroyed.]

10. Which is likely to be more frequently found in rocks: fossils of very old sea creatures or very old land creatures?

- [Fossils of very old land creatures are likely to be more common because oceanic crust is constantly subducted. Therefore, oceanic crust is likely to be destroyed along with any ancient sea fossils.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How did preconceived ideas in Steno's time make people blind to the reality of what fossils represent?

- [Most people in Steno's time turned to supernatural forces to explain fossils. For example, fossil shells found in mountains were thought to have been washed up during the Biblical flood. Fossils found deep within rocks were thought to have formed as a result of mysterious forces. These preconceived ideas prevented people from realizing that fossils were once part of living creatures and were formed by natural processes.]

How did Steno explain the presence of marine fossils in high mountains?

- [Steno thought that marine fossils in high mountains were originally deposited on the bed of an ancient sea that was later uplifted to form mountains.]

Why was Hutton's recognition of unconformities so significant?

- [Hutton's recognition of unconformities was so significant because it demonstrated that the age of Earth must be far greater than the 6000 years people of his time accepted as Earth's age.]

Can the relative ages of two rock layers that are very far apart be determined?

- [Yes; the relative ages can be determined if there are distinctive and extensive rock formations, index fossils, or key beds in the two rock layers.]

Can the same principles used to study Earth's history also be used to study the history of other planets?

- [Yes; principles such as uniformitarianism and superposition should apply to other planets as well and help scientists understand their history.]

11.4 Lesson 11.3: Absolute Ages of Rocks

Key Concepts

- Tree ring dating
- Ice cores and varves
- Radioactive decay
- Radiometric dating of rocks
- Age of Earth

Lesson Objectives

- Define the differences between absolute age and relative age.
- Describe four methods of absolute dating.
- Explain what radioactivity is and give examples of radioactive decay.
- Explain how the decay of radioactive materials helps to establish the age of an object.
- Estimate the age of an object, given the half-life and the amounts of radioactive and daughter materials.
- Give four examples of radioactive materials that are used to date objects, and explain how each is used.
- Describe how scientists know Earth is billions of years old.

Lesson Vocabulary

- **absolute age:** actual age of a rock or fossil in years
- **daughter product:** product of the radioactive decay of a parent isotope
- **half-life:** rate of decay of a radioactive isotope, equal to the time it takes for half of an original amount of the parent isotope to decay to the daughter product
- **ice core:** cylinder of ice extracted from a glacier or ice sheet
- **parent isotope:** unstable isotope that undergoes radioactive decay to form a daughter product
- **radioactive isotope:** isotope that is unstable and likely to decay into another, more stable isotope
- **radioactivity:** emission of high-energy particles by unstable isotopes
- **radiometric dating:** use of the concentrations of radioactive parent isotopes and daughter products to estimate the absolute age of a fossil or rock
- **tree ring:** ring of wood in a tree trunk that corresponds to one year of tree growth

Teaching Strategies

Introducing the Lesson

Display a timeline of horse evolution, such as the timeline at the URL below. Point out the ages in years that different horse ancestors lived. Ask students how they think the ages were determined. Accept all reasonable responses at this point, and tell students they will learn how ages are assigned to fossils and rocks when they read this lesson.

http://vcbequine.webstarts.com/all_about_horses.html

Using Visuals

Refer students to the images in the FlexBook® lesson that show tree rings, ice core layers, and varve sediments. Point out and explain the alternating light and dark bands in each object.

Question: How are these three objects similar?
Answer: All three provide an annual record of the past that can be used to determine their age in years.

Differentiated Instruction

Have students make a table comparing and contrasting the different methods of radiometric dating described in the lesson. Their table should include an example of a rock or fossil that might be dated with each method.

Enrichment

Use the AP-level activity at the URL below for students who need enrichment. It is a virtual lab in which students determine half-lives and absolute ages of rock samples. When students have finished the simulation, they can print a "Certificate of Completion as a Virtual Geochronologist." The lab is well suited for small groups of students working together.

http://www.sciencecourseware.com/VirtualDating/

Science Inquiry

Use the simple inquiry activity below so students can model the half-life of a radioactive element. This will give them a better understanding of the principles behind radiometric dating techniques.

http://evolution.about.com/od/teaching/a/Modeling-Half-Life-Lab.htm

Overcoming Misconceptions

Students may think that radiometric dating can be applied to any rock, including the sedimentary rock layers where most fossils are found. Explain that most sedimentary rocks cannot be dated with radiometric techniques because sedimentary rocks are composed of particles of pre-existing rock of various types and the particles can have different ages.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 11.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

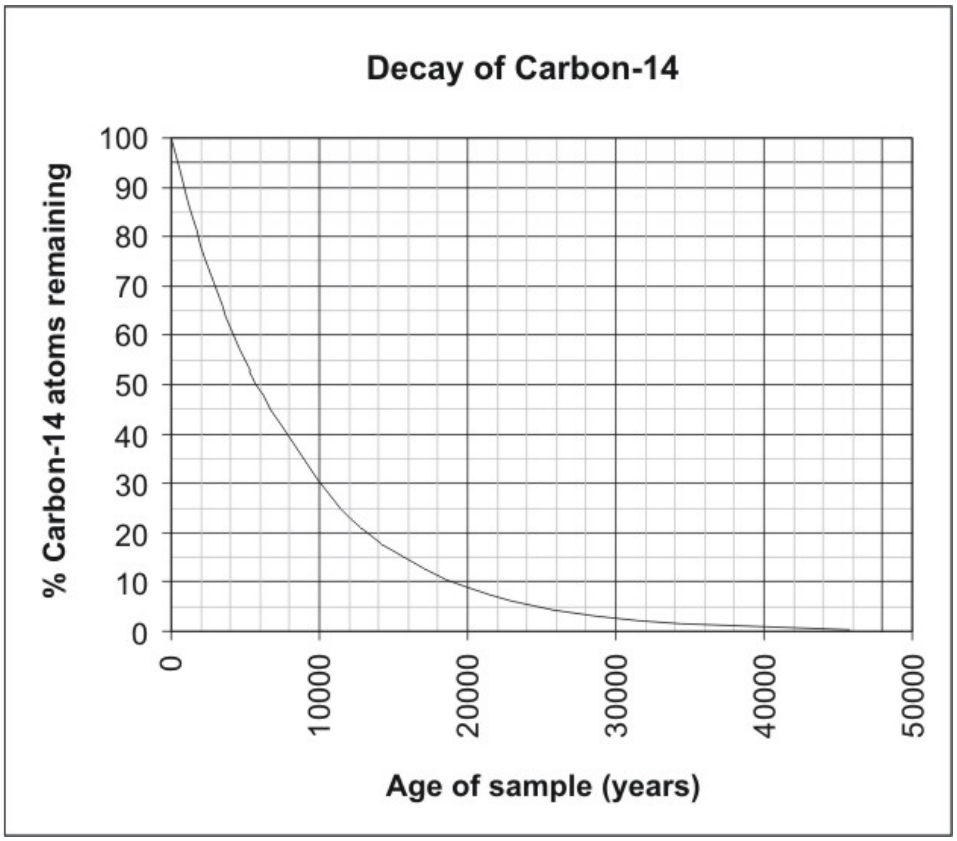
Have students answer the Review Questions at the end of Lesson 11.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents. 1. Name four techniques that are used to determine the absolute age of an object or event.

- [Four techniques that are used to determine the absolute age of an object or event are tree ring dating, ice cores, varves, and radiometric dating.]

2. A radioactive substance has a half-life of 5 million years. What is the age of a rock in which 25 percent of the original radioactive atoms remain?

- [The age of the rock is 10 million years. After one half-life (5 million years), 50 percent of the original radioactive atoms would remain. After two half-lives (10 million years), 25 percent of the original radioactive atoms would remain.]

3. A scientist is studying a piece of cloth from an ancient burial site. She determines that 40 percent of the original carbon-14 atoms remain in the cloth. Based on the carbon-decay graph (see figure below), what is the approximate age of the cloth?



- [The cloth is approximately 8000 years old. To use the graph, read across from 40%, and then read down to the age of the sample. Each tick mark on the x-axis represents 2000 years, so four tick marks represent 8000 years.]

4. Which radioactive isotope or isotopes would you use to date each of the following objects? Explain each of your choices.

1.) A 4-billion-year-old piece of granite.

2.) A 1-million-year-old bed of volcanic ash that contains the footprints of human ancestors.
3.) The fur of a woolly mammoth that was recently recovered, frozen in a glacier.

4.) A fossilized trilobite from a bed of sandstone that is about 500 million years old.

- [1.) You could use uranium/lead dating or potassium/argon dating. Granite contains all of these substances, and the long half-lives of each are conducive to dating very old rocks. 2.) Probably the best technique would be potassium/argon dating because potassium-40 has a relatively short half-life compared to uranium-238 and rubidium-87. Potassium-40 is commonly used to date relatively young rocks. 3.) Carbon-14 dating would work as long as the mammoth was not older than 50,000 years old. 4.) There is no direct way to find the absolute age of an ancient sedimentary rock like sandstone. To estimate its age, the deposit would have to be matched to other deposits that have reliable ages based on igneous rocks.]

5. Why is it important to assume that the rate of radioactive decay has remained constant over time?

- [If rates of decay changed over geologic time, then all radiometric dates would be unreliable. For example, if radioactive decay occurred more slowly in the past than it does today, then ancient rocks would appear to be younger than they really are. If radioactive decay occurred more quickly in the past than it does today, then ancient rocks would appear to be older than they really are.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why are techniques for dating, such as using tree rings, ice cores, and varves, only useful for events that occurred in the last few thousand years?

- [These techniques are useful only for relatively recent events because they extend back in time for just a few thousand years. For example, scientists have created continuous records of tree rings going back for a maximum of just 2000 years.]

Why is it important for geological and biological processes that Earth is very old?

- [Billions of years are needed for the geological and biological processes that have occurred on Earth to take place. For example, for evolutionary change to have produced the vast diversity of life on Earth requires far more time than Biblical accounts of Earth's age.]

Why is it important to use more than one method to find the age of a rock or other object?

- [It is important to use more than one method to find the age of a rock or other object so the accuracy of the calculated ages can be checked. If different methods produce similar ages, then scientists can be more confident that the estimates are correct.]

CHAPTER 12 HS TE Earth's History

Chapter Outline

12.1 Chapter 12: Earth's History

Chapter Overview

This chapter explains how Earth formed, how its atmosphere and oceans developed, and how its continents changed. It reviews geological changes that occurred during the Phanerozoic eon and traces the evolution of life on Earth, from its earliest beginnings during the Precambrian to the present.

Online Resources

See the following Web sites for appropriate laboratory activities:

When you teach about the origin of life in Lesson 12.2 ("Early Earth"), use the inquiry lab "Creating Coacervates" at the following URL. In the lab, students will make and observe coacervates: amoeba-like objects that change shape, flow, merge, divide, form "vacuoles," release "vacuole contents," and show other life-like properties. The lab will demonstrate how, under suitable conditions, life-like structures can form naturally from relatively simple materials, similar to how life may have begun on early Earth.

- http://www.indiana.edu/ ensiweb/lessons/coacerv.html

In this real-world simulation lab, students investigate the chapter concepts of variation, natural selection, and evolution, by focusing on wood lice as a case study. First, they measure the amount of variation in a natural population of wood lice. Then, they perform a simulated predation experiment to determine which traits are subject to selection by predators.

- http://www.ableweb.org/volumes/vol-19/15-berkelhamer.pdf

This Web-based lab leads students through an exploration of the patterns of biodiversity across planet Earth. Students are scaffolded as they practice data interpretation and scientific reasoning skills.

- http://evolution.berkeley.edu/evolibrary/article/0_0_0/ldg_01

These Web sites may also be helpful:

You (or your students) can review more detailed information on the origin of Earth and the moon at these URLs:

- http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=446
- http://www.onlineuniversity.net/earth-science/origin-of-the-moon/

This website offers a growing collection of teaching materials and research results that will aid in the understanding of, and teaching about, early Earth.

- http://serc.carleton.edu/NAGTWorkshops/earlyearth/index.html

You can find free online access to the National Academy of Sciences book "Teaching Evolution and the Nature of Science" at the following URL. It provides great perspective on a topic that is still controversial in some school districts. The book includes a discussion of the importance of teaching evolution and describes several classroom activities on the subject.

- http://www.nap.edu/openbook.php?record_id=5787&page=R1

Pacing the Lessons

TABLE 12.1: short caption

Lesson	Class Period(s) (60 min)
12.1 Early Earth	1.5
12.2 The Precambrian	2.5
12.3 Phanerozoic Earth History	1.5
12.4 History of Earth's Complex Life Forms	3.0

12.2 Lesson 12.1: Early Earth

Key Concepts

- Formation of Earth
- How the moon formed
- Earth's early atmosphere and oceans

Lesson Objectives

- Describe how Earth formed with other parts of the solar system about 4.6 billion years ago.
- Recount the moon's birth story.
- Explain how Earth's atmosphere has changed over time.
- Explain the conditions that allowed the first forms of life to develop on Earth.

Lesson Vocabulary

- **differentiation:** separation of planetary materials by density to create different layers
- **outgassing:** transfer of gases from Earth's mantle to the atmosphere by volcanic eruptions
- **paleontologist:** scientist who finds and studies fossils to learn about the history of life

Teaching Strategies

Introducing the Lesson

There's no better way to introduce the formation of the solar system than with an animated video showing how scientists think it happened. Show students the video at the URL below and tell them they will learn more about how Earth and the rest of the solar system formed when they read this lesson.

http://www.metacafe.com/watch/1111454/formation_of_the_solar_system_great_animation/

Discussion

Students learn in the FlexBook® lesson that soon after Earth formed it underwent differentiation and its matter separated into layers by density. Explain why Earth's differentiation is so important for the subsequent geologic history of Earth. Without differentiation, plate tectonics would not occur, and without plate tectonics, Earth would be a very different place. You can learn more at these URLs:

http://csep10.phys.utk.edu/astr161/lect/earth/differentiation.html

http://csep10.phys.utk.edu/astr161/lect/earth/consequences.html

Differentiated Instruction

Have students make a main ideas/details chart for the lesson. Suggest that they include at least one main idea for each heading in the lesson. Details should add supporting information for each main idea.

Enrichment

The modern impact hypothesis for the formation of the moon is described in the FlexBook® lesson. Ask a few students to learn about earlier hypotheses for the origin of the moon. Then have them present the hypotheses to the class and discuss how or whether they are supported by evidence. Some earlier hypotheses are given at the URL below. This is a good example of how science progresses as new evidence is discovered.

http://www.onlineuniversity.net/earth-science/origin-of-the-moon/

Science Inquiry

Elaborate on the nebular hypothesis of solar system formation. Explain that because of gas pressure and gravity, the rotating nebula began to contract and flatten into a spinning pancake shape with a bulge at the center. The bulge eventually formed the sun and the rest of the pancake became the planets and other bodies in the solar system. After sharing this information with students, provide them with the following evidence for the nebular hypothesis and ask them to explain how the evidence supports the hypothesis. You can find more information at the URL below.

- The orbits of the planets lie nearly in a plane with the sun at the center.
- The planets all revolve in the same direction.
- The planets mostly rotate in the same direction, with rotation axes nearly perpendicular to the orbital plane.

http://csep10.phys.utk.edu/astr161/lect/solarsys/nebular.html

History Connection

The nebular hypothesis has a surprisingly long history, as described at the URLs below. Share the history of the hypothesis with your students. It shows how good scientific ideas may withstand the test of time.

http://history.nasa.gov/SP-436/preface.htm

http://www.infoplease.com/encyclopedia/science/solar-system-origin-solar-system.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 12.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 12.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. From what sources did water arrive in Earth's atmosphere?

- [Water arrived in Earth's atmosphere as water vapor from the mantle by volcanic outgassing. It also arrived as ice on asteroids and comets that impacted Earth.]

2. Describe how Earth's different layers vary by density. When did the layers undergo differentiation?

- [The core is the densest layer of Earth, followed by the mantle, and then the crust, which is the least dense layer of Earth. The layers underwent differentiation soon after Earth first formed, when it was still entirely molten.]

3. What are the two main reasons that an oxygen-rich atmosphere is important for life on Earth?

- [Oxygen is needed to make ozone, which blocks harmful ultraviolet radiation from the sun. Oxygen is also needed by organisms for respiration. Animals cannot breathe without it.]

4. List three ways Earth is different today from when it was first formed.

- [*Sample answer*: When Earth first formed, it was very hot and lacked an atmosphere and oceans. Earth today is much cooler, and it has an atmosphere and oceans.]

5. If Earth had been much cooler when it first formed, how would the planet be different now from the way it actually is today?

- [If Earth had been much cooler when it first formed, the planet's interior would be cooler now that it actually is today. It would also be less active tectonically. For example, there would be fewer volcanoes. In addition, Earth materials would not have been molten, so they would not have been able to separate into layers by density. Instead, Earth would have the mix of materials as when it first formed almost 4.6 billion years ago.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What would you recognize from modern times if you traveled back to the early days of Earth?

- [If you traveled back to the early days of Earth, you would recognize Earth's geologic processes, such as volcanoes and earthquakes. You would also recognize the moon, sun, and stars.]

How do scientists know what happened on early Earth?

- [Scientists know what happened on early Earth from indirect evidence. The evidence includes zircon crystals, which are the oldest materials on Earth. They show that the earliest crust formed at least 4.4 billion years ago. Other evidence comes from meteorites that date from the beginning of the solar system nearly 4.6 billion years ago. Lunar rocks are another source of evidence. They represent the early days of the Earth-Moon system, as far back as 4.5 billion years ago.]

When was the planet ready for life to begin?

- [The planet was ready for life to begin when it had formed an atmosphere and oceans, around 4.2 to 4.4 billion years ago. The first evidence for life comes from about 3.5 to 3.8 billion years ago.]

12.3 Lesson 12.2: The Precambrian

Key Concepts

- Early continents
- Origin of life on Earth
- Changes in Earth's early atmosphere
- Evolution of early life forms

Lesson Objectives

- Describe how the early continents came together.
- Understand what was needed for the first life and the various ways it may have come about.
- Discuss the early atmosphere and how and why free oxygen finally increased.
- Know the features and advantages of multicellular organisms.

Lesson Vocabulary

- **amino acid:** type of organic molecule that is a building block of proteins and necessary for life
- **craton:** Precambrian felsic continental crust that forms the core of a continent
- **cyanobacteria:** single-celled prokaryotes abundant during the Precambrian and the first photosynthesizers
- **eukaryote:** type of organism whose cells contain a nucleus and other organelles
- **extinct:** event in which a species stops existing because it either dies out or evolves into a different species
- **greenstone:** metamorphosed volcanic rock that forms at a subduction zone and is found in deep-sea trenches
- **LUCA (last universal common ancestor):** last life form that was the ancestor of all life that evolved afterward
- **metabolism:** all of the chemical reactions that take place in the cells of an organism and allow the organism to live, grow, and reproduce
- **microbe:** microscopic organism, or microorganism
- **microcontinent:** fragment of crust that is smaller than a continent
- **nucleic acid:** organic compound that stores genetic information and passes it to the next generation; either DNA or RNA
- **paleogeography:** arrangement of the continents on early Earth; ancient geography
- **photosynthesis:** process in which plants produce simple sugars from carbon dioxide, water, using energy from sunlight, and release oxygen into the atmosphere
- **platform:** craton and its overlying younger sedimentary rocks
- **prokaryote:** type of organism whose cells lack a nucleus and other organelles
- **RNA world hypothesis:** hypothesis that RNA was the first organic molecule to evolve
- **shield:** place where a craton crops out at the surface
- **stromatolite:** reef-like structure of cyanobacteria that existed in the Precambrian and continued on into the Cambrian

- **supercontinent:** singe, massive continent that formed when all of Earth's landmasses came together
- **symbiotic:** relationship between different species in which both benefit and neither is harmed

Teaching Strategies

Introducing the Lesson

Pique student interest by showing the class "Origin of Life" cartoon 1 (search ID bven864) at the URL below. Tell students that the cartoon contains a germ of truth. Life on Earth really may have come from some other part of the solar system, as they will learn in this lesson.

http://www.cartoonstock.com/directory/o/origin_of_life.asp

Discussion

Ask students to relate the warmer interior of Earth during the Pre-Archean and Archean with plate tectonic activity during that time.

Question: Why were plate tectonic processes more vigorous during the Pre-Archean and Archean?
Answer: Earth's interior was warmer, so mantle convection was faster.
Question: Why were the early crustal plates relatively small?
Answer: The plates were small because subduction zones were more common.

Demonstration

Demonstrate Precambrian plate tectonics with the animations at the URL below. Students can observe the formation and breakup of Rodinia.

http://geosphere.gsapubs.org/content/3/6/511/suppl/DC1

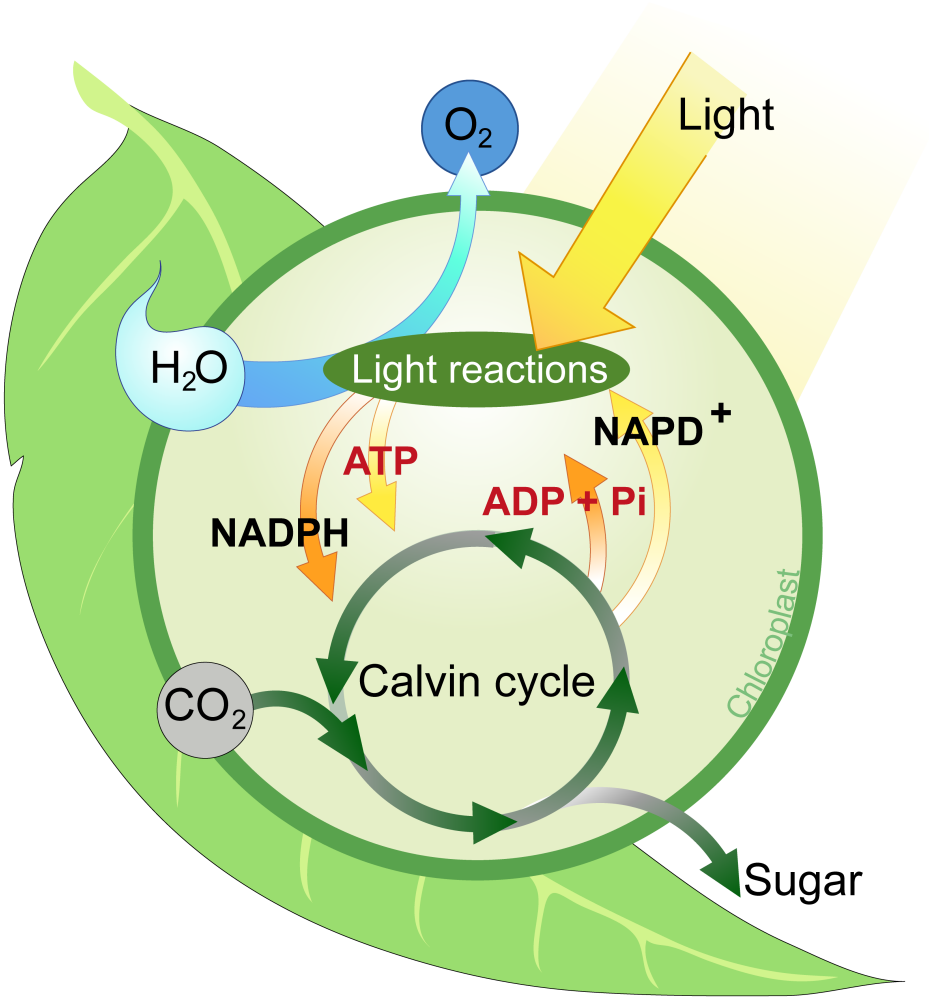
Discussion

Point out that photosynthesis is how cells of certain bacteria, plants, and some other organisms use light energy to make food and that the process releases oxygen. Discuss how the evolution of photosynthesis led to the addition of oxygen to Earth's atmosphere, which in turn allowed the evolution of cellular respiration. Explain that cellular respiration is a very efficient way of getting energy from food and it requires oxygen. Add that cellular respiration allowed more complex life forms to evolve. On the board, write the following equations for cellular respiration and photosynthesis, respectively. Ask students to identify which equation represents each process.

sugar (glucose) + oxygen (O_2) $\rightarrow$ carbon dioxide (CO_2) + water (H_2O) + energy

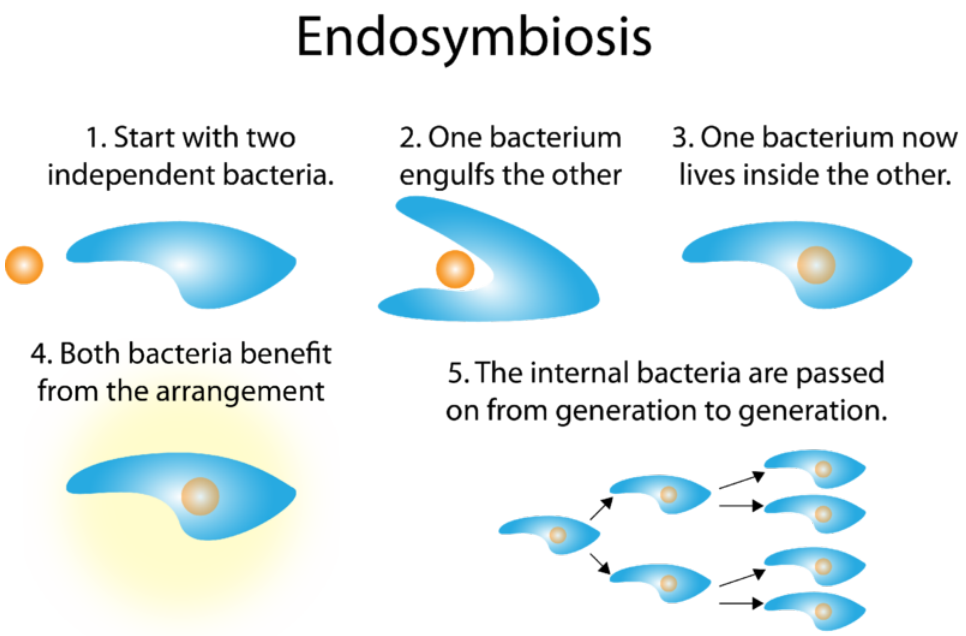
carbon dioxide (CO_2) + water (H_2O) + energy rarr; sugar (glucose) + oxygen (O_2)

With the help of students, create a diagram like the one below that shows how the two processes are related.



Discussion

Discuss endosymbiotic theory, which is the theory that eukaryotes evolved from symbiotic relationships between prokaryotes. Use the simple diagram below to help students understand the theory. Describe evidence supports the theory. You can learn more at this URL: http://evolution.berkeley.edu/evosite/history/endosym.shtml.



Differentiated Instruction

Do a think-pair-share activity to help students understand the most important lesson ideas. Ask students to think about the questions listed below. Then divide the class into pairs, and have partners discuss the questions.

1. What were the earliest continents like, and what happened to them?
2. When and how did the supercontinent Rodinia form?
3. How did the earliest simple cells evolve?
4. What is photosynthesis? How did it change Earth's atmosphere?

Enrichment

Ask one or more students to create a crossword puzzle using at least 15 of the lesson vocabulary terms. Make copies of the puzzle and distribute them to the rest of the class to complete as a review of lesson vocabulary.

Science Inquiry

Discuss the Miller-Urey experiment, which is described in the FlexBook® lesson. Call on students to describe the experiment and its results. Then guide students in interpreting the results of the experiment.

Question: What is an implicit assumption the researchers made in their experiment?
Answer: They assumed the simulation closely represented conditions on early Earth.

Question: What hypothesis is supported by the results of the experiment?

:Answer: Organic molecules can form spontaneously under conditions thought to represent conditions on early Earth.

Make sure students realize that the results of Miller and Urey's experiment do not prove that the earliest organic molecules formed as simulated in the experiment.

Chemistry Connection

Students can learn more about the RNA world hypothesis as it is currently being investigated by biochemists in Scott Lab at the University of California at Santa Cruz. Lab scientists are carrying out investigations that they hope will clarify the role of RNA in the origin of life. At the following URL, students can read about highlights of the research and some of the specific problems the scientists are investigating.

http://scottlab.ucsc.edu/scottlab/origins.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 12.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 12.2 in *CK-12 HS Earth Science*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is the difference between a craton, shield, and platform?

   - [A craton is a chunk of Precambrian felsic continental crust that forms the core of a continent. A shield is a place where a craton crops out at the surface. A platform is a craton and its overlying younger sedimentary rocks.]

2. If a rock contains rounded grains of sediments, what can you tell about that rock?

   - [If a rock contains rounded grains of sediments, you can tell that the rock formed from minerals that were eroded by water from an earlier rock type.]

3. What does a greenstone indicate about the plate tectonic environment in which it formed?

   - [A greenstone indicates the presence of a subduction zone.]

4. What happened to all of the heat Earth had when it formed?

   - [About half of the heat Earth had when it formed was lost to its surroundings as the planet cooled. The rest remains in the planet and is the source of the heat in the core and mantle today.]

5. What was Laurentia and what lands was it composed of? What happened to it?

   - [Laurentia was a continent that formed as early as 1.5 billion years ago. It was composed of the North American craton and the microcontinents and oceanic island arcs with which it collided. Around 1.1 billion years ago, Laurentia became part of the supercontinent Rodinia.]

6. How was Rodinia like Pangaea?

   - [Like Pangaea, Rodinia was a supercontinent that consisted of the majority of landmasses that make up today's continents.]

7. What were the possible sources of amino acids on ancient Earth?

- [Amino acids on ancient Earth could have evolved in the planet's seas, deep in the crust, or at hydrothermal vents. Alternatively, the amino acids could have been brought to Earth by meteorites from somewhere else in the solar system.]

8. What was the significance of the Miller-Urey experiment?

- [The Miller-Urey experiment demonstrated that organic compounds such as amino acids could have originated in the environment thought to be present on early Earth.]

9. What is the RNA world hypothesis and why is it called that?

- [The RNA world hypothesis is the hypothesis that RNA was the first organic molecule to evolve. Its name refers to the possibility that RNA is more ancient than DNA so that at one time all organisms contained RNA but not DNA.]

10. What is the difference between prokaryotes and eukaryotes?

- [Eukaryotes are organisms whose cells have a nucleus and other organelles. Prokaryotes are organisms whose cells lack a nucleus and other organelles.]

11. What was LUCA? Is LUCA still alive?

- [LUCA stands for "last universal common ancestor." It is the name for the organism thought to be ancestral to all life forms that came afterward. LUCA is not still alive but it shares similarities with all of today's living things. For example, it is thought that LUCA had a genetic code based on DNA.]

12. Why are banded-iron formations important?

- [Banded-iron formations are important because they indicate times when the atmosphere contained large quantities of oxygen.]

13. Why were cyanobacteria important on early Earth?

- [Cyanobacteria were important on early Earth because they changed Earth's early atmosphere by releasing oxygen into the air. These bacteria were the first photosynthetic organisms, and oxygen is a waste product of photosynthesis.]

14. How are eukaryotes thought to have originated?

- [Eukaryotes are thought to have originated when prokaryotic cells began to live together in symbiotic relationships. Different types of prokaryotic cells

took on specialized functions and became organelles within a larger eukaryotic cell. The organelles supplied energy, broke down wastes, or did other jobs that were needed for eukaryotic cells to become more complex.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What would life be like on Earth if there were no free oxygen?

- [Without free oxygen, there would be less ozone to protect living things from harmful ultraviolet radiation. Almost organisms need oxygen to survive, so very few organisms would be left on Earth.]

- Why did it take so long for eukaryotes or multicellular organisms to evolve?

- [The change from prokaryote to eukaryote actually involved a number of important changes, including a cell nucleus, other cell structures, and better organization. These new traits may have taken a long time to evolve, but they eventually allowed eukaryotes to become the dominant life forms.]

How did the evolution of life affect the non-biological parts of the planet?

- [One way the evolution of life affected the non-biological parts of the planet was the addition of oxygen to the atmosphere by the first photosynthesizing organisms, the cyanobacteria. Living things have also played an important role in weathering and the formation of soil.]

12.4 Lesson 12.3: Phanerozoic Earth History

Key Concepts

- Geology of the Paleozoic era
- Geology of the Mesozoic era
- Geology of the Cenozoic era

Lesson Objectives

- The Phanerozoic is divided into the Paleozoic, Mesozoic, and Cenozoic.
- Marine transgressions and regressions were common during the Paleozoic and Mesozoic.

Lesson Vocabulary

- **facies:** characteristic sedimentary rock layers that indicate the processes and environments in which they formed
- **marine regression:** falling of sea level so seas no longer cover the continents
- **marine transgression:** rising of sea level over the continents
- **orogeny:** mountain-building event

Teaching Strategies

Introducing the Lesson

Ask students to recall from the previous lesson ("The Precambrian") the time span covered by the Precambrian Eon (4.6 billion to about 570 million years ago). Remind them that the following (and current) eon is the Phanerozoic Eon. Point out that in terms of Earth's total history, the Phanerozoic Eon is shortabout half a billion years (this is apparent in the geologic time scale format shown at the URL below). However, important geological events and most biological evolution occurred during this eon. Tell students they will read about the geological changes of the Phanerozoic in this lesson and they will read about the evolutionary changes of the Phanerozoic in the following lesson.

http://palaeos.com/timescale/geotimescale.html

Using Visuals

Help students understand the rock evidence for Paleozoic marine transgressions and regressions. Refer them to the figure in the FlexBook® lesson that shows the Grand Canyon's three sets of rocks. Have them focus on the

layered Paleozoic rocks. Explain how the sedimentary rock sequences provide evidence of marine transgressions and regressions during the Paleozoic. For example, point out how the Tonto Group toward the bottom of the diagram (around 515 million years ago) represents a marine regression because it has the sequence sandstone, shale, and limestone, all of which were laid down during the Cambrian Period.

Question: Why do sandstones indicate that water depth was low?

Answer: Sandstones form from sand and other coarse-grained sediments, which are deposited in high-energy water that is relatively shallow.

Question: Why do limestones indicate that water depth was high?

Answer: Limestones form from very fine-grained sediments, which are deposited in low-energy water that is relatively deep.

Demonstration

You may want to use the interactive timeline at the following URL when you teach students about plate tectonics and climate change during the Phanerozoic. It demonstrates how Earth's continents moved from the Eocene through the Pleistocene. You can stop the motion at fixed points throughout the eon.

http://nature.ca/discover/exf/clmtpst/index_e.cfm

Differentiated Instruction

Have students make a table comparing and contrasting the eras of the Phanerozoic Eon: the Paleozoic, Mesozoic, and Cenozoic. Tell them to include for each era the time span, important geologic events, and climate. Have students leave a blank column for evolutionary events. They can fill in this column of the table when they read the next lesson. Suggest that they save their table in their science notebook.

Enrichment

Ask for volunteers to make a diorama illustrating life during the Pleistocene glaciations in North America. They should include typical flora and fauna of the period. Display their diorama in a prominent place in the classroom.

Science Inquiry

Students can further explore the Ice Ages with the inquiry activity at the URL below. By doing the activity, students will understand what causes ice ages, learn about organisms that lived during the Pleistocene Ice Ages, and understand why certain ice-age animals went extinct. With the take-home activity sheet, "Giving a Scientific Opinion," students will try to apply what they have learned about the Ice Ages to modern times.

http://www.discoveryeducation.com/teachers/free-lesson-plans/the-ice-age.cfm

Overcoming Misconceptions

A common misconception is that the "Ice Ages" happened in the past and are now over. Make students aware that we are still within the most recent ice age, which started about 2.58 million years ago during the late Pliocene. Since then, the world has seen four cycles of glaciation, with ice sheets repeatedly advancing (glacial periods) and retreating (interglacial periods). Explain that Earth is currently in an interglacial period and that the last glacial period ended about 10,000 years ago. All that remains of the continental ice sheets from the last glacial are the Greenland and Antarctic ice sheets and smaller glaciers such as on Baffin Island. Some scientists think that the

current interglacial may last another 50,000 years. However, the effect that global warming will have on the cycle is uncertain.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 12.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 12.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What are the possible causes of a marine transgression? Of a marine regression?

   - [For a marine transgression to occur, either the land must sink or sea level must rise. For sea level to rise, fresh water that is part of glaciers and ice caps can melt. Sea level also rises if seafloor spreading is rapid, which buoys up the ocean crust and essentially makes the volume of the ocean basin smaller. For a marine regression to occur, either the land must rise or sea level must fall. For sea level to fall, more water can be frozen in ice caps and glaciers or seafloor spreading can be less vigorous than normal.]

2. What rock sequence indicates a marine transgression? What rock sequence indicates a marine regression?

   - [A rock sequence that indicates a marine transgression is sandstone, shale, and limestone. A rock sequence that indicates a marine regression is the opposite: limestone, shale, and sandstone.]

3. How do the rocks of the Grand Canyon indicate marine transgressions or regressions?

   - [The sequences of sedimentary rocks of the Grand Canyon indicate marine transgressions and regressions. When sea level was rising, sandstone was replaced by shale and then by limestone. The opposite occurred when sea level was falling.]

4. What was the configuration of oceans during the time of the supercontinent Pangaea?

   - [During the time of Pangaea, most of Earth's ocean water was collected in a huge ocean called Panthalassa, with a few smaller seas.]

5. What geologic evidence is left after a continent breaks apart?

   - [The evidence is the same type of evidence that Alfred Wegener used for his continental drift hypothesis: the fit of the continents; the continuity of rock layers, structures, and mountain ranges across ocean basins; fossils of species that could not swim in salt water or fly far that are now separated by oceans; and evidence from paleomagnetism.]

6. What was the Pleistocene climate like?

   - [During most of the Pleistocene, the climate was cooler than it is today, leading to the formation of glaciers and the ice ages. The glaciers advanced and retreated four times in the Pleistocene. During the times when the glaciers retreated, the climate was actually warmer than it is today.]

7. Using the map above, describe the geologic history of North America. In what order did events occur? What is the cause of the orogenies lining the western and eastern continental margins?

- [The oldest portion of North America is the craton, which is exposed as the shield in the northeastern portion of the continent. Portions of the craton were later covered with sediments, some of which were eroded away, to create the platform. Continental collisions with other continents, microcontinents, or volcanic arcs created the rocks of the orogenies that line the western and eastern regions of the continent. Extension has caused some of the continent to pull apart, particularly inland from the California orogeny. Finally a large igneous province is visible as the basalts of the Snake River Plain and Columbia River regions.]

8. Look at Africa. Why is there no orogenic province on the western or eastern margins of the continent? What is the cause of the purple province in the northeast?

- [There is no orogenic province on the western coastal area of South America either, so the collision between South American and Africa when Pangaea came together did not create large mountain ranges. The purple igneous province in the east-central area is due to the East African rift, which is pulling the easternmost part of Africa away from the rest of the continent.]

9. Where are the mountains of South America located? What is the reason for those mountains?

- [The Andes mountains line western South America and are the result of subduction of oceanic crust beneath the continent.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How did the paleogeography of the planet affect the evolution of life?

- [Living things must adapt to the conditions of their environment. As continents moved together and apart, conditions changed and required living things to evolve different traits.]

How did climate affect the evolution of life?

- [Earth's climate changed repeatedly throughout the history of life on the planet. Organisms had to evolve to adapt to the changes. Those that could not adapt went extinct. Their places were taken by organisms that were able to adapt.]

How was human evolution related to major climatic events?

- [Humans first evolved in a warm climate in Africa but later spread around the world. In colder climates, especially during the Pleistocene ice ages, they used culture to adapt rather than evolving new physical characteristics to suit the lower temperatures. For example, they developed the controlled use of fire and clothing to stay warm.]

12.5 Lesson 12.4: History of Earth's Complex Life Forms

Key Concepts

- Adaptation and evolution of organisms
- Ediacara fauna
- Evolution of life forms during the Phanerozoic eon

Lesson Objectives

- Describe how adaptations develop.
- Explain how the fossil record shows us that species evolve over time.
- Describe the general development of Earth's life forms over the last 540 million years.

Lesson Vocabulary

- **adaptation:** inherited trait that helps an organism survive or reproduce in a given environment
- **adaptive radiation:** process in which many new species quickly evolve to fill available niches, often following a mass extinction
- **amniote egg:** egg that contains all the nutrients needed for the developing embryo and is protected by a shell
- **evolution:** change in the genetic makeup of a population or species over time
- **mutation:** random change in a gene, which can be beneficial, harmful, or neutral in its effects on the organism's fitness
- **natural selection:** mechanism of evolution; process in which inherited traits in a population or species change in frequency as individuals with certain traits are better able to survive and reproduce than individuals without the traits
- **paleontologist:** scientist who finds and studies fossils to learn about the history of life
- **tropical:** type of climate that is warm year-round and may be wet
- **variation:** difference in an inherited trait in a population

Teaching Strategies

Introducing the Lesson

Grab students' attention by sharing the amazing fact that there may be as many as 100 million species in existence on Earth today. Then tell students that because of human actions, species are going extinct at an alarming rate, with as many as 100,000 species going extinct each year. Explain that the current wave of extinctions is the sixth of a series of mass extinctions that occurred during the Phanerozoic Eon. Tell students they will learn about these mass extinctions, as well as the bursts of evolution that followed them, when they read this lesson.

Activity

Most descriptions of animal evolution in the Phanerozoic focus on vertebrates. Students can explore what invertebrate life was like in Mesozoic oceans with the interactive activity "Large Invertebrates" at this URL: http://nature.ca/discover/exf/lrgnvrtbrts/index_e.cfm.

Building Science Skills

In the interactive activity at the following URL, students can investigate the hypothesis that dinosaurs were already in decline before their extinction at the K/T boundary. They will observe fossils in rock layers as a snapshot of life at that time and decide whether it supports the hypothesis. Make sure they watch the short video by Dr. Kirk Johnson, who explains why all animals larger than housecats went extinct at the K/T boundary.

http://nature.ca/discover/exf/dclnngdvrsty/index_e.cfm

Differentiated Instruction

How natural selection works to bring about adaptations at the level of the population may be difficult for some students to conceptualize. Have them do one of the hands-on simulations of natural selection at the URLs below. They will see first-hand how a trait increases or decreases in a population through predation pressure. This is a good activity for less proficient readers and English language learners.

http://www.ucmp.berkeley.edu/education/lessons/candy_dish.html

http://www.accessexcellence.org/AE/AEPC/WWC/1995/beansbirds.html

Enrichment

Suggest that interested students explore the effects of volcanism on the Cretaceous mass extinction. The interactive activity at the URL below investigates the Deccan volcanic eruption that occurred around the time of the Cretaceous mass extinction and what role it may have played in the extinction.

http://nature.ca/discover/exf/vlcnsmndextncton/index_e.cfm

Science Inquiry

Continuing the dinosaur extinction theme, you can use the activity described at the following URL to have students practice scientific reasoning. They will read and discuss articles presenting two alternative models about the extinction of dinosaurs. Then they will use the same criteria that scientists use to choose the "best" solution.

http://www.indiana.edu/ ensiweb/lessons/theor.ch.html

Overcoming Misconceptions

Misconceptions about evolution are very common. The URL below lists and debunks 17 of the most widespread misconceptions about evolutionary theory. It should be required reading by all of your students.

http://sciencebasedlife.wordpress.com/2011/09/04/understanding-evolution-17-misconceptions-and-their-responses/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 12.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 12.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe how an adaptation comes about.

- [An adaptation comes about when certain variations in a population help some members survive and reproduce better than others.]

2. What is evolution? How is natural selection the mechanism for evolution?

- [Evolution is a change in the genetic makeup of a population or species over time. Evolution comes about through natural selection. In natural selection, certain inherited traits (and the genes that control them) increase in frequency because individuals with the traits are better able to survive and reproduce than individuals without the traits.]

3. How might a hard external skeleton, called an exoskeleton, be a favorable adaptation for the soft-bodied organisms that had lived before?

- [An exoskeleton protects the soft parts of an animal from harm from the environment or other organisms. This gives the organism a better chance of surviving.]

4. Explain why unfavorable traits usually do not get passed to offspring.

- [Unfavorable traits usually do not get passed to offspring because individuals with the traits are less likely to survive or reproduce.]

5. Why did it take 4 billion years of Earth history for multicellular organisms to evolve and diversify to the point of the Ediacara biota?

- [There are many possible explanations: evolutionary processes are slow, so it took a long time for complexity to evolve; there was no evolutionary advantage to being larger and more complex; atmospheric oxygen was limited so complex organisms could not evolve; the planet was too cold for complex life; and/or complex life evolved but was wiped out by massive global glaciations ("Snowball Earth").]

6. List the order in which the major types of animals appeared on Earth.

- [The order in which the major type of animals appeared on Earth is: fish, insects, amphibians, reptiles, dinosaurs, mammals, and birds.]

7. How might climate have affected the ability of plants to grow over large areas during a given time?

- [Plants were able to grow over large areas of land when the climate was mild or tropical. During cold periods, plants would not have been able to spread over as large an area.]

8. One cause of mass extinctions is a meteorite or comet impact. What might be some additional causes of mass extinctions?

- [*Sample answer*: Huge volcanic eruptions, rapidly changing climate, or human actions also might cause mass extinctions.]

9. What happens immediately after a mass extinction to the diversity of organisms? What happens thousands or millions of years later?

- [Immediately after a mass extinction, biodiversity is very low because most species have gone extinct. Then organisms start evolving rapidly to fill the vacant niches, and biodiversity increases rapidly. By thousands or millions of years later, life forms are likely to be very diverse but different from those that existed before the mass extinction occurred.]

10. Describe the big advance reptiles had over amphibians.

- [The big advance reptiles had over amphibians was evolving the amniote egg. This allowed them to move entirely away from water, even for reproduction.]

11. Why are there so many different species on Earth today?

- [There are so many different species on Earth today because there are a huge number of environmental niches that species can fill and life has had billions of years to evolve.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How did life on Earth change from one period of geologic time to the next?

- [The eras of the Phanerozoic Eon are separated by mass extinctions followed by adaptive radiations. For example, the largest mass extinction in Earth history occurred at the end of the Paleozoic Era. This was followed by a vigorous adaptive radiation at the beginning of the Mesozoic Era.]

How did climate affect the evolution of life?

- [Through time, organisms evolved adaptations to help them survive in the climate in which they lived. Changes in climate led to extinctions of many species but new opportunities for those species who could adapt to the change.]

Evolution is well documented in the fossil record. Why is it so controversial?

- [Evolution is controversial because it conflicts with the religious beliefs of some people, particular those who believe the Bible story that God created the world and all living things in six days.]

CHAPTER 13 HS TE Earth's Fresh Water

Chapter Outline

13.1 Chapter 13: Earth's Fresh Water

Chapter Overview

This chapter describes the water cycle and sources of Earth's fresh water, including streams, lakes, wetlands, and groundwater.

Online Resources

See the following Web sites for appropriate laboratory activities:

In the investigation at the following URL, students will create a model of a wetland to observe how it absorbs and filters water from the environment. They will also learn characteristics of wetland organisms and match various organisms to different types of wetlands.

- http://www.state.nj.us/education/21cclc/casp/lsc/unit2/Lesson8.pdf

Students will investigate groundwater with the lab at the URL below. They will describe the movement of the water table, locate saturation zones, and identify their function. http://www.wef.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=2535

These Web sites may also be helpful:

You can find water-related activities suitable for high school students at this URL: http://thewaterproject.org/community/student-resources/water-related-education-materials-for-high-school/.

You can access many teaching resources from the USGS Water Science School at this URL: http://ga.water.usgs.gov/edu/.

The following URL has numerous teaching resources and lesson plans about water.

- http://www.epa.gov/students/teachers.html#epawater

Pacing the Lessons

TABLE 13.1: **short caption**

Lesson	Class Period(s) (60 min)
13.1 Water on Earth	1.5
13.2 Surface Water	2.0
13.3 Groundwater	1.5

13.2 Lesson 13.1: Water on Earth

Key Concepts

- Distribution of Earth's water
- The hydrologic cycle

Lesson Objectives

- Describe how water is distributed on Earth.
- Describe what powers the water cycle and how water moves through this cycle.

Lesson Vocabulary

- **condensation:** process in which a gas changes to a liquid
- **evaporation:** process in which a liquid changes to a gas
- **fresh water:** water with a low concentration of salts, found in streams, lakes, ice, the ground, and the atmosphere
- **groundwater:** fresh water that moves through pore spaces in soil and fractures in rock beneath Earth's surface
- **hydrologic (water) cycle:** continuous movement of water around Earth between reservoirs, such as oceans, other bodies of surface water, the atmosphere, ice, and groundwater
- **precipitation:** water that falls from clouds to the ground as rain, snow, sleet, or hail
- **reservoir:** storage location for a substance such as water
- **residence time:** average amount of time a substance remains in a reservoir
- **sublimation:** process in which a solid changes directly to a gas without going through the liquid state
- **transpiration:** release of water vapor into the atmosphere from the leaves of plants
- **water vapor:** gaseous state of water

Teaching Strategies

Introducing the Lesson

Introduce the water cycle by playing the water cycle rap at the following URL. Tell students they will learn about the nature of water and the water cycle in this lesson.

http://www.educationalrap.com/song/water-cycle/

Discussion

Tell students that many of Earth's most interesting features are due to the unique properties of water and to the planet having the right environmental conditions for water to be present in all three states. Explain and discuss the properties of water with the class, including the following:

- Water is a polar molecule, having a slightly negative oxygen end and a slightly positive hydrogen end because oxygen attracts the shared electrons more strongly.
- Water molecules bind loosely together by weak hydrogen bonds that form between oppositely charged ends of water molecules. The hydrogen bonds require energy to break and they give water properties such as cohesion and high specific heat.
- Water molecules in ice form an open hexagonal framework. Unlike most substances, water is less dense as a solid than as a liquid, so ice floats on liquid water.

You (or your students) can find more information about water's unique properties at this URL: http://www.chem1.com/acad/webtext/states/water.html.

Differentiated Instruction

Pair less proficient readers and English language learners with other students, and ask partners to work together to make a simple cycle diagram of the water cycle. Tell them to include sketches to illustrate the steps in the cycle. Ask them to explain at least one way that water can travel through their cycle diagram. Suggest that students add their diagram to their science notebook.

Enrichment

Ask a small group of students to make a water cycle board game. Each player could be a molecule of water, and the object of the game might be to make one complete trip through the cycle. Players could draw cards or roll dice to determine what happens to them on each move, depending on their state of matter. For example, if a molecule of water is in the ocean, on the player's next turn a roll of the dice could decide whether the player remains as liquid water in the ocean or evaporates and enters the atmosphere as water vapor. After the students create and test their board game, encourage other students to play it.

Science Inquiry

Students can model the water cycle with the activity described in the PDF document below. In the activity, they will construct a model of the hydrologic cycle and explain how the hydrologic cycle works and why it is important. They will also compare the hydrologic cycle to other cycles in nature such as the nitrogen cycle and carbon cycle.

http://www.polytechnic.edu.na/academics/schools/engine_infotech/civil/libraries/water_resource_basics/Introduction_-Water.pdf

Overcoming Misconceptions

Common misconceptions about water and its states are listed below. The correct conceptions are given in brackets. For each pair of statements, ask students to select the correct one and explain why it is correct. You can find additional misconceptions at this URL: http://beyondpenguins.ehe.osu.edu/issue/water-ice-and-snow/common-misconceptions-about-states-and-changes-of-matter-and-the-water-cycle

1. When water boils and bubbles, the bubbles are air. [Bubbles formed by boiling water consist of water vapor.]

2. Steam is hot air. [Steam is water vapor.]
3. When steam is no longer visible it becomes air. [When water vapor condenses in the air it is visible as tiny water droplets.]

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 13.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 13.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. About what percent of Earth's water is fresh water?

- [About 3 percent of Earth's water is fresh water.]

2. About what percent of all of Earth's water is found in groundwater, streams, lakes, and rivers?

- [About 0.7 percent of all of Earth's water is found in groundwater, streams, lakes, and rivers.]

3. In what states does water appear on Earth and on other planets?

- [Earth is unique in having water exist in all three states. Other planets are too hot or too cold to have water exist in all three states.]

4. What powers the water cycle? How?

- [The sun powers the water cycle. It provides most of the energy that evaporates water and adds water vapor to the atmosphere. Unequal heating by the sun causes clouds and precipitation. The sun also provides virtually all of the energy needed by living things. In all these ways, the sun is the source of energy that keeps the water cycle going.]

5. In which state of matter would water be at 130 °C? At 45 °C?

- [Water would be in the gaseous state at 130 °C, and it would be in the liquid state at 45 °C.]

6. Define the words condensation and evaporation.

- [Condensation is the process in which a gas changes to a liquid. Evaporation is the process in which a liquid changes to a gas.]

7. Give a detailed summary of the water cycle.

- [The water cycle is the movement of water around Earth's surface. The sun evaporates water from the oceans and from bodies of fresh water on the surface, such as rivers and lakes. The water vapor enters the atmosphere, where it remains until it condenses and forms clouds. If the water droplets in clouds grow large enough, they fall to the surface as precipitation. Much of the precipitation falls into the oceans, and some falls into other bodies of water. Of the precipitation that falls on land, some runs over the land and eventually flows into bodies of water. Some of the precipitation that falls on land infiltrates the ground. Groundwater may eventually make its way to a body of water. All of this liquid water may eventually evaporate and repeat the cycle. Plants take up some of the water in soil through their roots and give off water vapor by transpiration through their leaves. Precipitation that falls as snow may eventually melt and then evaporate to enter the atmosphere again, or the snow may undergo sublimation and change directly to water vapor without going through the liquid state.]

8. What is transpiration? How is it like evaporation?

- [Transpiration is the process in which plants give off water vapor through their leaves. Evaporation is the process in which liquid water changes to water vapor. The two processes are similar because both add water vapor to the atmosphere.]

9. Why is the atmosphere so important to the water cycle?

- [The atmosphere is the reservoir for water vapor. Water must go through the gaseous state to complete the water cycle. Without water in the atmosphere, there would be no precipitation, so the atmosphere plays a crucial role in the cycle.]

10. If the sun grew much stronger in intensity, how would the water cycle be affected?

- [If the Sun grew much stronger in intensity, more water would evaporate, so there would be more water vapor in the atmosphere. There would also be more precipitation, so the overall rate of the water cycle would increase. On the other hand, the size of the oceans and other bodies of surface water might decrease.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How does precipitation affect the topography of Earth?

- [Heavy precipitation and runoff can cause erosion of Earth's surface. Precipitation also feeds streams and rivers, which are very important agents of erosion and deposition, creating many landforms such as river valleys and deltas.]

What natural disasters are caused by the water cycle?

- [Natural disasters caused by the water cycle include floods, which can occur when precipitation is higher than normal.]

How might building dams disrupt the natural water cycle?

- [Building dams might reduce the flow of rivers and create artificial lakes. However, the overall water cycle is unlikely to be much affected because the water is still on the surface where it can evaporate and recycle.]

As Earth's temperature warms, how might the water cycle be altered?

- [As Earth's temperature warms, more water might evaporate from Earth's surface. This would result in more water vapor in the atmosphere and higher levels of precipitation. This could speed up the water cycle.]

13.3 Lesson 13.2: Surface Water

Key Concepts

- Streams and rivers
- Ponds and lakes
- Wetlands
- Floods

Lesson Objectives

- Compare streams and rivers and their importance.
- Describe what ponds and lakes are and why they are important.
- Explain why wetlands are significant in the water cycle, and describe their biodiversity.
- Describe the causes of floods and their effects.

Lesson Vocabulary

- **brackish:**relating to water that is a mixture of fresh water and salt water
- **confluence:** place where two streams merge
- **continental divide:** ridge that separates all the water basins that empty into different oceans
- **divide:** highest ridge that separates one water basin from another
- **estuary:** wetland containing brackish water that forms where a stream meets the ocean
- **flood:** event in which a stream or river overflows its banks
- **lake:** large body of fresh water drained by a stream
- **levee:** raised structure built on a stream bank to hold back the water in case of a flood
- **limnology:** study of freshwater bodies and the organisms that live in them
- **marsh:** wetland with grasses and reeds but no trees, containing water that may be fresh, salty, or brackish
- **mouth:** part of a stream where it enters a large body of still water such as a lake or an ocean
- **pond:** small body of fresh water not drained by a stream
- **pool:** deep, slow-moving part of a stream where the stream may be wider than in other places
- **stream:** any body of fresh water that constantly flows downhill within banks (sides) and a bed (bottom)
- **swamp:** wetland in which water moves very slowly, oxygen levels are low, and trees and vines are common
- **tributary:** smaller of two streams that merge to make a larger stream
- **wetland:** land that is wet for most or all of the year

Teaching Strategies

Introducing the Lesson

Introduce the lesson with the short wetlands video at the URL below. This interesting movie shows young adult hosts emerging from an algae-covered swamp, so it will be sure to grab students' attention and pique their interest in wetlands.

http://www.youtube.com/watch?v=ft_2nj96jLM

Discussion

Discuss how human actionsbuilding levees for flood protectionactually increase flooding. You can learn more at this URL: http://www.nbcnews.com/id/3077314/ns/technology_and_science-science/t/floods-raise-scientific-dilemma/.

Differentiated Instruction

Pair students who need extra help with other students in the class, and ask partners to make and label a sketch of a river system. Their sketch should include a river, its source and mouth, tributaries, and divides to separate the river's watershed from that of other rivers. Post their sketches in the classroom.

Enrichment

Ask a small group of interested students to role-play a congressional hearing in which scientists testify before congress on the importance of wetlands and the need to protect them. Give the students a chance to present their role-play to the class.

Enrichment

Students who are interested in learning more about floods, such as their connection to El Niño and myths about floods, should read the articles at the following URLs. The National Geographic article includes a collection of excellent flood images.

http://www.pbs.org/newshour/infocus/floods/science.html

http://education.nationalgeographic.com/education/encyclopedia/flood/?ar_a=1

Science Inquiry

Have students do the estuary activity at the URL below. They will explain what an estuary is and why estuaries are important, build a model estuary, and examine how salinity affects aquatic plants.

http://www.state.nj.us/education/21cclc/casp/lsc/unit2/Lesson7.pdf

Biology Connection

With the activity at the following URL, students can identify the biotic and abiotic components of a freshwater ecosystem and create a freshwater ecosystem in a large plastic bottle. Then they can observe their mini-ecosystem over time to see what changes occur.

http://www.state.nj.us/education/21cclc/casp/lsc/unit2/Lesson3.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 13.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 13.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Where do streams originate?

- [Streams originate at their source. The source is likely to be in the high mountains where snow collects in winter and melts in summer, or the source might be a spring. A stream may have more than one source.]

2. Compare and contrast streams and rivers.

- [Streams are bodies of fresh water that flow through a channel. A stream may be any size. Rivers are large streams.]

3. What is an advantage and a disadvantage of living in floodplains?

- [Sample answer: An advantage of living in floodplains is that they have thick, fertile soil. A disadvantage is that they are prone to flooding.]

4. Compare and contrast ponds and lakes.

- [Both ponds and lakes are bodies of still water where water is blocked from flowing directly downhill. Ponds are small bodies of fresh water that usually have no outlet. Ponds are often fed by underground springs. Lakes are larger bodies of still water. Lake water is usually fresh water, but there are a few exceptions. Unlike a pond, a lake is usually drained by a stream.]

5. What are wetlands and what is the value of wetlands?

- [Wetlands are lands that are wet for a significant period of time each year. They are common where water and land meet. Wetlands are valuable because of their great biological diversity. Many species depend on wetlands to survive. Wetlands are also valuable because they naturally purify water. They remove pollutants such as fertilizer from water. In addition, wetlands act as a buffer between land and water and minimize the impact of floods.]

6. Consider an animal common in swamps and an animal common in rivers. What natural adaptations do they each have to live in their habitat?

- [Answers may vary but should reflect an understanding of the differences between rivers and swamps. For example, rivers have fresh water, whereas swamps may have fresh, salty, or brackish water. The water in a river may flow rapidly, whereas water moves through a swamp much more slowly and is likely to be low in oxygen.]

7. Deserts get little rain so why are they in danger of flash floods?

- [Deserts are in danger of flash floods because they have little vegetation to slow down runoff when rainfall is intense.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What types of streams have you seen in your area?

- [Depending on your area, students may have seen a range of streams, from small tributaries to large rivers such as the Mississippi.]

Why are bodies of water never really permanent?

- [Bodies of water are never really permanent because they are always changing. Streams and rivers constantly change their channels through erosion and deposition. Ponds and lakes may come and go with the seasons. Over time, ponds and lakes may disappear. They may be filled with sediments, the stream or river feeding them may dry up, or their outlet may grow because of erosion.]

Is it possible that your home could be flooded? What would you do if it were flooded?

- [You should move to higher ground as soon as possible and not return unless allowed to by authorities. A home that has been flooded is at risk of developing serious mold problems and flood waters may be contaminated with harmful substances or organisms. Flood waters may also make a home structurally unsound. If you can return home, prepare for the possibility of another flood. Have an evacuation plan and emergency flood kit. Consider the feasibility of using sandbags or other barriers to keep water out of your home. In all cases, evacuate when advised to do so.]

13.4 Lesson 13.3: Groundwater

Key Concepts

- Characteristics of groundwater
- Aquifers
- Springs
- Wells

Lesson Objectives

- Define groundwater.
- Explain the location, use, and importance of aquifers.
- Define springs.
- Describe how wells work and why they are important.

Lesson Vocabulary

- **aquifer:** permeable layer of underground rock, sand, or gravel that rests on an impermeable layer of rock and is saturated with groundwater
- **capillary action:** movement of a liquid such as water through narrow spaces because of intermolecular forces between the liquid and surrounding surfaces
- **impermeable:** unable to be penetrated by water
- **permeability:** ability to be penetrated by water because of the interconnectedness of pores within a material
- **porosity:** condition in which a material contains many small holes, or pores
- **spring:** place where the water table meets the surface so groundwater bubbles onto the surface
- **subsidence:** sinking of the land surface because of the extraction of groundwater below it
- **water table:** upper surface of groundwater
- **well:** circular hole dug or drilled down into an aquifer to allow people to access groundwater

Teaching Strategies

Introducing the Lesson

Ask students if they know the source of the water that is piped into their home or school. Possible sources could include a reservoir, lake, or well. Identify any correct responses, and then explain to the class that many people get their water from under the ground. This water, called groundwater, is accessed by wells. Tell students they will learn more about groundwater and how it's obtained in this lesson.

Activity

Use one or more of the four aquifer activities at the following URL when you teach this lesson: http://www.ngwa.org/fundamentals/teachers/pages/lesson-plans-from-ngwa.aspx. The activities are:

- How Water Flows in Aquifersactivity teaches students how water moves through an aquifer as well as how and why water storage in an aquifer changes over time.
- Making an Aquifer Modela follow-up to "How Water Flows in Aquifers," this activity teaches students more in-depth knowledge of aquifers and how they are an important component of the hydrologic cycle.
- Measuring Water Storage in Aquifersactivity builds on the previous two activities by determining the type of material that best contributes to aquifer water storage.
- Usability of Aquifer Waterthis activity, students will gain an appreciation for the importance of aquifers as drinking water sources and the reasons behind the need for water treatment.

Differentiated Instruction

Have less proficient readers and English language learners make a Frayer model for the term aquifer. They should draw a large box and divide it into quarters labeled "Definition," "Drawing," "Example," and "Nonexample." Then they should fill in each quarter with the relevant material.

Enrichment

Ask one or more students to learn about paving alternatives that may help reduce runoff and result in more water infiltrating the ground (see URLs below). Ask the students to summarize what they learn and share it with the rest of the class. This can introduce or follow up the science inquiry activity below.

http://www.tompkins-co.org/planning/vct/tool/pavementalternatives.html

http://brgov.com/dept/planning/pdf/bulletins/bull45.pdf

Science Inquiry

Challenge groups of students with the inquiry activity, "Groundwaterwe doing to our planet?" (see URL below). Students must solve the problem of how much runoff is created by an average shopping mall parking lot. The object is to determine how much water is lost that would otherwise have entered the groundwater system.

http://www.geosociety.org/educate/lessonplans/Groundwater.pdf

Overcoming Misconceptions

Some students may hold the misconception that groundwater and surface water are unconnected. Explain how surface water may become groundwater and vice-versa. Make sure students understand that both sources of water are part of the same global water cycle. To reinforce the correct conception, have students do the activity "What Goes on Down Under" at the following URL. They will identify sources for the recharge and discharge of groundwater and identify the connection between surface and groundwater.

http://www.wef.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=2534

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 13.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 13.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is groundwater?

- [Groundwater is fresh water that is located under Earth's surface. It is the largest reservoir of liquid fresh water on Earth.]

2. What is the water table?

- [The water table is the upper surface of groundwater.]

3. What are aquifers and why are they so important?

- [Aquifers are permeable layers of underground rock, sand, or gravel that rest on an impermeable layer of rock and are saturated with groundwater. Aquifers are so important because they are one of the main sources of fresh water for human use.]

4. Replenishing an aquifer is important because it makes the aquifer a resource that can last a long time. What do you think are ways to keep the amount of water used and the amount of water replenished the same?

- [*Sample answer*: Ways to keep the amounts of water used and replenished the same might include restricting less important uses of water, such as washing cars and watering lawns, especially during periods when less rain falls than normal.]

5. How does a well work?

- [A well is dug or drilled down into the ground below the level of the water table so it taps into an aquifer. A pump is generally used to bring water from the aquifer up to the surface.]

6. Since groundwater is largely unseen from the surface, how might you monitor how humans are affecting the amount of groundwater in an aquifer?

- [*Sample answer*: You might monitor the amount of groundwater in an aquifer by drilling holes in the ground to see how far below the surface the water table is and by monitoring the water level in wells that are drilled down into an aquifer.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Is water from a river or from a well more likely to be clean to drink?

- [The water is a well is more likely to be clean to drink, unless it is a very shallow well. Some of the water in an aquifer may have been deep underground for thousands or even millions of years. Even if recharge water is polluted, as it flows down though soil and rocks into an aquifer, many pollutants are filtered out of it. The water in a river may be polluted directly by people dumping pollutants into the water. It is also likely to be polluted by contaminants on the surface that are carried to the river by runoff.]

Why is overuse of groundwater a big concern?

- [Overuse of groundwater is a big concern because groundwater is a major source of the fresh water that humans need. Using up groundwater faster than it can be recharged may lead to wells running dry and subsidence of the land, which may cause damage to buildings and other structures.]

What policies might people put in place to conserve water levels in lakes and aquifers?

- [To conserve water levels in lakes and aquifers, people might put in place policies that limit water use to those uses that are essential, with stiff penalties for people who use water wastefully. Policies such as tax rebates might also encourage the use of water-conserving devices, such as low-flow toilets, washing machines, and showerheads.]

CHAPTER 14 HS TE Earth's Oceans

Chapter Outline

14.1 Chapter 14: Earth's Oceans

Chapter Overview

This chapter describes how Earth's oceans formed, ocean water composition, and ocean water movements (waves, tides, and currents). It also describes the seafloor and types of ocean organisms.

Online Resources

See the following Web site for an appropriate laboratory activity:

With the lab at the URL below, students will observe the effects of the layering of warmer and colder water and of water that is more or less saline. They will recognize that differences in salinity and temperature are the cause of differences in density of ocean water and the underlying cause of deep ocean currents.

- http://oceanservice.noaa.gov/education/lessons/hot_cold_lesson.html

These Web sites may also be helpful:

You can find several excellent videos pertaining to Earth's oceans at this URL: http://climate.nasa.gov/climate_reel/ .

You can access NeMO Explorer at the URL below. NeMO Explorer allows students to explore the NeMO seafloor observatory at Axial Seamount either geographically or by subject matter.

- http://www.pmel.noaa.gov/vents/nemo/explorer.html

The URL below provides 165 lesson plans developed to bring entire classrooms "on board" for exploration and discovery of ocean-related topics, such as deep-sea hydrothermal vents and benthic creatures on the ocean floor.

- http://oceanexplorer.noaa.gov/edu/welcome.html

You can find excellent articles on Earth's oceans at the Oceans Alive! URL below.

- http://legacy.mos.org/oceans/planet/index.html

At the following URL, you can access many videos and interactives pertaining to the oceans and the atmosphere.

- http://www.teachersdomain.org/browse/?start=0&fq_hierarchy=k12.sci.ess.watcyc.asint

Pacing the Lessons

TABLE 14.1: short caption

Lesson	Class Period(s) (60 min)
14.1 Introduction to the Oceans	1.0
14.2 Ocean Movements	3.0
14.3 The Seafloor	1.0
14.4 Ocean Life	2.0

14.2 Lesson 14.1: Introduction to the Oceans

Key Concepts

- Significance of the oceans
- The continental margin
- Composition of ocean water
- The water column

Lesson Objectives

- Explain the significance of the oceans.
- Describe the composition of ocean water.
- Define the parts of the water column and oceanic divisions.

Lesson Vocabulary

- **aphotic zone:** ocean zone deeper than 200 meters where too little sunlight penetrates for photosynthesis to occur
- **biomass:** total mass of living organisms in a given area
- **intertidal zone:** ocean zone that is closest to shore, between the high and low tide marks
- **neritic zone:** ocean zone that lies over the continental shelf between the intertidal zone and the oceanic zone
- **oceanic zone:** ocean zone that consists of the open ocean farther from shore than the neritic zone
- **photic zone:** ocean zone in the top 200 meters of water that receives enough sunlight for photosynthesis to occur
- **salinity:** concentration of dissolved salts in salt water
- **water column:** vertical column of ocean water, which is divided into different zones according to depth

Teaching Strategies

Introducing the Lesson

Introduce Earth's oceans by asking students how ocean water differs from water in a pond or river. (Ocean water is salty; water in a pond or river is fresh water.)

Question: If I had a liter of ocean water, how much salt do you think it would contain?
Answer: Answers may vary. The correct answer is about 35 grams.

Tell students they will learn more about the composition of ocean water in this lesson.

Discussion

Discuss how vertical and horizontal ocean zones are related to the needs of living organisms. Point out that the main vertical ocean zones (photic and aphotic zones) differ in the amount of sunlight they receive, whereas horizontal ocean zones (intertidal, neritic, and oceanic zones) differ in the amount of nutrients they receive. Tell students that zones closer to shore have more nutrients available to living things.

Question: Why are there more nutrients near shore than out in the open ocean?

Answer: Most nutrients enter the ocean from the land. They are washed into the water by runoff and rivers that flow into the ocean.

Differentiated Instruction

Have students complete a KWL chart for the lesson. Before they read the lesson, they should list in the "Know" column anything they already know about the oceans and in the "Want to Know" column what they would like to know. After they read the lesson, they should list in the "Learned" column what they learned about the oceans from the lesson.

Enrichment

Ask interested students to investigate the amazing 1959 descent of the bathyscaphe Trieste with two crewmembers to the Challenger Deep, the deepest place on Earth in the Mariana Trench. This was the last time a submersible vehicle would travel to this depth until 2012, when the film director James Cameron made the trip alone in the submersible Deepsea Challenger. Have the students them create a Web page about the Trieste and its accomplishment. Urge other students in the class to visit the Web page.

Science Inquiry

Explain the concept of specific heat as the amount of heat (in calories) needed to raise the temperature of one gram of a substance by one degree Celsius. Tell students that one of water's most significant properties is that it takes a lot of energy to make it get hot. Ocean water, for example, has to absorb about 0.9 calories of heat for the temperature of one gram of water to increase by one degree Celsius. The specific heat of soil is much lower. It takes only about 0.3 calories to raise the temperature of one gram of soil by one degree Celsius. At the URL below, students can watch an interactive simulation that demonstrates the different specific heats of water and land. Students will observe the temperature of a soil sample rising faster than the temperature of the same amount of water when both are exposed to the same heat sources. Following the simulation, challenge students to relate the differences in specific heat of land and water to differences in the temperatures of land and water between day and night and from one season to the next. Ask them to predict how the differences in temperature affect world and regional (coastal vs. continental) climates.

http://oceanservice.noaa.gov/education/pd/oceans_weather_climate/media/specific_heat.swf

Overcoming Misconceptions

In the article at the following URL, you can find a list of 110 misconceptions that have been documented in students. Discuss with your class the misconceptions that are especially germane to the content of this chapter.

http://www.tos.org/oceanography/archive/20-4_feller.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 14.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 14.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What percent of Earth's surface is covered by water?

   - [About 70 percent of Earth's surface is covered by water.]

2. How do the oceans help to moderate Earth's temperatures?

   - [The oceans, along with the atmosphere, keep temperatures fairly constant worldwide by distributing heat around the planet. The oceans absorb heat near the equator and then move it toward the poles. The oceans also moderate climates in coastal areas. Summer temperatures are not as hot and winter temperatures are not as cold because ocean water takes longer than land to heat up or cool down.]

3. What is the most common substance that is dissolved in ocean water?

   - [The most common dissolved substance is the salt sodium chloride.]

4. Define density. Why is density important to the water column?

   - [Density is mass per unit volume. The density of ocean water increases from the top to the bottom of the water column as water temperature decreases and water pressure increases.]

5. Compare and contrast the photic and aphotic zones.

   - [The photic and aphotic zones are ocean zones based on depth of water. The photic zone consists of the top 200 meters of water. This is the depth to which enough sunlight can penetrate to allow photosynthesis to occur. The aphotic zone consists of water below 200 meters. This is the depth to which too little sunlight can penetrate to allow photosynthesis to occur.]

6. Briefly describe the types of organisms found in the intertidal, neritic, and oceanic zones.

   - [Students can read about ocean organisms in the lesson "Ocean Life." After learning about ocean zones in the present lesson, they might infer that intertidal organisms must adapt to water in constant motion. Barnacles, which can cling to surfaces, are an example of an intertidal organism. Students also might infer that neritic organisms could include algae and other photosynthesizers because water in this zone is not very deep. Oceanic organisms would vary by depth of water, but would include fish.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How do water motions such as tides and waves affect living creatures in and near the sea?

- [Organisms that live in the intertidal zone must adapt to the constantly changing conditions there, including the constant motion of water because of waves and the continuous changes in water level because of tides.]

Is it possible to have a river in the middle of the ocean?

- [Yes; currents are similar to rivers in the ocean. Currents transport ocean water both on the surface of the oceans and deep below the surface.]

What factors affect the movement of ocean water? How do these factors affect the world's climate and the ocean's ecosystem?

- [Winds affect the movement of ocean water by causing waves. The moon's and sun's gravity affect the movement of ocean water by causing tides. Prevailing winds, Earth's rotation, and the shape of ocean basins affect the movement of ocean water by causing or influencing the direction of surface currents. Differences in water density affect the movement of ocean water by causing deep currents. Ocean currents affect the world's climate by transporting heat around the globe. All ocean motions affect the ocean's ecosystem by constantly moving ocean water so that heat and nutrients move throughout the ocean.]

14.3 Lesson 14.2: Ocean Movements

Key Concepts

- Waves
- Tides
- Surface currents
- Deep currents

Lesson Objectives

- Define waves and explain their formation.
- Describe what causes tides.
- Describe how surface currents form and how they affect the world's climate.
- Describe the causes of deep currents.
- Relate upwelling areas to the food chain.

Lesson Vocabulary

- **Coriolis effect:** apparent deflection of global winds and surface ocean currents because of Earth's rotation
- **downwelling:** sinking of higher density water from the top to the bottom of the ocean
- **gyre:** one of five major loops created by surface ocean currents
- **high tide:** highest water level in each tidal cycle
- **longshore current:** local surface current that moves along the shore in the same direction as the prevailing winds
- **low tide:** lowest water level in each tidal cycle
- **neap tide:** tide with the smallest range between high and low tide, which occurs twice in each lunar month during first and third quarters of the moon
- **rip current:** strong surface current that flows seaward from near the shore
- **spring tide:** tide with the largest range between high and low tides, which occurs twice in each lunar month during new and full moons
- **storm surge:** high water pushed ashore by storm winds
- **surface current:** ocean current caused mainly by winds that flows through the surface of the water
- **thermohaline circulation:** movement of ocean water in deep currents, which occur because of differences in temperature and salinity of the water
- **tidal range:** difference between high and low tide in a given tidal cycle
- **tide:** regular rise or fall of Earth's surface water twice a tidal day as a result of the moon's and sun's gravitational attraction and Earth's rotation
- **upwelling:** process in which nutrient-rich water rises from the deep ocean to the surface
- **wave:** transfer of energy through matter, such as the transfer of wind energy through water in an ocean wave

Teaching Strategies

Introducing the Lesson

Introduce currents and other ocean water motions with the fascinating animation at the URL below. The animation shows ocean surface currents from June 2005 to December 2007 based on data from NASA satellites. Students can observe how bigger currents like the Gulf Stream carry warm waters across thousands of miles at high speeds and how coastal currents like the Agulhas in the Southern Hemisphere move equatorial waters toward Earth's poles. They will also observe many other ocean currents that are confined to particular regions and form slow-moving, circular pools called eddies. Tell students they will learn why ocean water moves in these ways when they read this lesson.

http://www.nasa.gov/topics/earth/features/perpetual-ocean.html

Building Science Skills

With the activity "Ups and Downs" at the following URL, students can investigate the causes of tides. They will explain and model forces that cause and affect tides, analyze variations in tidal patterns and water levels in selected areas, and infer and discuss some conditions that may have influenced these variations. They will also explain how tides affect our lives and the importance of monitoring tides.

http://oceanservice.noaa.gov/education/lessons/ups_downs.html

Differentiated Instruction

Pair English language learners with other students, and ask partners to make a cycle diagram showing the monthly tide cycle. The diagram should show the phases of the moon and spring and neap tides. Suggest that students keep their cycle diagram in their science notebook.

Enrichment

Challenge students to predict how knowledge of waves might be important to surfers. Then have them investigate "surfology," the application of knowledge about waves to the sport of surfing. (They can start with the URLs below.) They should learn more about waves, including how they differ depending on factors such as wind, fetch, swell period, and the ocean floor (bathymetry). They should also learn how to choose the best swells for surfing. Ask the students to create a poster to convey what they learn. Display their poster in the classroom.

- http://www.surfing-waves.com/waves/best_waves.htm
- http://surfing.isport.com/surfing-guides/how-to-read-waves-for-surfing
- http://www.surfscience.com/topics/learn-to-surf/surfing-101/how-to-choose-a-good-wave/

Science Inquiry

With the inquiry activity at the following URL, groups of students will try to answer the question: What factors drive water circulation in the Arctic Ocean? By doing the activity, they will be able to identify the primary driving forces for ocean currents. They will also be able to infer the type of water circulation to be expected in the Arctic Ocean, given information on temperature, salinity, and bathymetry.

http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_c_events.pdf

Overcoming Misconceptions

Students may think that the Coriolis effect is a force, like the force of gravity, and that it causes the actual deflection of global winds and surface currents. Use a globe and other items to create a three-dimensional model that demonstrates the Coriolis effect and shows that is only an apparent deflection of winds or currents. Explain how the Coriolis effect occurs because of Earth's rotation. Point out that Earth's surface moves, not the air or water.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 14.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 14.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What factors of wind determine the size of a wave?

   - [The size of a wave is determined by the strength of the wind, the length of time it blows, and the distance over which it blows.]

2. Tsunamis are sometimes incorrectly called "tidal waves." Explain why this is not correct.

   - [Tsunamis are waves that are caused by disturbances to ocean water, such as earthquakes, and are not related to tides.]

3. Describe what causes tides.

   - [Tides are caused primarily by the pull of the moon's gravity on Earth's water and secondarily by the pull of the sun's gravity.]

4. What is a tidal range? In what types of tides is the tidal range the greatest? The least?

   - [A tidal range is the difference in sea level between high and low tide at a given location The tidal range is the greatest in spring tides and the least in neap tides.]

5. Why do some places have a greater tidal range than other places?

   - [Some places have a greater tidal range than other places because tidal range is influenced by a number of factors that differ from place to place, such as the slope of the seafloor.]

6. What causes the patterns of surface currents in the ocean?

   - [The patterns of surface currents are caused by global wind patterns, Earth's rotation (Coriolis effect), and the shape of the ocean basins.]

7. How do ocean surface currents affect climate?

- [Ocean surface currents affect climate by distributing heat around the planet. They transfer heat from equatorial regions to high latitudes. For example, the Gulf Stream carries warm water that is heated at the equator up the East Coast of North America and then across the Atlantic Ocean to Europe. The Gulf Stream's warm water raises temperatures in the North Sea and in western European cities such as London, U.K.]

8. What is the Coriolis effect?

- [The Coriolis effect is the apparent deflection of global winds and surface ocean currents because of Earth's rotation.]

9. What process can make deep, dense water rise to the surface?

- [The process of upwelling can make deep, dense water rise to the surface. Upwelling generally occurs along a coast when strong winds blow surface water away from the shore. This leaves a void that is filled by deep water that rises to the surface.]

10. Why are upwelling areas important to marine life?

- [Upwelling areas are important to marine life because upwelling brings nutrients that have collected on the bottom up to surface. The nutrients support the growth of plankton and form the base of a rich ecosystem.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Some scientists have hypothesized that if enough ice in Greenland melts, the Gulf Stream might be shut down. Why might this happen?

- [This might happen because when glaciers melt, they add fresh water to the ocean and fresh water is less dense than salt water. This less dense fresh water would not sink because it is similar in density to the warm water in the Gulf stream coming north from the Caribbean. There might be enough of this fresh water to push the Gulf Stream out of the North Atlantic Ocean, preventing the Gulf Stream from making it to Europe.

If the Gulf Stream shuts down, what would be the result on climate in Europe?

- [If the Gulf Stream shuts down, the climate in western Europe would be colder.]

How do the movements of ocean water contribute to the ocean's life?

- [Upwelling brings nutrients to the surface that support ocean life. Movements of the water also distribute heat throughout the oceans and affect the distribution of organisms that require a specific temperature range to survive.]

14.4 Lesson 14.3: The Seafloor

Key Concepts

- How scientists study the seafloor
- Features of the seafloor
- Ocean resources

Lesson Objectives

- Describe the methods scientists have for studying the seafloor.
- Describe the features of the seafloor.
- List the living and non-living resources that people use from the seafloor.

Lesson Vocabulary

- **bottom trawling:** fishing by dragging nets along the ocean floor
- **manganese nodule:** rock on the ocean floor that contains valuable minerals including manganese

Teaching Strategies

Introducing the Lesson

Generate student interest in the ocean floor by showing them one or more animated 3-D bathymetric maps of features of the ocean floor. You can find a collection of maps at the first URL below. http://oceanexplorer.noaa.gov/gallery/maps/maps.html

Activity

Students can take a virtual trip to the seafloor and explore the hydrothermal vents of the Magic Mountain Chimney Fields by clicking on the interactive map below. When they click on an area of the map, they will view a virtual fly-through and panorama of one of four sites. Ask students to describe what they observe. Discuss these features of the ocean floor with the class.

http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html

Building Science Skills

Students can build science skills with the sunken sub activity at the URL below. They will identify features of the ocean floor, draw an ocean floor profile using data points, and then use the profile to find a sunken submarine.

http://www.smithsonianeducation.org/educators/lesson_plans/ocean/acrobat/secret.pdf

Differentiated Instruction

Work with students to make a cluster map of ways to study the seafloor using an overhead transparency or the blackboard. Write "Studying the Seafloor" in a central circle. Four surrounding circles should be labeled "Mapping," "Sampling Remotely," "Submersibles, and "Remotely Operated Vehicles." As you discuss each way of studying the seafloor, have students add important points or keywords to the appropriate circles.

Enrichment

Tell students that the growth of manganese nodule is thought to be one of the slowest of all geological phenomena. It takes several million years for a nodule to grow just a centimeter in diameter. Call on one or more volunteers to investigate the challenging topic of how manganese nodules grow, regarding which there are several current theories. Students can find information at the following URLs. Ask the student(s) to create a poster or PowerPoint presentation to explain the various geological processes that can increase nodule size. Then have them lead a class discussion of implications of the slow growth rate for the use of nodules as mineral resources.

http://www.isa.org.jm/files/documents/EN/Brochures/ENG7.pdf

http://www.currentscience.ac.in/Downloads/article_id_078_03_0300_0308_0.pdf

Science Inquiry

The activity at the following URL focuses on the use of robots in ocean floor exploration. The activity is designated for middle school students but it is also appropriate for high school students. The activity addresses the question: How can underwater robots be used to assist scientific explorations? Learning objectives include contrasting at least three types of underwater robots used for scientific explorations, discussing the advantages and disadvantages of using underwater robots in scientific explorations, and identifying robotic vehicles best suited to carry out a specific underwater exploration task.

http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Overcoming Misconceptions

As a homework assignment have students use Internet sources, such as those below, to find at least one misconception about the seafloor. The next day, call on students to read their misconceptions and restate them as correct conceptions. Discuss each correct conception and evidence that supports it.

- http://www.tos.org/oceanography/archive/20-4_feller.pdf
- http://beyondpenguins.ehe.osu.edu/issue/polar-oceans/common-misconceptions-about-oceans#misconceptions
- http://www.encorewiki.org/display/OSER/Ocean+Misconceptions

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 14.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 14.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Scientists sometimes say that we know less about the oceans than the far side of the Moon. Why is it so difficult to learn about the oceans?

- [It is so difficult to learn about the oceans because people cannot go very far below the water's surface due to the conditions at greater depths, including the extremely high pressure of the water. Scuba divers, for example, can dive only to about 40 meters below the surface and they cannot stay down there for very long.]

2. The atmospheric pressure is about 1 kilogram per centimeter squared (14.7 pounds per square inch, or 1 atmosphere) at sea level. About what is the pressure if you are 100 meters deep in the ocean?

- [For every 10 meters you go below sea level, the pressure increases by 14.7 pounds per square inch (psi), so at 100 meters the pressure is:

(14.7 psi $\times$ 10) + 14.7 psi (pressure at sea level) = 161.7 psi.]

3. Where on the ocean floor will you find the greatest amount of living organisms?

- [You will find the greatest amount of living organisms on the ocean floor where the water is less than 200 meters deep because this is where photosynthesis can occur. Water this shallow is found relatively close to shore in the neritic zone.]

4. Compare and contrast the continental shelf and the abyssal plain.

- [The continental shelf is the gently sloping ocean floor at the edges of continents. The abyssal plain is one of the flat areas that make up much of the ocean floor out past the continental shelf.]

5. Why do you think mapping the seafloor is important to the Navy? What part of the seafloor is the Navy most interested in?

- [Answers may vary. Sample answer: The Navy uses submarines, so it is important for them to know how deep the ocean is.]

6. Why is bottom trawling damaging to the seafloor?

- [Bottom trawling is damaging to the seafloor because the large nets disturb seafloor ecosystems.]

7. As world population grows and the ocean is called on to provide more and more resources, what can people do to be sure the resources are used sustainably?

- [People can avoid overharvesting fish so their rate of reproduction can keep up with the rate at which people consume them.]

8. What is a manganese nodule?

- [A manganese nodule is a rock on the ocean floor that contains valuable minerals, especially manganese.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If the seafloor is not well known, how much do you think is known about marine life?

- [The oceans are home to a large portion of all life on Earth. There are likely to be many marine species that live on or near the seafloor that are unknown or poorly known.]

What methods are needed to learn about organisms at the ocean surface, the mid-depths, or on the seafloor?

- [Different methods are needed to learn about organisms at different depths. For example, it might be possible to study organisms at the ocean surface with satellites orbiting Earth. To study organisms on the seafloor, in contrast, might require the use of submersibles.]

Are techniques that are used for understanding ocean physics, chemistry, and geology also useful for studying marine life?

- [Basic scientific methods and some techniques such as sampling methods are also likely to be useful for studying marine life.]

14.5 Lesson 14.4: Ocean Life

Key Concepts

- Types of ocean organisms
- Interactions among ocean organisms

Lesson Objectives

- Describe the different types of ocean organisms.
- Describe the interactions among different ocean organisms.

Lesson Vocabulary

- **chemosynthesis:** process of using chemical energy to make food
- **hydrothermal vent:** fissure at a mid-ocean ridge where hot mineral water pours out
- **invertebrate:** animal that lacks a backbone
- **phytoplankton:** "plant-like" plankton such as algae that make food by photosynthesis
- **plankton:** diverse group of mainly microscopic marine organisms that are suspended in the photic zone and form the basis of most marine food chains; include phytoplankton and zooplankton
- **primary productivity:** creation of food energy by photosynthesis or chemosynthesis
- **reef:** large underwater structure created from the calcium carbonate skeletons of coral organisms
- **vertebrate:** animal that has a backbone
- **zooplankton:** "animal-like" plankton that consume phytoplankton

Teaching Strategies

Introducing the Lesson

Share the following facts and figures about living things in the ocean with your students as an introduction to ocean life.

- Life began in the seas as long ago as 3.8 billion years. The first land dwellers appeared far more recently, at just 400 million years ago.
- Today, as much as 80 percent of all life on Earth is found in the ocean.
- Tiny phytoplankton provide 50 percent of the oxygen in Earth's atmosphere and form the basis of ocean food chains, all the way up to big fish, marine mammals, and humans.
- A study of a deep-sea community found almost 900 species from more than 100 families in an area about half the size of a tennis court. More than half of these species were unknown until this discovery.

- Coral reefs are the nurseries of the ocean and biodiversity hot spots. On some tropical coral reefs, there may be a thousand species per square meter!

Collaborative Learning

Students can work together to learn about marine food webs by doing the group activity and extension at the URL below. Groups will distinguish between different trophic levels, describe examples of food chains in different major marine ecosystems, and order organisms in a food chain by trophic level. With the extension activity, groups will try to fit their food chains together to create a single marine food web.

http://education.nationalgeographic.com/education/activity/marine-food-chains-and-biodiversity/?ar_a=1

Differentiated Instruction

Have students make a Venn diagram comparing and contrasting what are arguably the most important organisms in the oceans: phytoplankton and zooplankton. Discuss with students why these organisms are so important. Have them sketch a simple marine food chain that contains both types of plankton.

Enrichment

Ask a few students to learn more about hydrothermal vent ecosystems and then teach the topic to the rest of the class. Suggest that they start with the URLs below. They should include images of, and interesting facts about, vent organisms in their presentation. They should also spend some time discussing threats to hydrothermal vent communities posed by mining.

- http://www.pmel.noaa.gov/vents/nemo/explorer/concepts/hydrothermal.html
- http://www.botos.com/marine/vents01.html
- http://www.boundless.com/microbiology/microbial-ecology/microbial-symbioses/hydrothermal-vent-microbial-ecosystems/

Science Inquiry

Challenge students with the questions: Why are coral reefs important, and what can be done to protect them from major threats? Then have them do the inquiry activity below. In the activity, they will identify how coral reefs benefit human beings, major threats to coral reefs, and major components of the Coral Reef Early Warning System. They will also obtain and analyze several types of oceanographic data from remote-sensing satellites. Finally, they will identify and discuss actions that can be taken to reduce or eliminate threats to coral reefs.

http://oceanservice.noaa.gov/education/lessons/keep_watch.html

Overcoming Misconceptions

Students may assume incorrectly that coral reefs are found in all oceans. Explain that corals are typically found only in tropical and subtropical waters because coral organisms have very specific needs in terms of temperature, water salinity, and light.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 14.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 14.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is an invertebrate? Name two types.

- [An invertebrate is an animal that lacks a backbone. Types may vary. They might include sea slugs, sea anemones, starfish, octopi, squid, clams, sea stars, sponges, sea worms, crabs, mussels, and/or lobsters.]

2. What is the role of phytoplankton in ocean ecosystems?

- [Phytoplankton are the primary producers in most ocean ecosystems.]

3. If fish require oxygen to live, why can't they survive on land?

- [Fish have gills that allow them to obtain oxygen from water. They cannot use oxygen in the air, so they can't survive on land.]

4. Are polar bears marine mammals or land animals like all other bears? What is your opinion?

- [Answers may vary. *Sample answer*: In my opinion, polar bears are marine mammals because they spend most of their time at sea and depend on marine organisms for food. They also have adaptations for marine life, such as the ability to swim long distances.]

5. What are four major habitats of ocean organisms?

- [Answers may vary. The four habitats of ocean organisms described in the lesson are the intertidal zone, coral reefs, the oceanic zone, and hydrothermal vents.]

6. Describe adaptations that an organism that lives in a reef might have. How might these adaptations be different from an organism that lives in the open ocean?

- [*Sample answer*: Because reefs are such diverse, densely populated ecosystems, an organism that lives in a reef might have adaptations for living in symbiotic relationships with other organisms or for defending itself from predators. A reef organism is also likely to be relatively small to fit into the nooks and crannies of a reef. The open ocean, in contrast, is not as densely populated. An organism that lives in the open ocean might have adaptations that help it find food or attract prey, especially in the dark if it lives in the aphotic zone. It may also have adaptations that make it an excellent swimmer.]

7. Describe the importance of maintaining ocean ecosystems.

- [Answers may vary. *Sample answer*: Ocean ecosystems, like all ecosystems, should be valued for their biodiversity. Ocean ecosystems are home to the majority of organisms on Earth, and we depend on animals in ocean ecosystems for a relatively large proportion of our food. In addition, ocean producers are a major source of oxygen in the atmosphere.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How does the ocean interact with the atmosphere?

- [The ocean and the atmosphere exchange gases, including oxygen and carbon dioxide. Moving air in the atmosphere (wind) causes ocean movements (waves and surface currents), and ocean water may heat or cool the air above it.]

How is energy transferred around the planet and how does this affect life on Earth?

- [Energy is transferred around the planet by ocean currents and moving air (winds and air masses). The transfer of energy gives Earth less extreme and more stable temperatures. This helps living things adapt and survive on Earth.]

What would be the effect of pollution on the oceans?

- [Pollution would travel throughout the oceans because of ocean currents and other water movements. It might harm or even kill marine organisms.]

CHAPTER 15 HS TE Earth's Atmosphere

Chapter Outline

15.1 Chapter 15: Earth's Atmosphere

Chapter Overview

This chapter describes the properties, significance, and layers of Earth's atmosphere. It also explains how energy is transferred in the atmosphere and how air circulates through the atmosphere and flows over Earth's surface as wind.

Online Resources

See the following Web sites for appropriate laboratory activities:

Students can learn how heat is transferred in the atmosphere by doing the heat transfer lab at the URL below. They will observe the three main heat transfer methods (radiation, conduction, and convection). The complete lab can be downloaded after free registration at the Web site.

- http://betterlesson.com/lesson/5214/04-heat-transfer-lab

With the lab at the following URL, students will analyze and graph weather data to investigate the formation of a thermal circulation cell and land and sea breezes.

- http://kingfish.coastal.edu/marine/risingtide/breeze/index.html

These Web sites may also be helpful:

You can find many common student misconceptions about the atmosphere at this URL: http://www.csulb.edu/ lhenriqu/NARST2000.htm.

The following URL is a video clip in which Bill Nye the Science Guy explains the layers of the atmosphere in his usual entertaining fashion.

- http://www.watchknowlearn.org/Video.aspx?VideoID=25695&CategoryID=2666

This excellent video, "The Precious Envelope," from the University of Maryland introduces students to the atmosphere and its importance as well as how human actions are changing it.

- http://www.watchknowlearn.org/Video.aspx?VideoID=18356&CategoryID=2666

You can find a set of useful slides covering the information in the lesson "Air Movement" at this URL: http://www.slideshare.net/cpelfrey/global-and-local-winds.

Pacing the Lessons

TABLE 15.1: short caption

Lesson	Class Period(s) (60 min)
15.1 The Atmosphere	1.5
15.2 Atmospheric Layers	1.5
15.3 Energy in the Atmosphere	2.0
15.4 Air Movement	2.0

15.2 Lesson 15.1: The Atmosphere

Key Concepts

- Significance of the atmosphere
- Composition of the atmosphere
- Air pressure and density

Lesson Objectives

- Describe the importance of the atmosphere to our planet and its life.
- Outline the role of the atmosphere in the water cycle.
- List the major components of the atmosphere and their functions.
- Describe how atmospheric pressure changes with altitude.

Lesson Vocabulary

- **air pressure:** force of air pressing on a given area
- **altitude:** height above sea level
- **atmosphere:** layer of gases that surround a planet
- **greenhouse gas:**gas such as carbon dioxide or methane that absorbs and holds heat that is re-radiated from the surface of the planet into the atmosphere
- **humidity:** amount of water vapor in the atmosphere
- **ozone:** gas consisting of molecules of three oxygen atoms each (O_3), which is a pollutant in the lower atmosphere but in the upper atmosphere absorbs and protects living things from ultraviolet radiation
- **respiration:** process in which organisms convert sugar into useful energy, using oxygen and releasing carbon dioxide
- **ultraviolet (UV) radiation:** high-energy radiation from the sun that can be harmful to organisms on Earth
- **water vapor:** gaseous form of water
- **weather:** temporary state of the atmosphere in a given area, such as its temperature and humidity

Teaching Strategies

Introducing the Lesson

Introduce the atmosphere by placing it in context as one of Earth's four geospheres: lithosphere (solid rocky Earth), biosphere (living things on Earth), hydrosphere (Earth's waters), and atmosphere (body of air surrounding the planet). Tell students they will learn about Earth's atmosphere in this chapter.

Demonstration

Demonstrate air pressure with a simple but effective activity. Do demonstration #26, "Stubborn Paper Wad," at the following URL. In the demonstration, you will place a bottle on its side on a table, put a pea-sized wad of paper just inside the mouth of the bottle, and blow hard and fast into the bottle. The paper wad should fly out of the bottle toward you (adjust wad placement and degree of blowing if necessary). Ask students to explain why this happens. (It occurs because the rapidly moving air goes past the wad and strikes the bottom and sides of the bottle, increasing air pressure inside the bottle. Air suddenly rushes out of the bottle to equalize the pressure, and it pushes the wad out with it.)

http://www.colorado.edu/geolsci/courses/DEMOS/seicontribution/101_lowtech_earth_science%20demos.pdf

Differentiated Instruction

Have students make a cluster diagram of the significance of the atmosphere. It should include the following ways the atmosphere is important:

- Atmospheric gases are needed by living organisms for photosynthesis and respiration.
- The atmosphere is a crucial part of the water cycle.
- The ozone layer protects living things from harmful UV radiation.
- The atmosphere keeps Earth's temperature moderate.
- Gases in the atmosphere carry sound waves and allow us to hear.

Enrichment

Suggest that curious students do a Web quest to answer these questions: What is the "Goldilocks principle"? How does this principle apply to Earth's atmosphere? Some useful references are supplied below. They should share their answers with the class.

- http://curiosity.discovery.com/question/what-is-goldilocks-principle
- http://www.windows2universe.org/earth/interior/Goldilocks.html

Science Inquiry

With the teacher-developed inquiry activity at the URL below, students will construct a cumulative graph and then draw connections between the amounts of atmospheric gases and changes in life patterns on Earth.

http://betterlesson.com/lesson/5027/02-atmosphere-and-living-things

Overcoming Misconceptions

Studies have identified several student misconceptions about air pressure, a few of which are listed below. Think of a counter-example for each misconception that shows the misconception is false.

- Air exerts pressure only when it is flowing (as in wind).
- Gases flow just like liquids, so they can be unevenly distributed in a container.
- Gases exert pressure only if they undergo a force or are heated.
- Gases exert pressure in only one direction (usually down).
- Air pressure is not the same in all directions.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 15.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 15.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What gas is used and what gas is created during photosynthesis? What gas is used and what gas is created during respiration?

- [During photosynthesis, carbon dioxide is used and oxygen is created. During respiration, oxygen is used and carbon dioxide is created.]

2. Describe two reasons why photosynthesis is important.

- [Photosynthesis is important because it provides food for most living things. It also adds oxygen to the atmosphere, and most organisms need oxygen for respiration in order to get usable energy from food.]

3. On an unusual February day in Portland, Oregon, the temperature is 18 °C (65 °F) and it is dry and sunny. The winter climate in Portland is usually chilly and rainy. How could you explain a warm, dry day in Portland in winter?

- [The weather on any given day in a location can be very different from the average weather, or climate, for that location. The next day in Portland may be wet and chilly, which is more typical for the climate.]

4. What important role do greenhouse gases play in the atmosphere?

- [Greenhouse gases trap heat so that daily temperature fluctuations are small and temperature is more moderate.]

5. Why do your ears pop when you are in an airplane and the plane descends for a landing?

- [Your ears pop as the plane descends because the air pressure outside your ears increases as the altitude decreases. At some point, the air molecules inside your ears suddenly move through small tubes in your ears to equalize the pressure. This is felt as a popping sensation.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How would Earth be different if it did not have an atmosphere?

- [There are many ways Earth would be different if it did not have an atmosphere. Life as we know it would not be able to survive without the gases in the atmosphere. There would also be no weather and therefore no weathering without the atmosphere. Without weathering, there would be no soil and Earth's surface would not wear down. For example, impact craters from meteorites would not weather away but would remain on the surface indefinitely, as they do on the moon.]

What are the most important components of the atmosphere?

- [The most important components of the atmosphere for living things are oxygen and carbon dioxide. Oxygen is needed for respiration, and carbon dioxide is needed for photosynthesis. Water vapor in the atmosphere is also important. It is needed for the water cycle and weather.]

How does the atmosphere vary with altitude?

- [The density and pressure of the atmosphere decrease with increasing altitude. The temperature of the atmosphere also varies with altitude but in a more complex way than density and pressure, first decreasing, then increasing, and finally decreasing again.]

15.3 Lesson 15.2: Atmospheric Layers

Key Concepts

- Air temperature
- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Ionosphere
- Magnetosphere
- Exosphere

Lesson Objectives

- List the major layers of the atmosphere and their temperatures.
- Discuss why all weather takes place in the troposphere.
- Discuss how the ozone layer protects the surface from harmful radiation.

Lesson Vocabulary

- **aurora:** spectacular light display that occurs in the ionosphere near the poles when charged particles from solar storms energize oxygen and nitrogen molecules in the atmosphere
- **exosphere:** outermost layer of the atmosphere where gas molecules are extremely far apart
- **inversion:** situation in which warm air lies above cold air
- **ionosphere:** layer of ions within the thermosphere
- **magnetosphere:** charged particles beyond the atmosphere that are held in place by Earth's magnetic field
- **mesosphere:** layer of the atmosphere that lies between the stratosphere and the thermosphere and where temperature decreases with increasing altitude
- **ozone layer:** layer within the stratosphere where ozone gas is concentrated
- **solar wind:** high-speed protons and electrons traveling through the solar system from the sun and extending millions of kilometers out into space
- **stratosphere:** layer of the atmosphere that lies between the troposphere and the mesosphere and where temperature increases with increasing altitude because of the concentration of ozone in this layer
- **temperature gradient:** change in temperature with distance
- **thermosphere:** layer of the atmosphere that lies between the mesosphere and exosphere and where temperature increases with increasing altitude
- **troposphere:** lowest layer of the atmosphere that lies between Earth's surface and the thermosphere and where temperature decreases with increasing altitude

Teaching Strategies

Introducing the Lesson

Use the teacher-made rap at the URL below to introduce layers of the atmosphere. The rap uses a familiar tune from Kanye West. It repeats the names of the layers in the refrain and describes a few features of each layer in the verses.

http://www.watchknowlearn.org/Video.aspx?VideoID=26842&CategoryID=2666

Activity

Have students do the very informative interactive activity at the following URL to learn about the layers of the atmosphere.

http://www.watchknowlearn.org/Video.aspx?VideoID=46675&CategoryID=2666

Differentiated Instruction

Suggest that students make a compare/contrast table for atmospheric layers. Have them use the following table headings: Name of Layer, Temperature Gradient, and Distinguishing Feature(s). For example, for the troposphere, temperature decreases and a distinguishing feature is that all weather takes place in this layer.

Enrichment

Ask a few students to investigate the effects of the hole in the stratospheric ozone layer on living things. They can start with the URL below. Ask them to make a poster or Web page to illustrate the concepts.

- http://www.epa.gov/ozone/science/effects/
- http://www.eco-action.org/dt/ozone.html
- http://www.theozonehole.com/askthescientist.htm

Science Inquiry

Show students how changing air temperature affects air pressure with the simple demonstration "The Collapsing Bottle" (demonstration #37 at the URL below). You will half fill a plastic bottle with hot water, empty the bottle, and then immediately place the cap on it. Students will observe that the bottle soon collapses. Challenge them to explain why this happens. (The hot water heats the air inside the bottle. After the bottle is emptied and capped, the air inside cools, takes up less space, and exerts less pressure on the inside of the bottle. The greater air pressure outside the bottle causes it to collapse.) Challenge students to relate their observations and explanation to the behavior of air in the atmosphere when it is heated or cooled.

http://www.colorado.edu/geolsci/courses/DEMOS/seicontribution/101_lowtech_earth_science%20demos.pdf

Real-World Connection

Tell the class about the Montreal Protocol, a 1987 international agreement with the intention of limiting production of CFCs, the major cause of depletion of the stratospheric ozone layer. You (or your students) can learn more, including how CFCs deplete ozone and how effective the agreement has been, at the following URLs.

- http://ozone.unep.org/new_site/en/montreal_protocol.php
- http://www.environment.gov.au/atmosphere/ozone/legislation/montp.html
- http://www.theozonehole.com/montreal.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 15.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 15.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Give a detailed explanation of why warm air rises.

- [When gas molecules are warmer, they move more vigorously and take up more space. This decreases the density of the air because there are fewer gas molecules in a given volume. The warmer air is lighter and more buoyant than cooler air, so it rises.]

2. Why doesn't air temperature change uniformly with altitude? Give examples.

- [Air temperature doesn't change uniformly with altitude because the source of heat is different for different layers of the atmosphere. In some layers, the heat source is below the layer. In other layers, the heat source is above the layer. For example, the heat source for the troposphere is mainly Earth's surface, so temperature in the troposphere decreases with increasing altitude. The heat source for the stratosphere is the sun, so temperature in the stratosphere increases with altitude.]

3. Describe how the ground acts as the heat source for the troposphere. What is the source of energy and what happens to that energy?

- [Earth's surface is a major source of heat for the troposphere, although nearly all of that heat comes originally from the sun. Rock, soil, and water on Earth absorb solar energy and radiate it back into the atmosphere as heat. The temperature of the troposphere is higher near the surface because that is the main source of heat and also because the air is denser near the surface. Because warmer air is less dense than cooler air, this condition is unstable. As a result, the warmer air near the surface rises and the cooler air higher in the troposphere sinks. These movements of air cause a lot of mixing of air in the troposphere.]

4. How stable is an inversion and why? How does an inversion form?

- [An inversion is very stable because warmer, less dense air sits above cooler, denser air. An inversion can form in different ways. One way is when cold land at night or in the winter cools the air near the surface so it is colder than the air above it. Another way is when cold seawater cools the air above it and the denser, cooler air moves inland, sliding beneath warmer air over the land.]

5. Phoenix, Arizona, is a city in the Southwestern desert. Summers are extremely hot. Winter days are often fairly warm but winter nights can be quite chilly. In December, inversions are quite common. How does an inversion form under these conditions and what are the consequences of an inversion to this sprawling, car-dependent city?

- [Under these conditions, an inversion forms when the land cools at night in the winter and makes the air near the surface colder than the air above it. Because temperature inversions are stable, they often trap pollutants near the surface and produce unhealthy air conditions in cities. This is likely to be a bigger problem in a sprawling, car-dependent city that has a lot of vehicle traffic and therefore a lot of air pollution from vehicles.]

6. Why can't air from the troposphere and the stratosphere mix freely?

- [The air from the troposphere and the stratosphere cannot mix freely because these two layers of the atmosphere are separated by a thin layer called the tropopause, in which temperature does not change with increasing altitude. This means that the cooler, denser air of the troposphere is trapped beneath the warmer, less dense air of the stratosphere. This is a stable condition that prevents air from the troposphere and stratosphere from mixing.]

7. What is the heat source for the stratosphere? How is that heat absorbed?

- [The heat source for the stratosphere is the sun. That heat is absorbed by ozone molecules in the ozone layer within the stratosphere.]

8. Describe ozone creation and loss in the ozone layer. Does one occur more than the other?

- [Ozone is created in the stratosphere by ultraviolet light striking oxygen molecules (O_2). This produces two individual oxygen atoms, each of which can combine with an oxygen molecule to form a molecule of ozone (O_3). An ozone molecule is unstable. When ultraviolet light strikes it, the ozone molecule splits to form a molecule of oxygen and a single atom of oxygen.

9. How and where are "shooting stars" created?

- [Meteors, or "shooting stars," occur when meteors pass through the mesosphere and burn up.]

10. Why would an unprotected traveler's blood boil in the mesosphere?

- [Blood would boil in the mesosphere at normal body temperature because the pressure of air in the atmosphere is so low in this layer of the atmosphere.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How does solar energy create the atmosphere's layers?

- [The atmosphere's layers are based on differences in temperature gradients in the atmosphere. Solar energy is the source of heat in the atmosphere and ultimately responsible for the temperature gradients. For example, solar energy re-radiated from Earth's surface is the main source of heat in the troposphere, explaining why temperature decreases with increasing altitude in the troposphere. Solar radiation is directly responsible for heating the stratosphere, which is why temperature in this layer increases with increasing altitude.]

How does solar energy create the weather?

- [The atmosphere is heated by solar energy. The amount of solar energy received by different areas varies, depending on factors such as latitude. This causes unequal heating of the atmosphere, which is the main cause of Earth's weather.]

What would happen to life on Earth if there was less ozone in the ozone layer?

- [With less ozone in the ozone layer, more ultraviolet radiation would reach Earth's surface. This would harm life on Earth and possibly cause extinctions.]

15.4 Lesson 15.3: Energy in the Atmosphere

Key Concepts

- Energy, temperature, and heat
- Energy from the sun
- Seasons on Earth
- Heat transfer in the atmosphere
- Heat at Earth's surface
- Greenhouse effect

Lesson Objectives

- Describe how energy is transmitted.
- Describe Earth's heat budget and what happens to the sun's energy.
- Discuss the importance of convection in the atmosphere.
- Describe how a planet's heat budget can be balanced.
- Describe the greenhouse effect and why it is so important for life on Earth.

Lesson Vocabulary

- **albedo:** measure of the amount of light that reflects off a surface
- **electromagnetic wave:** wave with both electric and magnetic properties that can travel through space by radiation
- **greenhouse effect:** trapping of heat in Earth's atmosphere by greenhouse gases, which absorb heat that radiates from Earth's surface
- **insolation:** amount of solar radiation striking a given area over a given period of time
- **insulation:** material that inhibits conduction of heat or electricity
- **latent heat:** energy absorbed or released when a substance changes state
- **reflection:** change in direction of a wave at the surface of a new medium so that the wave travels back through the original medium
- **specific heat:** amount of heat needed to raise the temperature of one gram of a substance by one degree Celsius
- **temperature:** measure of the hotness of a material, which reflects how quickly its atoms are vibrating

Teaching Strategies

Introducing the Lesson

Before students read about energy in the atmosphere, help them recall what they already know about energy.

Question: What is energy?
Answer: Energy is the ability to do work or change matter.
Question: What are some different forms that energy may take?
Answer: Forms of energy include light, sound, electrical energy, and chemical energy.
Question: What is heat?
Answer: Heat is energy associated with the movement of atoms or molecules.

Tell students they will learn in this lesson where the atmosphere gets heat energy and how heat moves through the atmosphere.

Building Science Skills

Students can build their observation skills and see how the angle of the sun's rays affect their strength if you do a simple demonstration (demonstration # 36, "Comb Beams," at the URL below). Using a light source, comb, and piece of white cardboard, you will demonstrate how light rays can be spread out or concentrated to cover more or less area by changing the angle at which the rays strike the surface. Have students relate the demonstration to rays of sunlight striking Earth's surface at different angles during different times of the year. Discuss how these differences in light energy are related to the seasons.

http://www.colorado.edu/geolsci/courses/DEMOS/seicontribution/101_lowtech_earth_science%20demos.pdf

Differentiated Instruction

Have students make a concept map of lesson content. Their concept map should include such concepts as energy, temperature, heat, radiation, conduction, convection, and greenhouse effect.

Enrichment

Many students erroneously think that greenhouse gases in Earth's atmosphere trap energy directly from the sun and thereby make Earth warmer than it would otherwise be. Ask one or more students to teach the class how greenhouse gases in the atmosphere actually moderate Earth's temperature (i.e., by absorbing heat that is re-radiated from Earth's surface and preventing it from escaping into space).

Science Inquiry

Have students do the first inquiry activity (Lab 1: "Heating from Below") at the following URL to investigate how convection transfers heat in the atmosphere. The activity involves increasing the temperature of water and observing the motion of a dye caused by changes in temperature and density of the water.

http://www.woodrow.org/teachers/esi/2001/princeton/project/zerba/activities/activities.htm

Overcoming Misconceptions

Many people think that the seasons are caused by changes in the distance of Earth to the sun. In fact, the seasons are mostly due to changes in the tilt of Earth on its axis. As explained at the following URL, misconceptions like this one, which seem logical and reasonable, are often the most difficult to correct. The URL also explains a way to demonstrate the fallacy of this particular misconception.

http://www.badastronomy.com/bad/misc/seasons.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 15.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 15.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents. 1. What is the difference between temperature and heat?

- [Temperature measures how fast a material's atoms are vibrating. Heat measures the material's total energy, which depends on both temperature and the number of vibrating atoms (mass) of the material.]

2. Give a complete description of these three categories of energy relative to each other in terms of their wavelengths and energy: infrared, visible, and ultraviolet light.

- [Infrared, visible, and ultraviolet light are all forms of electromagnetic radiation. They differ in wavelength and amount of energy. Infrared light has the longest wavelengths and least amount of energy, followed by visible light, with ultraviolet light having the shortest wavelengths and greatest amount of energy.]

3. Why do the polar regions have high albedo?

- [Polar regions have less solar energy so they have more snow and ice. Snow and ice give polar regions high albedo because they reflect a lot of solar radiation.]

4. Give an example of the saying "energy can't be created or destroyed."

- [Energy can't be created or destroyed, but it often changes form. For example, during photosynthesis, energy changes from light energy in sunlight to chemical energy in sugar molecules. New energy is not created, and old energy is not destroyed. The energy just changes form.]

5. Describe what happens to the temperature of a pot of water and to the state of the water as the dial on the stove is changed from no heat to the highest heat.

- [The temperature of the pot of water increases until it reaches the boiling point of water (100 °C). At that point, the liquid water starts changing to water vapor. Individual molecules of liquid water gain enough energy to pull apart from other water molecules and escape into the air.]

6. Describe where the sun is relative to Earth on summer solstice, autumnal equinox, winter solstice and spring equinox. How much sunlight does the North Pole get on June 21? How much does the South Pole get on that same day?

- [At both equinoxes, Earth's axis is tilted relative to the sun so that the sun's rays strike the equator most directly. Day and night are about equal in length in both hemispheres on these two days. The summer solstice in the Northern Hemisphere occurs on June 21. This is the winter solstice in the Southern Hemisphere. On this day, the sun's rays strike the Tropic of Cancer most directly. This is the longest day of the year in the Northern Hemisphere. The winter solstice in the Northern Hemisphere occurs on December 21. This is the summer solstice in the Southern Hemisphere. On this day, the sun's rays strike the Tropic of Capricorn most directly. This is the shortest day of the year in the Northern Hemisphere. On June 21, the North Pole gets 24 hours of sunlight; on the same day, the South Pole gets zero hours of sunlight.]

7. What is the difference between conduction and convection?

- [Conduction is the transfer of heat by direct contact between vibrating molecules of matter. Heat is transferred from molecules that are vibrating more quickly to molecules that are vibrating more slowly. Convection is the transfer of heat by currents that travel through liquids or gases due to differences in density.]

8. What is a planet's heat budget? Is Earth's heat budget balanced or not?

- [A planet's heat budget is the amount of energy entering and escaping the planet. The heat budget is balanced if the same amount of energy enters as escapes. With a balanced heat budget, a planet's temperature does not change. Earth's heat budget is not balanced because more heat is coming in than leaving.]

9. On a map of average annual temperature, why are the lower latitudes so much warmer than the higher latitudes?

- [The lower latitudes are so much warmer than the higher latitudes because they receive more direct rays of the sun and therefore more intense solar radiation.]

10. Why is carbon dioxide the most important greenhouse gas?

- [Carbon dioxide is the most important greenhouse gas because it is the most abundant greenhouse gas in the atmosphere.]

11. How does the amount of greenhouse gases in the atmosphere affect the atmosphere's temperature?

- [The greater the amount of greenhouse gases in the atmosphere, the greater the greenhouse effect is and the warmer the temperature of the atmosphere is.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How does the difference in solar radiation that reaches the lower and upper latitudes explain the way the atmosphere circulates?

- [Differences in temperature of the atmosphere by latitude drive atmospheric circulation. Warm air rises and cool air sinks, creating differences in air pressure and convection cells in the troposphere.]

How does the atmosphere protect life on Earth from harmful radiation and from extreme temperatures?

- [The atmosphere protects life on Earth from harmful radiation by absorbing the most harmful wavelengths of radiation from the sun. The atmosphere also protects life from extreme temperatures by circulate heat on the planet and by the greenhouse effect.]

What would the consequences be if Earth's overall heat budget were not balanced?

- [If Earth's overall heat budget were not balanced, Earth's temperature would change. If the planet were to receive more heat than it loses, its temperature would rise. If the planet were to lose more heat than it receives, its temperature would fall.]

15.5 Lesson 15.4: Air Movement

Key Concepts

- Air pressure and winds
- Local winds
- Atmospheric circulation
- Global wind belts
- Polar fronts and jet streams

Lesson Objectives

- List the properties of the air currents within a convection cell.
- Describe how high and low pressure cells create local winds and explain how several types of local winds form.
- Discuss how global convection cells lead to the global wind belts.

Lesson Vocabulary

- **advection:** horizontal movement of fluid, such as the horizontal flow of air in the troposphere
- **Chinook wind (Foehn wind):** wind that blows when low pressure draws air over a mountain range
- **haboob:** desert sandstorm that forms in the downdrafts at the front of a thunderstorm
- **high pressure zone:** region where relatively cool, dense air is sinking to the surface
- **jet stream:** fast-flowing "river" of air at the top of the troposphere where air masses with very different temperatures and humidities move past each other
- **katabatic wind:** wind that flows down a slope
- **land breeze:** local wind that blows from land to sea in the winter when the land is cooler than the sea
- **low pressure zone:** region where relatively warm, light air is rising above the surface
- **monsoon:** local wind that blows from sea to land in summer and from land to sea in winter where very hot lands are located next to the sea
- **mountain breeze:** wind that blows from a mountain to a valley at night when mountain air cools off more quickly than air in the valley
- **polar front:** boundary between cold continental air and warmer subtropical air that occurs at about 50 °N and 50 °S latitude
- **rain shadow:** location on the leeward side of a mountain range where very little rain falls due to dry descending air
- **Santa Ana wind:** hot, dry wind that blows east to west across Southern California in the fall and winter
- **sea breeze:** local wind that blows from sea to land in the summer when the sea is cooler than the land
- **valley breeze:** uphill flow of air that occurs when warm air rises and draws cool air up from a valley

Teaching Strategies

Introducing the Lesson

Generate student interest in the lesson with a simple demonstration (demonstration #22, "Pop Top" at the URL below). You will place a wet cap upside down on top of an empty plastic pop bottle and then simply hold the bottle. The cap will eventually "jump" off the bottle because the heat of your hands will warm the air in the bottle, causing it to expand and knock off the bottle cap. Challenge students to explain what happens. Accept all reasonable responses at this point, and then tell students they will learn the correct explanation when they read this lesson.

http://www.colorado.edu/geolsci/courses/DEMOS/seicontribution/101_lowtech_earth_science%20demos.pdf

Activity

The high-speed winds of jet streams, found near the top of the troposphere, play a major role in guiding weather systems. Many factors, including Earth's rotation and the sun's uneven heating of Earth's surface, contribute to the formation of the powerful eastward flows of the jet streams. In this interactive resource from NOVA Online, students can learn about the factors that create these powerful meteorological forces.

http://www.watchknowlearn.org/Video.aspx?VideoID=18356&CategoryID=2666

Differentiated Instruction

Have students make a table comparing and contrasting the different types of local winds described in the lesson. They should include the time, season, or other conditions when each wind blows and its direction.

Enrichment

Suggest that students watch the interesting video below to see how NASA is using special rockets to learn about ultra-high, super-fast winds in a part of the atmosphere that is little known and hard to study.

http://www.watchknowlearn.org/Video.aspx?VideoID=51029&CategoryID=2666

Science Inquiry

Use the inquiry activity at the following URL to guide students through a better understanding of global wind patterns and why they occur. The activity has both hands-on and kinesthetic components during which students will learn how winds move in global patterns and from high to low pressure systems.

http://teachingboxes.org/jsp/teachingboxes/weatherEssentials/wind/sequence/lesson4_activity1.jsp

Overcoming Misconceptions

Students may think that all air movements are from areas of higher pressure to areas of lower pressure. Make sure students understand that this principle applies only to surface winds. Explain that high-altitude winds and vertical air movements are caused by convection in the atmosphere.

Reinforce and Review

Lesson Worksheets

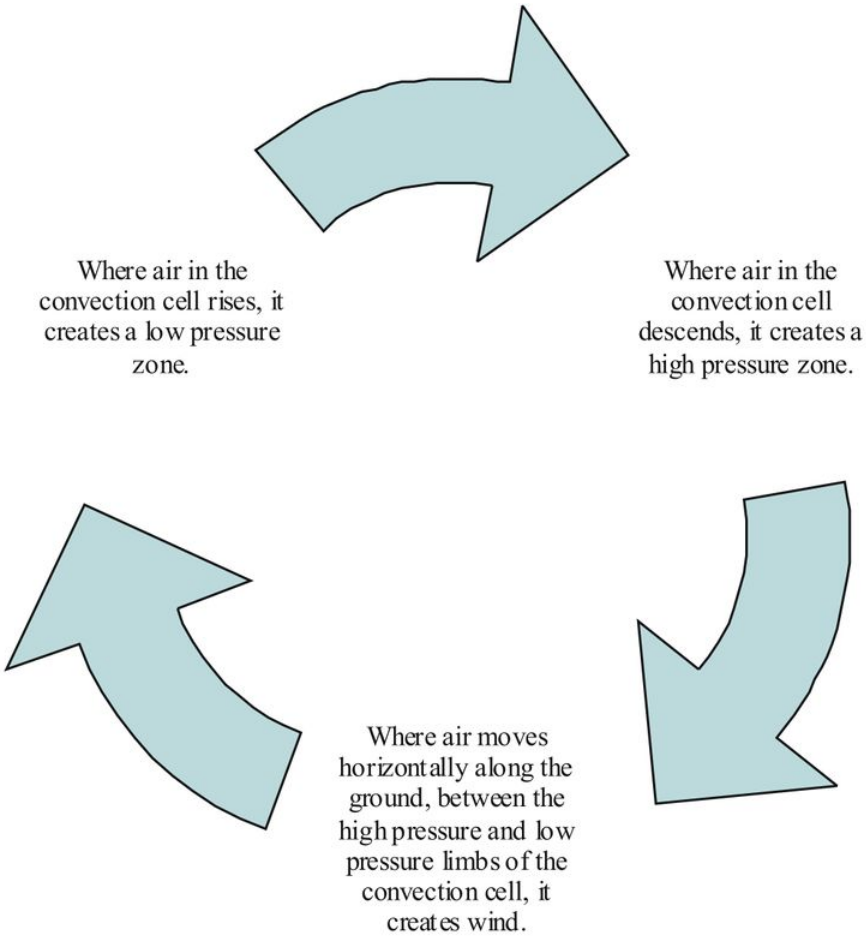
Copy and distribute the Lesson 15.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 15.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Draw a picture of a convection cell in the atmosphere. Label the low and high pressure zones and where the wind is.

- [Sample picture:



2. Under what circumstances will winds be very strong?

- [Winds will be very strong when the difference in pressure between the high and low pressure zones is great.]

3. Given what you know about global-scale convection cells, where would you travel if you were interested in experiencing warm, plentiful rain?

- [*Sample answer*: I would travel to the equator. Warm, humid air rises at the equator. When it cools, it loses some of its moisture and produces rain.]

4. Describe the atmospheric circulation for two places where you are likely to find deserts, and explain why these regions are relatively warm and dry.

- [Deserts are found where relatively warm air descends. Compression causes the air to heat and heating allows the air to hold more moisture, resulting in more evaporation than precipitation. One place where this is likely to happen is at the junction between Hadley and Ferrell Cells, at about 30 °N and 30 °S latitudes. Another place where this is likely to happen is on the leeward side of a mountain range, where rain shadow effect creates a desert.]

5. How could the Indian monsoons be reduced in magnitude? What effect would a reduction in these important monsoons have on that part of the world?

- [The monsoons are driven by the extreme difference in temperature between the Indian subcontinent and the nearby ocean. A reduction in the monsoon could be caused by a decrease in the temperature difference between the two areas. This would occur if the land did not heat up as much or if the ocean heated up more. The result of a diminished monsoon would be that 2 billion people would have less water for drinking and for irrigating their crops.]

6. Why is the name "snow eater" an apt description of Chinook winds?

- [As air descends on the leeward side of a mountain range, the descending air may become very warm and dry. When these winds strike, they may raise the air temperature tens of degrees, which will likely melt any snow in the vicinity.]

7. Why does the Coriolis effect cause air to appear to move clockwise in the Northern Hemisphere? When does Coriolis effect cause air to appear to move counterclockwise?

- [The Coriolis effect causes air to be deflected to the right in the Northern Hemisphere. If something is continually deflected to the right, it will appear to be moving clockwise. In the Southern Hemisphere, the Coriolis effect causes air to be continually deflected to the left, so it appears to be moving counterclockwise.]

8. Sailors once referred to a portion of the ocean as the doldrums. This is a region where there is frequently no wind, so ships would become becalmed for days or even weeks. Where do you think the doldrums might be relative to the atmospheric circulation cells?

- [The doldrums must be in a location where air is moving vertically, since these are areas of little wind. This would be at the equator or at the boundaries of the circulation cells. It actually refers to the region around the equator where low pressure causes the air to be humid and still.]

9. Imagine that the jet stream is located further south than usual for the summer. What is the weather like in regions just north of the jet stream, as compared to a normal summer?

- [The weather is colder than normal for that time of year.]

10. Give a general description of how winds form.

- [Winds form when there is a difference in air pressure. Winds always blow from a high pressure zone to a low pressure zone. These zones are the result of differential heating of various locations on land and over water.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How do local winds affect the weather in an area?

- [Local winds may affect temperature or precipitation in an area. For example, a summer monsoon brings heavy rains to the land, and a winter ocean breeze brings warmer temperatures to the land.]

How do the global wind belts affect the climate in an area?

- [Global wind belts determine the direction the wind usually blows in a given area. This, in turn, affects the type of a climate in an area. For example, areas in which wind usually blows from an ocean generally have relatively mild, moist climates. The circulation cells that produce global wind belts also determine in a general way the amount of precipitation a region receives. For example, where dry air sinks at about 30 °N and 30 °S latitude, precipitation is low, explaining why most of the world's deserts occur at these latitudes.]

What are the main principles that control how the atmosphere circulates?

- [The main principles include: convection cells form in the atmosphere when air is heated unequally in different locations by the sun; warm air rises and creates low pressure zones; cold air sinks and creates high pressure zones; and winds blow from high pressure zones to low pressure zones. These principles determine both global and local winds that circulate air in the atmosphere.]

CHAPTER 16 HS TE Weather

Chapter Outline

16.1 Chapter 16: Weather

Chapter Overview

This chapter describes weather and weather factors, such as types of clouds and precipitation and movement of air masses. It also explains how different types of storms develop and how meteorologists forecast weather, including the use of various tools, maps, and models.

Online Resources

See the following Web site for an appropriate laboratory activity:

With the online Weather Lab at the following URL, students can create their own weather instruments and then use them to gather weather data in several different experiments. A weather data sheet is included so students can record data for all of their experiments.

- http://teacher.scholastic.com/activities/wwatch/gather_data/

These Web sites may also be helpful:

At the following URL, you can connect with five lessons plans to teach weather-related topics to your student. Included are classroom activities and real-time data investigations to study factors that affect weather.

- http://ciese.org/curriculum/weatherproj2/en/index.shtml

You can find a large collection of weather-related games and simulations at this URL: http://spark.ucar.edu/longcontent/games-sims-weather-climate-atmosphere.

The URL below provides 10 satellite meteorology learning modules for middle and high school students that include exciting activities and hands-on tools for investigation, inquiry, and analysis.

- http://cimss.ssec.wisc.edu/satmet/index.html

Go to this URL for a wide variety of teaching resources relating to weather and the atmosphere: http://www.education.noaa.gov/Weather_and_Atmosphere/.

At the following URLs, you can access lesson plans and activities in the National Weather Service's Jetstream Online Weather School.

- http://www.srh.noaa.gov/jetstream/append/lessonplans.htm
- http://www.srh.noaa.gov/jetstream/append/coolstuff_matrix.htm

Pacing the Lessons

TABLE 16.1: short caption

Lesson	Class Period(s) (60 min)		
16.1 Weather and Atmospheric Water	1.5		
16.2 Changing Weather	1.5		
16.3 Storms	2.5	16.4 Weather Forecasting	2.0

16.2 Lesson 16.1: Weather and Atmospheric Water

Key Concepts

- Weather vs. climate
- Clouds
- Fog
- Precipitation

Lesson Objectives

- Discuss the difference between weather and climate.
- Describe the relationship between air temperature and humidity, including the concept of dew point.
- List the basics of the different cloud types and what they indicate about current and future weather.
- Explain how the different types of precipitation form.

Lesson Vocabulary

- **cloud:** cluster of water droplets or ice crystals that have condensed in the atmosphere
- **dew point:** temperature at which air is saturated with water so it has 100 percent relative humidity
- **relative humidity:** amount of water vapor in the air relative to the maximum amount of water vapor that air could hold at that temperature

Teaching Strategies

Introducing the Lesson

Introduce weather by astounding students with a description of the largest hailstone ever recovered in the United States. The monster hailstone fell in Aurora, Nebraska, in June of 2003. It measured 17.8 cm (7 in) in diameter, making it almost as large as a soccer ball. .The hailstone is now at the National Center for Atmospheric Research in Boulder, Colorado, where it will be preserved indefinitely. Tell students they will learn how hailstones form when they read this lesson.

Activity

In the activity at the following URL, students will produce a cloud in a jar and observe the effect of adding a small amount of nuclei (smoke) on the formation of the cloud.

http://www.srh.noaa.gov/jetstream/clouds/ll_smoke.htm

Demonstration

Show the class the ability of the wind to suspend rain and hail in clouds by doing the simple demonstration described at the URL below. You will suspend a ping pong ball in the stream of air supplied by a hair dryer to demonstrate how hail is supported in thunderstorms.

http://www.srh.noaa.gov/jetstream/tstorms/ll_updrafts.htm

Differentiated Instruction

Humidity may be a difficult concept for some students to grasp because it measures something that is invisible: water vapor. Tell students to make a Frayer model for the concept of humidity. They should draw a large box and divide it into four parts, labeled "Definition," "Drawing," "Example," and "Non-example." Then they should fill in each part of the box for humidity. Ask pairs of students to compare and discuss each other's Frayer models.

Enrichment

Suggest that interested students learn more about fog with a Web quest. Have them use the Internet to find answers to the three questions listed below. Ask them to share what they learn with the class.

1. What conditions lead to the formation of fog?
2. Where are some of the foggiest places in the world?
3. How does fog cause problems for people?

Science Inquiry

Divide the class into groups, and assign a different type of cloud to each group. Have students within each group collaborate to make a three-dimensional model of their assigned cloud type. They might use materials such as cotton puffs or tissue paper for their models. Urge them to be creative while accurately representing basic features of their cloud type. Give groups a chance to show their models to the class, and then put the models on display in the classroom. Students can refer to them as they continue to learn about weather in this chapter.

Overcoming Misconceptions

Students may have misconceptions about humidity. Two are listed below. Discuss with the class why each misconception is false.

- Humidity is moisture (i.e., liquid water) in the air. [No; humidity is the amount of water vapor in the air.]
- Humid air is denser (heavier) than dry air. [No; humid air is actually less dense than dry air because the molecular weight of water is less than the molecular weight of dry air.]

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 16.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 16.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What factors need to be included in a thorough weather report?

- [A thorough weather report needs to include air temperature, air pressure, humidity, cloud cover, fog, precipitation, wind speed, and wind direction.]

2. If Phoenix, Arizona, experiences a cool, wet day in June (when the weather is usually hot and dry), does that mean the region's climate is changing?

- [No; climate is the average weather for a place over a long period of time. Weather may vary from day to day but the average weather, or climate, isn't necessarily changing. A June day in Phoenix that is cooler and wetter than average might be followed the next day by weather that is hotter and drier than average.]

3. What happens when a batch of air reaches its dew point? What is the temperature?

- [When a batch of air reaches its dew point, water vapor starts condensing out of the air. This may cause clouds to form. The temperature when this occurs is the temperature at which the relative humidity is 100 percent.]

4. What effect do clouds have on weather?

- [Clouds affect weather by preventing solar radiation from reaching the ground and by absorbing heat re-emitted by the ground. They keep the surface cooler during the day by shading the ground, and they keep the surface warmer during the night by absorbing heat from the ground. Clouds are also the source of precipitation.]

5. You are standing in a location that is clear in the morning, but in the afternoon there are thunderstorms. There is no wind during the day, so the thunderstorms build directly above you. Describe how this happens.

- [Thunderstorms occur when cumulonimbus clouds form. This can happen when warm, moist surface air rises and forms convection currents in the troposphere. The rising air cools and water vapor condenses, creating cumulus clouds that rise vertically in the troposphere. When the vertical air currents are strong, cumulonimbus clouds that produce thunderstorms result.]

6. What are the four different cloud groups and how are they classified?

- [The four cloud groups are high clouds, middle clouds, low clouds, and vertical clouds. High clouds are found above 6000 m in altitude. Middle clouds occur between 2000 and 7000 m. Low clouds below 2000 m. The fourth group includes clouds that grow vertically rather than horizontally.]

7. How does sleet form? How does glaze form?

- [Sleet is rain that freezes as it passes through a layer of freezing air near the ground. It strikes the ground as small ice pellets. Glaze is a thin layer of ice that forms when rain freezes as it contacts cold surfaces at or near the ground.]

8. What circumstances must be present for enormous balls of hail to grow and then fall to the ground?

- [Hail forms in cumulonimbus clouds with strong updrafts. An ice particle travels up and down through the clouds until it becomes too heavy to stay aloft and drops to the ground. For enormous balls of hail to grow, the updrafts must be very strong.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

When thinking about the weather, what factors do you consider important?

- [Important weather factors include air temperature, humidity and air pressure.]

How do air temperature, humidity, and pressure differences create different weather?

- [When air masses with different temperature, humidity, and pressure meet, it causes changes in the weather.]

Think about the types of weather described in this lesson. Imagine types of weather that you have not experienced; look at photos, and ask friends and relatives who've lived in other places what their weather is like.

- [Suggest that students try to find out about any types of storms they have not experienced, such as tornadoes, blizzards, or hurricanes.]

16.3 Lesson 16.2: Changing Weather

Key Concepts

- Air mass formation and movement
- Types of fronts

Lesson Objectives

- Describe the characteristics of air masses and how they get those characteristics.
- Discuss what happens when air masses meet.
- List the differences between stationary, cold, warm, and occluded fronts.

Lesson Vocabulary

- **air mass:** large body of air with about the same temperature and humidity throughout
- **cold front:** boundary between two air masses in which a cold air mass pushes a warm air mass upward
- **front:** boundary that forms where two air masses with different characteristics meet
- **occluded front:** front that forms when a cold front overtakes a warm front, so a warm air mass is trapped between two cold air masses
- **squall line:** line of thunderstorms that forms at the edge of a cold front
- **stationary front:** boundary between air masses that are stalled in the same place
- **warm front:** boundary between two air masses in which a warm air mass replaces a cold air mass

Teaching Strategies

Introducing the Lesson

Show the class an example of a weather map that shows one or more fronts. The last figure in this FlexBook® lesson is a good example. Point out the front lines on the map, and ask students if they know what they represent. As necessary, explain that the lines represent fronts, which are boundaries where large masses of air meet. Tell students they will learn about air masses and fronts and why they are important when they read this lesson.

Cooperative Learning

Students can work collaboratively to learn about the four different types of fronts. Divide the class into groups of four students each, and have each student in the group research a different type of front. Students should learn how

their front forms, the type of weather associated with it, and how it is represented on a weather map. After they collect the information, have students meet again as a group and share what they learned with group members.

Differentiated Instruction

Pair English language learners and less-proficient readers with other students, and ask partners to make a Venn diagram comparing and contrasting warm and cold fronts. Have pairs of students exchange and compare Venn diagrams with other pairs.

Enrichment

Students can learn more about the movement of air masses by investigating how the jet stream is related to the movement of air masses across North America. Before they start their research, have them use their current knowledge of weather and the atmosphere to develop a hypothesis for how the jet stream and air mass movement are related. You could do this step as a class or group brainstorming session. Then have students do online research to see if their hypothesis is correct. Students should write a summary of what they discover in their investigation.

Science Inquiry

Use the activity at the following URL when students learn about cold and warm fronts. In the activity, they will infer the location of cold and warm fronts on a map plotted with weather observations.

http://www.srh.noaa.gov/jetstream/synoptic/ll_analyze.htm

Overcoming Misconceptions

A relatively common misconception is that a front is a thin wall of weather. This idea may come from the way fronts are indicated by lines on weather maps. Point out that the line on a weather map that represents a front shows only the boundary between two air masses, whereas the weather associated with the front may actually extend over many miles on either side of the frontal boundary.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 16.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 16.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What type of air mass is created if a batch of air sits over the equatorial Pacific Ocean for a few days? What is the symbol for this type of air mass?

- [A maritime equatorial air mass forms under these circumstances. A maritime equatorial air mass is represented by the symbol mE.]

2. What conditions must be present for air to sit over a location long enough to acquire the characteristics of the land or water beneath it?

- [Generally, air must sit over a high- or low-pressure zone to remain in one location long enough to acquire the characteristics of the land or water beneath it.]

3. How does latitude affect the creation of air masses in tropical, temperate, and polar zones?

- [Latitude affects the temperature of air masses that are created in tropical, temperate, and polar zones. Tropical air masses are warm, temperate air masses are moderate, and polar air masses are cold.]

4. Why are the directions fronts move in the Southern Hemisphere a mirror image of the directions they move in the Northern Hemisphere?

- [Fronts are boundaries between moving air masses. Cold air masses tend to move toward the equator and warm air masses tend to move toward the North or South Pole. This means that air masses in the Southern hemisphere flow in opposite directions to those in the Northern Hemisphere, making them a mirror image of those in the Northern Hemisphere.]

5. How is a stationary front different from a cold or warm front?

- [Unlike a cold or warm front, a stationary front has air masses that do not move for several days.]

6. What sort of weather will you experience as a cold front passes over you?

- [As a cold front passes over you, you are likely to experience stormy weather.]

7. What sort of weather will you experience as a warm front passes over you?

- [As a warm front passes over you, you are likely to experience cloudy weather and precipitation.]

8. How does an occlusion form?

- [An occlusion usually forms around a low pressure system. The occlusion starts when a cold front catches up to a warm front, so a warm air mass is flanked by two cold air masses.]

9. What situation creates a cold occlusion and what creates a warm occlusion?

- [A cold occlusion is created when the third air mass to arrive is colder than the other two air masses, so the third air mass slips beneath the other two. A warm occlusion is created when the third air mass to arrive is warmer than the other two air masses, so the third air mass rides over the other two.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How do the various types of fronts lead to different types of weather?

- [Various types of fronts lead to different types of weather because air masses interact differently at different types of fronts. For example, at a cold front, a cold air mass forces a warm air mass up over it, producing sudden stormy weather. At a warm front, in contrast, a warm air mass gradually flows over a cold air mass, producing increasing cloudiness and perhaps light precipitation.]

Why are some regions prone to certain types of weather fronts and other regions prone to other types of weather fronts?

- [Different types of air masses form in different regions. The movement of air masses and the types of fronts they form depends on the type of air mass and the direction they move. For example, warm air masses form over equatorial and tropical regions and generally move away from the equator. Cold air masses form over polar regions and generally move toward the equator. The movement of air masses is also influenced by prevailing winds, so different regions are prone to different types of air masses and fronts depending on the direction of the winds they generally receive.]

Why does the weather sometimes change so rapidly and sometimes remain very similar for many days?

- [How quickly weather changes depends mainly on the type of front that causes the weather to change. Cold fronts generally bring rapidly changing weather conditions. Stationary fronts cause the weather to remain similar for many days.]

16.4 Lesson 16.3: Storms

Key Concepts

- Thunderstorms
- Tornadoes
- Cyclones
- Hurricanes
- Blizzards and lake-effect snow
- Heat waves

Lesson Objectives

- Describe how atmospheric circulation patterns cause storms to form and travel.
- Understand the weather patterns that lead to tornadoes, and identify the different types of cyclones.
- Know what causes a hurricane to form, what causes it to disappear, and what sorts of damage it can do.
- Know the damage that heat waves and droughts can cause.

Lesson Vocabulary

- **anticyclone:** wind system that rotates around a high-pressure center
- **blizzard:** large snowstorm with cold temperatures, high winds, and reduced visibility because of wind-blown snow
- **cyclone:** wind system that rotates around a low-pressure center
- **heat wave:** prolonged period of excessively hot weather for a given region
- **hurricane:** large storm with high winds and heavy rains that forms from a tropical cyclone
- **lake-effect snow:** heavy snowfall caused by the evaporation of water from a relatively warm lake into a cold front that then drops the moisture as snow on the leeward side of the lake
- **lightning:** huge discharge of static electricity that typically occurs during a thunderstorm
- **mid-latitude cyclone:** cyclone that forms in the middle latitudes at the polar front
- **nor'easter:** mid-latitude cyclone storm that strikes the northeastern United States
- **thunder:** loud noise produced by lightning because the discharge of electricity causes the air to heat and expand so quickly that it explodes
- **thunderstorm:** storm caused by upwelling air and characterized by cumulonimbus clouds, lightning, and thunder
- **tornado:** rotating funnel cloud with extremely high winds that grows downward from a cumulonimbus cloud
- **tropical depression:** low-pressure cell that rises in the tropics and from which thunderstorms develop

Teaching Strategies

Introducing the Lesson

Share these facts and figures about lighting with your class to pique student interest in storms:

- At any given time, almost 2000 lightning storms are occurring in Earth's atmosphere.
- Over the course of a year, millions of lightning storms occur.
- Each flash of lightning contains millions of volts of electricity.
- Lightning can reach temperatures as high as 54,000 °C (97,232 °F).
- Lightning can travel at the "lightning-fast" speed of 60,000 m/s (130,000 mph).

Tell students they will learn more about lightning storms and other kinds of storms when they read this lesson.

Activity

In the learning module at the following URL, students will use hands-on applets to learn about storms, including thunderstorms, hurricanes, tornadoes, and blizzards. They will also learn the role of satellites in tracking severe weather, and they will identify key features for each type of storm using satellite images.

http://cimss.ssec.wisc.edu/satmet/modules/8_wild_weather/ww-1.html

Building Science Skills

Use the learning module at the URL below to help students become better consumers of weather information and learn more about hurricanes. The Web site provides dynamic graphics, animations, and science content about remote sensing, satellite imagery, and hurricanes. As part of the module, students will apply what they've learned by exploring recent hurricanes through satellite imagery. After completing the module, they should be able to view satellite imagery in a typical weather forecast and recognize the importance of certain features.

http://www.comet.ucar.edu/nsflab/web/index.htm

Differentiated Instruction

Work with students to create a flow chart, diagram, or sketch showing how lake-effect snow occurs. It should show wind:

1. blowing across a warm lake,
2. warming and picking up water vapor,
3. cooling and producing snow when it reaches land on the leeward side of the lake.

Enrichment

Ask two or more students to collaborate on making a crossword puzzle that incorporates all of the lesson vocabulary terms. Tell them to write the clues in such a way that each missing term consists of a single word. They can make the crossword puzzle by hand or use a free online puzzle maker (see URL below). Make copies of their puzzle and hand them out to other students to complete as a review of lesson vocabulary.

http://www.discoveryeducation.com/free-puzzlemaker/?CFID=265931&CFTOKEN=42971909

Science Inquiry

In the activity "Severe Weather: Hurricanes!" at the URL below, teams of students will review the action of Hurricane Andrew (1992) in preparation for tracking, analyzing, and predicting the course of a new hurricane that may threaten North America this school year. Teams will check radio, television, and newspapers for reports of the next hurricane to threaten the United States. Then they will use a series of remote-sensing images from NOAA weather satellites to determine the forward speed of a current hurricane, track its course, and predict where and when it will come ashore. This activity is best done during the late summer or early fall when hurricane season is at its peak.

http://www.cotf.edu/ete/modules/sevweath/sevweath.html

Real-World Connection

At the following URL, students can use the National Weather Service's (NWS) Hotseat Warning Simulator to gain an appreciation of the meteorology of severe weather events and the decision-making process that goes into NWS warnings. They will learn more about severe weather and also become more informed consumers of NWS warnings in the process.

http://www.srh.noaa.gov/ffc/?n=hotseat

Overcoming Misconceptions

Many people believe the misconception that lightning never strikes the same place twice. Explain to students that the most likely place for lightning to strike is the highest point in the area. Therefore, a tall building or tree is more likely to be struckstruck againa low-lying point such as a ditch. Tell students that the 381-meter (1250-foot) tall Empire State Building in New York City is struck by lightning about 100 times each year. In fact, it was constructed in part to act as a lightning rod for the surrounding area.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 16.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 16.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe in detail how a thunderstorm forms and where the energy to fuel it comes from. Start with a warm day and no clouds.

- [Thunderstorms form when ground temperatures are high, ordinarily in the late afternoon or early evening in spring and summer. As temperatures increase, warm moist air rises. These updrafts first form a cumulus and then a cumulonimbus cloud. As water vapor condenses to form the cloud, the latent heat makes the air in the cloud warmer than the air outside the cloud. Water droplets and ice fly up through the cloud in updrafts. When these droplets get heavy enough, they fall. This starts a downdraft, and soon there is a convection cell within the cloud. The cloud grows into a cumulonimbus giant. Eventually the drops become large enough to fall all

the way to the ground. At this time the thunderstorm is mature, and it produces gusty winds, lightning, heavy precipitation, and often hail.]

2. How does a thunderstorm break apart and disappear?

   - [The downdrafts cool the air at the base of the thunderhead, so the air is no longer warm enough to rise. As a result, convection shuts down. Without convection, water vapor does not condense, no latent heat is released, and the thunderhead runs out of energy.]

3. Why does a thunderstorm get more severe rather than losing energy and disappearing?

   - [With severe thunderstorms, the downdrafts are so intense that when they hit the ground, it sends warm air from the ground upward into the storm. The warm air gives the convection cells more energy. Raindrops and hail grow very large before gravity pulls them down to the ground. Severe thunderstorms can last for hours.]

4. What are lightning and thunder?

   - [So much energy collects in cumulonimbus clouds that a huge release of electricity, called lightning, may result. The electrical discharge may be between one part of a cloud and another, between two different clouds, or between a cloud and the ground. Thunder is the loud noise that results when lightning causes the air to heat and expand so quickly that it explodes.]

5. Discuss the pros and cons of living in an area that is prone to tornadoes versus one that is prone to hurricanes.

   - [Tornadoes typically have higher-speed winds than hurricanes. They are extremely dangerous because they occur with very little warning and it isn't possible to predict exactly where and when a tornado will touch down. Therefore, people generally do not have time to evacuate and may not be able to reach safe shelter. Fortunately, tornadoes do not last very long, and they generally cover only a narrow area. Hurricanes cause storm surge when they come ashore, which causes as much or more damage than the high winds. Hurricanes are huge storms that may last for days and cover hundreds of kilometers. However, they generally can be predicted days in advance so people can prepare for the storm or evacuate the area in order to stay safe.]

6. Where are tornadoes most common in the United States?

   - [Tornadoes are most common in the United States in the central plains states in an area called Tornado Alley. It includes parts of Texas, Oklahoma, Nebraska, and South Dakota.]

7. What is a cyclone? What are the two types of cyclone and how do they differ?

   - [A cyclone is a system of winds rotating around a low-pressure center. In the Northern Hemisphere, the winds rotate in a counterclockwise direction. In the Southern Hemisphere, they rotate in a clockwise direction. The two types of cyclones are middle latitude cyclones and tropical cyclones. Middle-latitude cyclones are the main cause of winter storms in the middle latitudes. They form at the polar front when the temperature difference between two air masses is large. Tropical cyclones are also known as hurricanes, typhoons, and or willy-willies. They are the most damaging storms on Earth. They are huge storms with high winds. They arise in the tropical latitudes in summer and autumn when sea surface temperatures are high.]

8. Describe in detail how a hurricane forms.

   - [Over a tropical ocean, the warm water creates a large humid air mass. The warm air rises and forms a low-pressure cell, known as a tropical depression. Thunderstorms form around the tropical depression. If the temperature reaches or exceeds 28 °C, the air begins to rotate around the low-pressure center. As the air rises, water vapor condenses, releasing energy from latent heat. The release of latent heat generates enormous amounts of energy, and tornadoes may spin off from the hurricane.]

9. What level is the most damaging hurricane on the Saffir-Simpson scale? What sorts of damage do you expect from such a strong hurricane?

- [The most damaging hurricane on the Saffir-Simpson scale is a category 5 hurricane. Such a strong hurricane may completely destroy roofs or even entire buildings.]

10. What causes damage from hurricanes?

- [Damage from hurricanes is caused by the high winds, heavy rains, and storm surge. Storm surge occurs as the storm's low-pressure center comes onto land, causing the sea level to rise to an unusually high level. Flooding from storm surge can be devastating, especially along low-lying coastlines]

11. What could have been done in New Orleans to lessen the damage and deaths from hurricane Katrina?

- [Most of the damage and deaths from hurricane Katrina in New Orleans occurred because of failure of the levees that had been built to protect the city from storm surge. Building higher, stronger levees could have lessened the damage and deaths from this storm.]

12. Do you think New Orleans should be rebuilt in its current location?

- [Answers may vary. Students may or may not think New Orleans should be rebuilt in its current location because of the danger of hurricanes in this part of the country.]

13. Where do blizzards develop?

- [Blizzards develop across the middle latitudes and toward the poles, usually as part of a middle-latitude cyclone. They develop when a cold northern air mass comes into contact with a warmer semitropical air mass.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why is predicting where tornadoes will go and how strong they will be so difficult?

- [Tornadoes form from thunderstorms and hurricanes, but they form very quickly. As a result, meteorologists can predict tornado danger only over a wide region. They cannot predict exactly where and when tornadoes will touch down or how strong they will be.]

How would the damage done by hurricane Katrina have been different if the storm had taken place 100 years ago?

- [If hurricane Katrina had taken place 100 years ago, there would have been much less advance warning that the storm was coming, so people would have had far less time to prepare for it. However, 100 years ago the population of New Orleans was smaller, so fewer people and structures would have been at risk of death or damage.]

What knowledge do meteorologists need to better understand storms?

- [To better understand storms, meteorologists need more knowledge of weather factors and how they interact to produce storms.]

16.5 Lesson 16.4: Weather Forecasting

Key Concepts

- Tools for collecting weather data
- Numerical weather prediction
- Weather maps

Lesson Objectives

- List some of the instruments that meteorologists use to collect weather data.
- Describe how these instruments are used to collect weather data from many geographic locations and many altitudes.
- Discuss the role of satellites and computers in modern weather forecasting.
- Describe how meteorologists develop accurate weather forecasts.

Lesson Vocabulary

- **barometer:** weather instrument that measures air pressure
- **isobar:** line on a weather map that connects points with the same air pressure
- **isotach:** line on a weather map that connects points with the same wind speed
- **isotherm:** line on a weather map that connects points with the same temperature
- **radar:** radio detection and ranging device that emits radio waves and receives them after they reflect from the nearest surface, including water droplets in the atmosphere
- **radiosonde:** group of instruments that measure atmospheric characteristics, such as temperature and humidity, as they move through the air
- **thermometer:** instrument that measures temperature
- **weather map:** map showing weather conditions over a particular area at a given time

Teaching Strategies

Introducing the Lesson

List the following weather factors on the board, and call on students to name the device that is used to measure each factor:

- temperature (thermometer)
- air pressure (barometer)

- humidity (hygrometer)
- wind speed (anemometer)
- wind direction (wind vane)
- amount of rain (rain gauge)

Students are unlikely to be able to name all of the measuring devices. Tell them they will learn the names of the other weather instruments when they read this lesson.

Demonstration

Show students the video "NEXRAD: Eye to the Sky" at the URL below. From the video, they will learn how the NEXRAD Doppler radar system works and how its data are used.

http://www.norman.noaa.gov/2007/10/nexrad-eye-to-the-sky/

Cooperative Learning

With the activity at the following URL, students will design and construct a rain gauge, barometer, anemometer, psychrometer, and wind vane using the materials of their choice. Assign each instrument to a different group of students to construct. Have each group use their weather instrument to monitor weather conditions at school for at least a week. At the end of the week, ask groups to explain to the class how their devices work and to share the weather data they collected.

http://school.discoveryeducation.com/lessonplans/activities/weatherstation/

Differentiated Instruction

Suggest that less proficient readers make a main ideas/details chart for the lesson. It will help them focus on the most important information in the lesson. They can divide a sheet of paper in half and on the left side write the main ideas and on the right side write the details supporting each main idea.

Enrichment

Tell students there are many proverbs that have long been used to help predict the weather. Some of them include:

- When dew is on the grass, rain will not come to pass.
- A morning fog that hides the sun's ray means the coming of a clear day.
- Mackerel sky (i.e., high-level cumulus clouds), 12 hours dry.
- A wind from the west means weather's fair; a wind from the east means foul weather's near.
- Red sky at night, sailors delight; red sky at morning, sailors take warning.

Ask each student to select one of these proverbs and investigate the science that explains why it applies. Then have students try to come up with some of their own weather-prediction proverbs. Their proverbs can be about everyday weather, storms, or other weather phenomena. Share the following ideas with students to help them develop their proverbs:

- Air always moves from an area of high pressure to an area of low pressure.
- A bright reflection from clouds north of the sun may mean colder weather is coming, while a bright reflection from clouds south of the sun may mean warmer weather is coming.
- If air pressure is rising, fair weather is likely to be approaching; if air pressure is falling, stormy weather may be on its way.
- Warm, humid air in early spring or late fall may indicate storms will form.

Science Inquiry

Students can monitor the weather and make weather predictions with the activity "Weather or Not," which is described at the URL below. They will pick an outdoor event, such as a sporting event, that is scheduled to take place today or within the next few days. They will use real-time images and other resources in the monitoring area to come up with a prediction of the weather, which they will share with other students. Then they will find out if their prediction was right by looking for the weather report in the locale where the event took place. They might check the weather map in a newspaper or satellite images on a TV weather report. If the event was televised, they might be able to observe for themselves what the weather was like.

http://www.cotf.edu/ete/modules/weathernot/weathernot.html

Overcoming Misconceptions

Students may have the misconception that weather forecasting is an exact science, or that a single exact formula or method may be used to forecast weather accurately. Have students read the article at the following URL. They will learn that weather forecasting is at best an inexact science and never easy. Because weather is so complex and variable, it requires skill, experience, and even a bit of luck to forecast the weather accurately.

http://www.theweatherprediction.com/philosophy/conception/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 16.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 16.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What types of instruments would you expect to find at a weather station and what do these instruments measure?

- [At a weather station, you would expect to find a thermometer, a barometer, and other weather instruments, such as those that measure wind speed, wind direction, humidity, and amount of precipitation.]

2. How does a thermometer work?

- [In an old-fashioned mercury thermometer, mercury is placed in a long, narrow tube with a bulb at one end. The mercury expands and rises in the tube when the temperature increases. The temperature can be read on the side of the tube at the level to which the mercury rises. Some modern thermometers used a coiled strip instead of mercury to detect temperature changes. The coil is composed of two kinds of metal, each of which conducts heat differently. As the temperature rises and falls, the coil unfolds or curls up tighter. Other modern thermometers measure temperature using infrared radiation or electrical resistance.]

3. How could a barometer at a single weather station predict an approaching storm?

- [A barometer measures air pressure. A change in barometric pressure at a single weather station indicates that a change in weather is coming. If air pressure falls, a low-pressure cell is coming and will likely bring a storm.]

4. Why are weather balloons important for weather prediction? What information do they give that isn't obtainable in other ways?

- [Weather balloons have instruments that measure atmospheric characteristics as the balloons rise through the atmosphere. The balloons can also be tracked in flight to obtain wind speed and direction. A radio is used to communicate the data from the balloon to a computer on the surface. Weather balloons gather weather data directly from high in the atmosphere. This information is not obtainable in other ways.]

5. How does radar work, and what is its value in weather prediction?

- [A radar transmitter sends out radio waves that bounce off the nearest object and then return to the receiver. Weather radar reflects off water in the atmosphere, so it can detect precipitation, including its motion and intensity. Doppler radar can track how fast the precipitation is falling. Radar can outline the structure of a storm and estimate its possible effects.]

6. Imagine that your teacher asks you to predict what the weather will be like tomorrow. You can go outside or use a telephone, but you can't use a TV or computer. What method will you use?

- [Answers may vary. *Sample answer*: I would call someone I know who lives upwind from my location. The weather they have today is likely to be similar to the weather I will have tomorrow.]

7. Same as in question 6, only now you have access to electronics but not weather forecasts. You can look at weather maps and radar images but not look at interpretations made by a meteorologist. What method will you use?

- [Answers may vary. *Sample answer*: I would use a weather map and my knowledge of weather to make a forecast for my area. I would look to see what types of fronts and pressure centers are found on the weather map and are likely to be moving my way, based on the direction that weather usually moves in my region. For example, if a low-pressure center or cold front is approaching, I would predict that stormy weather is coming.]

8. No rain is in the forecast, but it's pouring outside. How could the NWP weather forecast have missed this weather event?

- [Answers may vary. *Sample answer*: Possible reasons the rain was missed include not enough initial data in the program, a flawed computer model that doesn't accurately calculate atmospheric behavior, a model that covers too small an area, or simply unpredictable changes in the atmosphere.]

9. What does it mean to say that weather is a chaotic system? How does this affect the ability to predict the weather?

- [Small, unpredictable changes cause chaos in the weather system, so we can't always predict how the weather will behave. A weather forecast is more likely to go off track the farther into the future the prediction is made because more small and unpredictable changes can occur over a longer time period.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

With so much advanced technology available, what is the role of meteorologists in creating accurate weather forecasts?

- [The role of meteorologists is to use their experience to analyze and interpret the forecasts made by computer models.]

With so much advanced technology available, why are weather forecasts so often wrong?

- [Weather forecasts are so often wrong because weather systems are so complex and chaotic. Small, unpredictable changes in weather factors can cause the weather to change in unpredictable ways.]

What advances do you think will be necessary for meteorologists to create accurate weather forecasts one to two weeks in advance of a major weather event?

- [Advances might include more data and more accurate mathematical models for atmospheric behavior.]

CHAPTER 17 HS TE Climate

Chapter Outline

17.1 Chapter 17: Climate

Chapter Overview

This chapter describes factors that affect climate, the different climates found worldwide, and the causes and effects of climate change.

Online Resources

See the following Web sites for appropriate laboratory activities:

In the "Paleoclimate Reconstruction Lab" at the following URL, students will reconstruct past climates using lake varves as a proxy for temperature. They will use the data to explore and interpret long-term climate patterns and to understand annual sediment deposition as it relates to weather and climate patterns.

- http://www.ei.lehigh.edu/eli/cc/sequence/day13.html

With the gold-star simulation lab at the URL below, students can explore the greenhouse effect and its impact on recent climate change. Specifically, using the simulation, students will investigate how atmospheric changes affect global temperature, examine how clouds contribute to the greenhouse effect, and predict how changing greenhouse gas levels affect global temperature.

- http://phet.colorado.edu/en/contributions/view/3092

In the STEM lab "Exploring the Relationship between CO_2 and Temperature Using Brassica Plants," students directly investigate the relationships between temperature and CO_2 over a period of 21 days. During days 8-14 of the experiment, students will insert a large amount of CO_2 into the system and then measure the effect this added CO_2 has on temperature. The lab requires students to develop a hypothesis about the relationship between CO_2 and temperature, analyze the data they collect, and use the data to support their conclusion in a formal report. An assessment rubric is provided.

- http://osep.northwestern.edu/sites/default/files/ClimateChange/CO2AndTemperature.pdf

These Web sites may also be helpful:

The URL below is one of the best online climate change resources for teachers. It includes a variety of materials for teaching about climate, climate change, and sustainability across the curriculum. You can explore tips, advice, and ideas for teaching this potentially controversial and misunderstood topic, addressing misconceptions, making interdisciplinary connections, and making the topics relevant to students' lives.

- http://serc.carleton.edu/teachearth/site_guides/climate.html

At the following URL, you can download a climate change guide that contains information and activities relating to climate change that are suitable for grades 7–12.

- http://dnr.wi.gov/org/caer/ce/eek/teacher/climatechangeguide.htm

You can access many climate change resources for teachers and students at this URL: http://www.globalsystemsscience.org/uptodate/cc.

At the URL below, you can find links to numerous games and simulations relating to climate.

- http://spark.ucar.edu/longcontent/games-sims-weather-climate-atmosphere

This guide points K-12 educators to the best sites for teaching about climate change: several that offer first-rate background material, and others that include detailed lesson plans and experiments. It begins with the top ten things people need to know about global warming and why there is so much controversy surrounding this issue.

- http://hdgc.epp.cmu.edu/teachersguide/teachersguide.htm

Explore best practices for teaching global climate change to high school students with these free, self-paced modules for teachers. Each module includes STEM resources that will increase your knowledge of climate change concepts and can be used directly with students.

- http://climate.nasa.gov/education/pbs_modules

Pacing the Lessons

TABLE 17.1: short caption

Lesson	Class Period(s) (60 min)
17.1 Climate and Its Causes	1.5
17.2 World Climates	2.5
17.3 Climate Change	2.5

17.2 Lesson 17.1: Climate and Its Causes

Key Concepts

- Definition of climate
- Latitude and climate
- Relationship of atmospheric circulation cells to climate
- Continental position and climate
- Ocean currents and climate
- Effects of altitude and mountain ranges on climate

Lesson Objectives

- Describe the effect of latitude on climate.
- Diagram the Hadley, Ferrell, and Polar atmospheric circulation cells, and show how they influence the climate of various locations.
- Discuss other important factors that influence a location's climate: position in the global wind belts, proximity to a large water body, position relative to a mountain range, and others.

Lesson Vocabulary

- **continental climate:** climate with extreme temperature differences due to location within a continent
- **Intertropical Convergence Zone (ITCZ):** low-pressure area at the equator where the northern and southern Hadley cells meet
- **maritime climate:** moderate climate influenced by a nearby ocean

Teaching Strategies

Introducing the Lesson

Write the following quote from American humorist Mark Twain on the board or an overhead:

Climate is what we expect, weather is what we get.

Lead the class in a discussion of how climate differs from weather starting with the quote. ("Weather is what we get" because weather consists of the actual conditions of the atmosphere on any given day. "Climate is what we expect" because climate refers to the expected weather conditions for that day and expectations are based on average weather over many years.) Tell students they will learn more about climate and how it differs from weather when they read this chapter.

Demonstration

Demonstrate atmospheric circulation cells with one or more of the animations at the following URLs.

- http://www.informmotion.biz/EarthLabs/Moving_Heat.html
- http://higheredbcs.wiley.com/legacy/college/strahler/0471417416/animations/ch05/page6.mov
- http://www.geography.hunter.cuny.edu/tbw/wc.notes/7.circ.atm/animations/GlobalWind.html
- http://kisdwebs.katyisd.org/campuses/MRHS/teacherweb/hallk/Teacher%20Documents/AP%20Biology%20Materials/Ecology/Tropical%20Atmospheric%20Circulation/50_A01s.swf
- http://www.youtube.com/watch?v=DHrapzHPCSA

Discussion

Discuss the relationship between atmospheric circulation cells and precipitation. Review how warm, moist air rises at the ITCZ and how cool, dry air sinks at a Hadley-Ferrell Cell boundary. Have students find these latitudes on a world rainfall map (see URL below) and identify the average annual precipitation that is found at each latitude. Call on volunteers to explain how atmospheric circulation is related to the precipitation levels.

http://www.climate-charts.com/World-Climate-Maps.html#rain

Differentiated Instruction

Divide the class into pairs that partner any differential learners with other students. Have each pair make a Venn diagram comparing and contrasting maritime and continental climates. Ask partners to discuss with each other why the climates differ. Then have each pair of students exchange and discuss their Venn diagrams with another pair.

Enrichment

Ask students to predict several locations in the world where they think deserts might occur because of rain shadow effect. Then have them find rainfall data for the locations to see if their predictions were correct. They should write a paragraph summarizing their predictions, the reasons for them, and whether they were supported by the data.

Science Inquiry

Have students do the inquiry activity "Local Geography and Climate" at the following URL. In the activity, students will first compare actual temperature data from coastal and inland cities in Peru. Then they will do a hands-on experiment to compare the heat capacity of soil and water. Finally, they will apply their experimental results to explain the temperature data. Links to real-time temperature data and ideas for homework extensions of the activity are included.

http://www.ciese.org/curriculum/weatherproj2/en/activityC4.shtml

Economics Connection

Discuss possible relationships between climate and economics with your class. Tell students that people have long observed that nations with tropical climates are generally less economically successful than those with temperate climates. Recent research offers two possible explanations for this relationship. The researchers argue that areas that have a cold winter season with annual hard frosts have an advantage for two reasons. Frost helps farmers increase agricultural productivity because it results in a buildup of organic matter in soil and produces adequate spring moisture for crops. Frost also helps control diseases, particularly malaria, because insect vectors die off in

the winter. You and/or your students can learn more by reading the summary of the research at this URL: http://www.scienceagogo.com/news/20010817233944data_trunc_sys.shtml.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 17.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 17.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe the weather of the location where you are right now. How is the weather today typical or atypical of your usual climate for today's date?

- [Answers will vary depending on the location and date. The weather may or may not be typical for the usual climate for today's date because weather can vary greatly for a given climate.]

2. In what two ways could a desert be found at 30 °N?

- [*Sample answer*: A desert could be found at 30 °N latitude because at this latitude, the air is descending at a Hadley and Ferrell cell boundary, and sinking air warms and causes evaporation rather than precipitation. The location could also be dry because it is in a rain shadow. This would occur if the location is on the leeward side of a mountain range.]

3. Could a desert form at 45 °N latitude? Explain how.

- [Yes; a desert could form at 45 °N latitude. Possible causes of a desert at this latitude include: rain shadow effect, because the desert is located on the leeward side of a mountain range; or a location in the interior of a continent, where typical air masses travel over large expanses of land so they are usually dry.]

4. Why is there so little wind in the locations where the atmospheric circulation cells meet?

- [Where the atmospheric circulation cells meet, air is either rising or sinking, so there is little horizontal air movement.]

5. If it is windy at 30 °N where there is normally little wind, does that mean the model of the atmospheric circulation cells is wrong?

- [No; there are many reasons for wind, and atmospheric circulation cells are just one cause. Local winds can form in almost any location. For example, land and sea breezes form along coasts because of temperature differences between land and water.]

6. What is the ITCZ? What winds do you expect to find there?

- [The ITCZ is the Intertropical Convergence Zone. This is a low-pressure area at the equator where the northern and southern Hadley cells meet. This area is called the doldrums because there are no steady winds.]

7. How does the polar jet stream move from summer to winter? How does this affect the climate of the locations where it moves?

- [The polar jet stream moves north in the summer and south in the winter. Because it divides cooler polar air from warmer tropical air, its location determines if a region will be under a relatively cool or relatively warm air mass. The polar jet stream is also often a zone of turbulent weather, so its location determines where storms are likely to occur.]

8. Imagine two cities in North America. How does the climate of a city at 45 °N near the Pacific Ocean differ from one at the same latitude near the Atlantic Coast?

- [The city near the Pacific Ocean will have a maritime climate, whereas the city near the Atlantic coast will have a continental climate. At 45 °N latitude, the prevailing winds blow from west to east. Therefore, on the Pacific coast the climate will be influenced by the Pacific Ocean to its west, while on the Atlantic coast the climate will be influenced by the continental land mass to its west. The Pacific coast location will have cooler summers and warmer winters than the Atlantic coast city.]

9. Why does the ocean water off California cool the western portion of the state, while the water off the southeastern United States warms that region?

- [The water off California is cool because of the cool, southward-flowing California current. There is also upwelling of cold deep water off the California coast. The water off the southeastern United States is warm because of the warm, northward-flowing Gulf Stream, which comes from near the equator.]

10. Think about what you know about surface ocean currents. How would you expect the climate of western South America to be influenced by the Pacific Ocean? Could this same effect happen in the Northern Hemisphere?

- [The Peru Current travels from the high latitudes toward the equator along the western side of South America. This cold current cools the region. Also, there is upwelling of cold deep water that helps to cool the region. The same effect happens along the western coast of the Northern Hemisphere.]

11. The Andes Mountains line western South America. How do you think they influence the climate of that region and the lands to the east of them?

- [The Andes Mountains block cool, moist coastal air just as the mountains of the Western United States do. The Andes create a rain shadow on the eastern side of the mountain range, causing the climate to be very dry.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Describe how two cities at the same latitude can have very different climates. For example, Tucson, Arizona, has a hot, dry desert climate and New Orleans, Louisiana, has a warm, muggy climate even though both cities are at approximately the same latitude.

- [Two cities at the same latitude can have very different climates because of their locations relative to oceans or mountain ranges. For example, Tucson, Arizona, has a hot, dry climate because it receives hot, dry air masses from Mexico. New Orleans, Louisiana, at approximately the same latitude, has a warm, muggy climate because it receives warm, moist air masses from the Gulf of Mexico.]

How does climate influence the plants and animals that live in a particular place?

- [Climate determines the types of plants and animals that live in a particular place. It is an important factor that shapes the kinds of adaptations the organisms evolve over time.]

Would you expect climate at similar latitudes to be the same or different on the opposite side of the equator. For example, how would the climate of a city at 45 °N be similar or different to one at 45 °S latitude?

- [The climates would be similar if the two cities were similar not just in latitude but also in terms of other factors that affect climate, such as their locations relative to oceans and mountain ranges. It is important to note that places in the Southern Hemisphere do not have true continental climates because the Southern Hemisphere continents are too narrow.]

17.3 Lesson 17.2: World Climates

Key Concepts

- Climate zones and biomes
- Tropical moist climates
- Dry climates
- Moist subtropical mid-latitude climates
- Continental climates
- Subpolar climates
- Polar climates
- Microclimates

Lesson Objectives

- Describe the relationship between climate zones and the factors that influence climate.
- Discuss the relationship between climate zones and biomes.
- Discuss the different biomes based on a general description.

Lesson Vocabulary

- **biodiversity:** measure of the number of different species of organisms in a region
- **biome:** major climate type and the organisms that live there
- **chaparral:** scrubby, woody vegetation that grows in a Mediterranean climate
- **desert:** very dry climate with low precipitation, high evaporation, and sparse vegetation
- **ice cap:** thick layer of permanent ice found mainly in Greenland and Antarctica
- **microclimate:** local climate that differs from the major climate type of the region where it is located
- **permafrost:** sub-surface layer of permanently frozen ground in an area with a polar climate
- **savanna:** tropical wet and dry biome characterized by grasses and widely scattered deciduous trees
- **steppe:** mid-latitude, semi-arid desert biome characterized by bunch grasses, scattered low bushes, and sagebrush
- **taiga:** coniferous forest that grows in a subpolar continental climate
- **tropical rainforest:** wet tropical biome characterized by abundant broadleaf evergreen trees and great biodiversity
- **tundra:** polar climate biome characterized by small plants such as mosses and no trees

Teaching Strategies

Introducing the Lesson

Introduce types of world climates by asking students what type of climate they have in their area. (Students might identify their climate as temperate, rainy, or in some other descriptive way but are unlikely to know their climate's classification). Give students the name of the type of climate where they live and tell them they will learn more about this and other types of climates when they read this lesson.

Cooperative Learning

Divide the class into five groups, and assign each group one of the major world climates described in the FlexBook® lesson: tropical moist climate, dry climate, moist subtropical mid-latitude climate, continental climate, and polar climate. Ask students in each group to collaborate on researching and creating a poster or brochure about their climate type. They should include climate sub-types, locations, typical organisms, and average weather conditions for their major climate type. Schedule a block of class time for groups to present their work to the rest of the class.

Using Visuals

When you discuss tropical moist (group A) climates with the class, call their attention to the images in the FlexBook® lesson that illustrate the diversity of climates within this group. Point out the tropical rainforest and African savanna pictures in the text. Call on students to explain why the biomes are so different when they are both located at or very near the equator. (The main difference is the amount and timing of precipitation.) Use this example as a way to make the point that all of the major climate groups have climate sub-types that may be quite variable.

Differentiated Instruction

The sheer amount of detail, with the descriptions of all the climate sub-types in this lesson, may be overwhelming for some students. Work with them to make a compare/contrast table for just the major climate groups (groups A). They should compare the climate groups with regard to temperature, precipitation, typical vegetation, and location.

Enrichment

Define microclimate and then challenge students to think about and write answers to these questions:

1. How small is a microclimate? (Microclimates can be a small as a few square centimeters or as large as several square kilometers.)
2. What is an example of a small microclimate? (*Sample answer*: A small area on the north side of rock that is usually shaded may have a cooler microclimate than an area just a few centimeters away.)
3. Would you expect to find microclimates in cities? (Cities can produce a wide variety of microclimates due to concrete acting as a heat sink and tall buildings creating wind tunnels.)

Science Inquiry

Hold a class discussion of the value of classification in scientific inquiry. Begin the discussion by asking students why they think it is important for scientists to classify climate. Then extend the discussion to classification in general. Points that might be made include the following:

- When scientists classify things, whether it is organisms or climates, they group similar things together.
- Scientists use classification to organize information and objects.
- Classification systems help scientists make sense of the world around them. (The world would be a chaotic place if we didn't have a way of organizing things.)
- When things are sorted into groups, it makes them easier to understand.
- Classifying things also makes it easier to see the relationships between them.

Overcoming Misconceptions

Many students may have the misconception that all deserts are hot. They have probably seen pictures of deserts such as the Sahara Desert, which is hot as well as very dry and sandy because it is relatively close to the equator. In actuality, deserts do not have to be in hot climates. An area is classified as a desert based on the amount of precipitation it receives. Deserts are also located at higher latitudes, and these deserts are not hot, at least not all of the time, and may be quite cold at times, especially at night.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 17.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 17.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why are most climate zones found in similar locations on continents within the Northern Hemisphere?

- [Most climate zones are found in similar locations because they have similar conditions. For example, they have similar latitudes and are affected by the same wind belts.]

2. Why do climate zones differ between continents, even though locations are similar?

- [Climate zones differ between continents for a variety of reasons. There might be geographic differences such as the presence or absence of mountain ranges or large bodies of water. For coastal climates, the ocean currents might be different. For example, one coastal climate might be influenced by a cold current and another by a warm current.]

3. Why do organisms in the same biome often look the same even though they are not the same species? Think about desert plants, for example. Why are the plants that live in low-latitude deserts on different continents so similar?

- [Organisms in the same biome must adapt to the same environmental challenges even if they live on different continents. Therefore, they may evolve some of the same adaptations and appear similar. In low-latitude deserts, for example, plants have similar characteristics, such as shallow roots that cover a wide area to maximize the amount of water the plants can take in, or thick fleshy leaves to store water and minimize evaporation.]

4. Why is the length of the dry season important in distinguishing different types of climate zones? Give an example.

- [Many species of plants need a steady supply of water to survive. Soil can store moisture for some period of time, so the plants can survive during a short dry spell. If the dry period is longer than the time that the soil can store moisture, a different type of plant must live in the region. An example of this occurs in tropical climates. In a tropical wet climate, rain falls year round and supports tropical rainforest plants. In a tropical wet and dry climate, in contrast, most of the rain falls in a single season and the dry season is too long to allow tropical rainforests to grow. Instead, this type of climate has savanna vegetation in which grasses are the most common plants.]

5. Since the equator receives the most solar radiation over the course of a year, why are the hottest temperatures found in the low-latitude deserts? Why are low-latitude deserts often chilly at night, even in the summer?

- [The hottest temperatures are found in low-latitude deserts rather than tropical rainforests because deserts are so much drier. Dry sand and rock heat up much more rapidly than water or moist soil and vegetation. Sand and rock also lose heat more quickly, explaining why low-latitude deserts are often chilly at night. The lack of cloud cover in deserts also contributes to their temperature extremes. There are no clouds to partially block strong solar radiation during the day or to hold in heat at night.]

6. What are the differences between arid and semi-arid deserts?

- [One difference between arid and semi-arid deserts is the amount of precipitation they receive. Arid deserts receive less than 25 cm (10 inches) of rain per year, whereas semi-arid deserts receive between 20 and 40 cm (8 to 16 inches) of rain per year. Another difference between the two types of deserts is latitude. Arid deserts are located between 15 ° and 30 ° latitude, whereas semi-arid deserts are located at higher latitudes in continental interiors or rain shadows. The differences in latitude result in arid deserts having warmer temperatures than semi-arid deserts.]

7. What conditions bring about the hot and humid summer days of the American South?

- [Summer days are hot in the American South because the latitude is relatively low, so there is a lot of solar radiation. Prevailing winds blow from the west over the continent, where temperatures are high during the summer, making the South even hotter. Westerly winds also bring in moist air from the Gulf of Mexico, which makes the weather humid.]

8. What is the most important factor in determining the presence of a forest?

- [The most important factor is water. Forests can grow in a variety of temperatures and may be able to survive large temperature ranges, but they cannot survive for long without adequate water.]

9. Look at the map of the Köppen climate classification system. Which climate types are found and where are they found in California? Which is most abundant? Why does California have so many major climate types?

- [The most common climate type in California is a Mediterranean climate. This climate type is found along much of the coast and in the Central Valley. The arid desert climate type is found in the southeastern portion of the state, near the Arizona border. Semi-arid desert is found in the southern Central Valley, north of the arid desert, and also in the rain shadow of the southern Sierra Nevada. In the northern Sierra Nevada at high altitudes, there are polar and subpolar climates. California has so many major climate types because it covers a wide range of latitudes and is influenced both by the ocean and by major mountain ranges.]

10. Polar regions receive little precipitation. Why are they not considered deserts?

- [Polar regions are not considered deserts even though they receive little precipitation because they are too cold to have much evaporation. As a result, they are not as dry as deserts.]

11. What is permafrost? Does it stay the same year round?

- [Permafrost is a sub-surface layer of permanently frozen ground in an area with a polar climate. The frozen layer may extend hundreds of meters below the surface. During the summer, warmer temperatures defrost the uppermost portion of the permafrost, but most of the permafrost remains frozen year round.]

12. Why are microclimates important to living things?

- [Microclimates are important to living things because they allow much more biodiversity to occur over a given area of land. Small areas with different climates may also provide temporary or seasonal homes for migrating organisms. For example, deer may move up a mountain in summer and down the mountain in winter to find forage.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why aren't biomes always determined by latitude? What geographic features or other factors affect the climate?

- [Biomes aren't always determined by latitude because other factors also affect the climate, including the presence of oceans or mountain ranges.]

Climate zones and biomes depend on many climate features. If climate changes, which of these features changes too?

- [If climate changes, many related features may also change, including sea levels and weather patterns.]

If global warming is increasing average global temperatures, how would you expect biomes to be affected?

- [Temperature is an important factor that defines biomes and determines which organisms are found in particular biomes. As average global temperatures increase, biomes may shift their location to higher latitudes or higher altitudes where temperatures are lower. Some organisms may be able to either migrate or adapt to changing conditions, but many others are likely to go extinct.]

17.4 Lesson 17.3: Climate Change

Key Concepts

- Climate change in Earth's history
- Short-term climate changes
- Causes of long-term climate change
- Global warming

Lesson Objectives

- Describe some ways that climate change has been an important part of Earth history.
- Discuss what factors can cause climate to change and which of these can be exacerbated by human activities.
- Discuss the consequences of rising greenhouse gas levels in the atmosphere, the impacts that are already being measured, and the impacts that are likely to occur in the future.

Lesson Vocabulary

- **El Niño:** natural, short-term climate variation in which the trade winds weaken or reverse directions and warm water accumulates on the surface of the Pacific Ocean off South America
- **global warming:** recent increase in Earth's average atmospheric temperature mainly due to human actions, especially the burning of fossil fuels
- **La Niña:** natural, short-term climate variation in which the trade winds are stronger than normal and cold water comes to the surface of the Pacific Ocean off South America
- **Milankovitch cycle:** 100,000-year cyclic change in Earth's position relative to the sun that affects Earth's global climate
- **slash-and-burn agriculture:** method of clearing land for farming, in which trees are cut and burned on the ground to make way for planting crops; occurs commonly in tropical rainforests
- **sunspot:** cool, dark area on the sun's surface that has a lower temperature than surrounding areas

Teaching Strategies

Introducing the Lesson

Providing students with some facts about recent and projected global climate trends and their predicted consequences is a good way to engage students in issues relating to climate change. First tell students that scientists predict that Earth's average temperature will rise from 2 to 4 degrees Celsius in the current century. Explain that a temperature increase of this magnitude may seem insignificant, but it would actually have catastrophic consequences. For example:

- Island states such as the Maldives would suffer major storm surges and rising sea levels that could cause many of the islands to disappear.
- Millions more people could experience coastal flooding each year.
- Some kinds of food productivity would decrease at low latitudes, and growing numbers of people in the poorest countries would suffer from malnutrition and serious diseases.
- Up to 30 per cent of all species would be at increasing risk of extinction.
- Water supplies to hundreds of millions of people would be in jeopardy.
- Climate [U+2010] related natural disastersas serious floods, droughts, and hurricanesincrease in number and severity, affecting hundreds of millions of people.
- The amount of money required to deal with climate [U+2010] related disasters would skyrocket.

Tell students they will learn more about these and other consequences of climate change, as well as the causes of climate change, when they read this lesson.

Building Science Skills

Have students do the activity "Track Your School's Climate Impact" at the URL below. With the activity, students can investigate the link between everyday actions at their high school, greenhouse gas emissions, and climate change. Using EPA's Climate Change Emission Calculator Kit (Climate CHECK), students can learn about climate change, estimate their school's greenhouse gas emissions, and identify ways to mitigate their school's climate impact. Students will gain detailed understandings of climate-change drivers, impacts, and science; and produce an emission inventory and action plan. They can even submit the results of their emission inventory to their school district. In addition, they can compare the energy use of their school with other schools nationwide, and they can earn the ENERGY STAR for their school if it qualifies as a top performer.

http://www.epa.gov/climatechange/wycd/school.html

Activity

Students can learn more about El Niño with the data-based activity at the following URL. In the activity, they will read an article, gather and analyze online data, and make predictions about the occurrence and economic impacts of El Niño based on their data.

http://www.oar.noaa.gov/k12/html/elnino2.html

Differentiated Instruction

Suggest that students outline the lesson to organize the information and focus on the most important points. They can use the headings in the lesson as their main outline entries and then add important details under each heading.

Enrichment

Challenge your more advanced students with the activity at the URL below. The activity is designed to give students an understanding of carbon capture and sequestration (CCS). Students will read three articles from which they will extract information on CCS and the pros and cons of different techniques. In the activity assessment, students will be presented with a conflicting viewpoint passage, similar to those found on college-admissions tests such as the ACT. The summation of the activity is a writing assignment in which students will present their own opinion on CCS and support it with information from the assigned articles or their own research.

http://osep.northwestern.edu/sites/default/files/ClimateChange/CarbonCaptureAndSequestration.pdf

Enrichment

If students are interested in learning more about global climate change, and especially about climate change research, direct them to the excellent and well-illustrated article at this URL: http://www.exploratorium.edu/climate/index.html.

Science Inquiry

The document below provides a set of three inquiry activities that allow students to investigate the chemistry of climate change. The focus is on the effects of pollution on the greenhouse effect and global climate change. Students will identify sources of air pollution and solutions to air pollution. They will also distinguish between natural and human-caused sources of air pollution. In addition, students will calculate the weight of various pollutants and visualize the amount of air pollution emitted by a car each year.

http://dnr.wi.gov/org/caer/ce/eek/teacher/Climateguide/pdf/02-2629-chemistry.pdf

Overcoming Misconceptions

People commonly think that weather anomalies can be used as evidence for or against climate change. Explain to your class that there is a link between climate change and weather, but any particular weather event cannot "prove" that climate change is happening. Instead, an important source of evidence for climate change comes from observations that average weather has changed for a region. You can find additional misconceptions about climate change at these URLs:

- http://cires.colorado.edu/education/outreach/climateCommunication/CC%20Misconceptions%20Handout.pdf
- http://www.c2es.org/publications/realities-vs-misconceptions-about-science-climate-change

Real World Connection

Have students do the activity "Climate Change Causes and Alternative Energy Solutions," which you can access at the following URL. The main goal of the activity is to help students better understand the current energy crisis and options available to help mitigate the problem. Students will learn why curbing and controlling the damage is so difficult financially and socially. Also, by studying the causes and effects of climate change, students will realize changes they can make in their own lives, no matter how small, to help decrease their carbon footprint.

http://osep.northwestern.edu/sites/default/files/ClimateChange/AlternativeEnergyProject.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 17.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 17.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why is the climate currently warming?

- [Earth's climate is warming mainly due to human actions that have added greenhouse gases to the environment, such as carbon dioxide from the burning of fossil fuels.]

2. Why does sea level rise and fall during interglacial and glacial periods?

- [If water is frozen as glacial ice, it is not available to be in the ocean. When glaciers melt, the water enters the ocean and sea level rises.]

3. How can the human history of Greenland be related to climate cycles?

- [When climate was warm, as it was during the Medieval Warm Period, the Vikings were able to colonize Greenland and grow crops there. When Earth's temperature decreased during the Little Ice Age, the Vikings were no longer able to grow crops in Greenland and were forced to leave.]

4. If climate has been much warmer in Earth history, why do we need to worry about global warming now?

- [We depend on conditions being the way they are now. Farms are placed where weather and soils have traditionally been good for farming. Cities are built at the shoreline, which depends on the sea level being stable. We depend on the species we know and on diseases being where we expect them to be.]

5. When the weather along coastal California is especially rainy with many winter storms, what is likely to be happening in the equatorial Pacific?

- [There is likely to be an El Niño. The Southern Oscillation brings warm waters across the Pacific Ocean, changing California's normal high pressure to low pressure. Low-pressure areas are often rainy.]

6. The Peruvian anchovy fishery collapsed in 1972. Using what you know about climate and food webs, can you devise an explanation for this event?

- [In 1972, there was an El Niño, which caused phytoplankton populations to collapse. The anchovy fishery had already been decimated by overfishing and so with the loss of their food supply, the fishery collapsed.]

7. What two events must occur for there to be an ice age?

- [Milankovitch cycles must be at the point where the Northern Hemisphere gets less solar radiation than normal. Also, plate tectonics must have moved the continents so that they are at or near the poles.]

8. What human activities are responsible for increasing greenhouse gases in the atmosphere?

- [Burning biomass and burning fossil fuels are two activities responsible for increasing greenhouse gases. Both release carbon dioxide into the atmosphere. In addition, with fewer plants, less carbon dioxide is removed from the atmosphere for photosynthesis.]

9. Why are CO_2 emissions projected to increase by so much during the next few decades?

- [Large nations, such as China and India, are growing rapidly. These countries are expected to increase their CO_2 emissions as they power homes, vehicles, and industries for their increasing populations.]

10. What role do the developed nations play a role in increasing CO_2 emissions in the next few decades?

- [These nations will increase emissions as standards of living increase and populations grow. Developed nations also play a role in emissions increases in China and other developing nations since many of the products that are created in those nations are exported to the developed nations.]

11. Why do storms increase in frequency and intensity as global temperatures increase?

- [Warm air can hold more moisture than cold air, which makes more water vapor available for storms. Hurricanes form only over ocean waters that are very warm (at least 28 °C). Energy in the atmosphere in general is what powers storms, so a warmer atmosphere means more frequent and more intense storms.]

12. Earth is undergoing some important changes, some of which are known about and monitored by satellites. Describe the sort of global change that satellites can monitor.

- [There are many possible answers. Satellites can monitor sea surface temperature changes, snow pack in mountain ranges, changes in storm tracks, and many other factors that indicate changes in climate.]

13. What will happen if sea level rises by 60 cm (2 feet) by the end of this century? Which locations will be hardest hit?

- [Low-lying areas will be hardest hit. Bangladesh, which already loses many people whenever there is a big flood, will lose many more. In the United States, flat coastal regions like the Gulf Coast will flood. Cities will require expensive modifications or will flood periodically.]

14. What can be done to reduce greenhouse gas emissions?

- [Students should think of ideas that include reducing emissions personally and making a more coordinated effort at all levels of government. Ideas could include riding a bus instead of driving, conserving energy at home and in industries, and switching to alternative energy sources such as solar, water, or wind power.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Nearly all climate scientists agree that human activities are causing the accelerated warming of the planet that we see today. Why do you think that the media are still talking about the controversy about this idea when scientists are almost entirely in agreement?

- [Virtually all credible scientists agree that Earth is warming and human actions are largely to blame. The evidence comes from many areas of science, including chemistry, glaciology, ecology, oceanography, remote sensing, agricultural science, and others. Because the media like to present a "balanced" story, media outlets often give equal time to climate skeptics who do not believe that global warming is happening, or if it is happening that human actions are largely responsible.]

If greenhouse gas emissions must be lowered to avoid some of the more serious consequences of global warming, why have humans not done something to lower these emissions instead of letting them increase?

- [There are many possible answers. Encourage a diversity of responses.]

In what ways can progress be made in reducing greenhouse gas emissions? Think about this on a variety of scales: for individuals, local communities, nations, and the global community.

- [Individuals can change their behavior, for example, by carpooling instead of driving alone. Local, national, and global communities can adopt policies and pass laws or sign treaties to reduce greenhouse gas emissions.]

CHAPTER 18 HS TE Ecosystems and Human Populations

Chapter Outline

18.1 Chapter 18: Ecosystems and Human Populations

Chapter Overview

This chapter describes ecosystems and explains how matter and energy flow through ecosystems. It also describe how the human population has grown and how it affects our global ecosystem

Online Resources

See the following Web sites for appropriate laboratory activities:

In the lab "Night Creatures of the Kalahari" (see URL below), students will investigate predator-prey relationships in spiders and fruit flies. They will create a set of food chain chambers (one control chamber and three chambers in which variables have been altered). Then they will make predictions and record observations for each chamber. After the lab, students will relate the chambers to real-life situations.

- http://www.pbs.org/wgbh/nova/education/activities/2501_kalahari.html

When students learn about the carbon cycle in Lesson 18.2, "Cycles of Matter," have them do the lab "The Oceans: Carbon Sink or Carbon Source?" at the following URL. First, students will learn how the oceans "absorb" carbon by biological and physical processes. Then, they will focus on biological processes by investigating the role of phytoplankton in the carbon cycle and analyzing conditions and locations for the growth of phytoplankton. They will also view seasonal and decadal changes in phytoplankton populations using a visualization from the NASA SeaWIFS satellite program. After completing the lab, students should be able to describe the biological and physical processes that make the ocean a carbon sink, describe the role of phytoplankton in maintaining the ocean biological carbon pump, and use systems thinking to predict the causal effects of warmer water on the biological carbon pump.

- http://serc.carleton.edu/eslabs/carbon/lab6.html

These Web sites may also be helpful:

At this URL, you can find a large collection of teacher-approved videos about ecosystems, biomes, and populations.

- http://www.neok12.com/Ecosystems.htm

For more information and many links on ecosystems, biomes, and habitats, go to this URL: http://www.fi.edu/tfi/units/life/habitat/.

A more sophisticated overview of cycles of matter, including some cycles not covered in the chapter, is available here:

- http://www.lenntech.com/matter-cycles.htm

You can find an excellent educator's guide to cycles of matter and the flow of energy through ecosystems at the following URL.

- http://astroventure.arc.nasa.gov/teachers/pdf/AV-Biolesson-6.pdf

At these URLs, you can access high school activities relating to the human population:

- http://www.worldof7billion.org/teacher_resources
- http://education.nationalgeographic.com/education/collections/population-7-billion/?ar_a=1

Pacing the Lessons

TABLE 18.1: short caption

Lesson	Class Period(s) (60 min)
18.1 Ecosystems	2.0
18.2 Cycles of Matter	2.0
18.3 Human Populations	2.5

18.2 Lesson 18.1: Ecosystems

Key Concepts

- Ecosystems and communities
- Roles in ecosystems
- Flow of energy in ecosystems
- Flow of matter in ecosystems

Lesson Objectives

- Discuss the importance of chemical and physical factors to living organisms.
- Describe the role of different species in an ecosystem.
- Describe the function of an ecosystem, and how different species fill different roles in different ecosystems.
- Describe energy transfer from the lowest to the highest trophic level in a food chain, including energy loss at every trophic level.
- Discuss how materials are cycled between trophic levels and how they can enter or leave a food web at any time.

Lesson Vocabulary

- **abiotic factor:** nonliving feature of an ecosystem, such as space, air, or water
- **biotic factor:** living feature of an ecosystem, such as a plant or an animal
- **carnivore:** type of consumer that eats only animals
- **commensalism:** relationship between organisms of different species in which one organism benefits and the other organism neither benefits nor is harmed
- **community:** all the populations of all the species in a particular ecosystem
- **competition:** relationship between organisms of different species that are both trying to obtain the same resources
- **consumer:** type of organism that uses other organisms for food
- **decomposer:** type of organism that breaks down the tissues of dead organisms or the wastes of living things and releases their nutrients to the environment
- **ecosystem:** community of living things and their environment
- **food chain:** simple model showing one pathway of energy through an ecosystem that includes a producer and one or more consumers
- **food web:** complex model that shows intersecting pathways of energy through an ecosystem
- **habitat:** place where a given organism is best suited to live
- **herbivore:** type of consumer that eats only plants
- **mutualism:** relationship between organisms of different species in which both organisms benefit
- **niche:** a species' particular "job" in an ecosystem
- **nutrient:** nonliving matter that organisms need to live and grow

- **omnivore:** type of consumer that eats both plants and animals
- **parasitism:** relationship between organisms of different species in which one organism benefits and the other organism is harmed.
- **population:** all the individuals of a species that live in the same place at the same time
- **predator:** animal that kills and eats other animals called prey
- **prey:** animal that is killed and eaten by a predator
- **producer:** type of organism that uses energy to make food for itself and other organisms by photosynthesis or chemosynthesis
- **scavenger:** type of consumer that eats animals that are already dead
- **species:** unique group of organisms that can interbreed and produce fertile offspring together but not with members of other such groups
- **symbiosis:** any relationship between organisms of different species in which at least one of the organisms benefits; mutualism, commensalism, or parasitism
- **trophic level:** energy level in a food chain or food web, such as producer, primary consumer, or secondary consumer

Teaching Strategies

Introducing the Lesson

The term ecosystem is likely to be familiar to most if not all of your students from previous science classes. Introduce ecosystems with a word association game. Call on each student in turn to say the first word that comes to mind when they hear the term ecosystem. Continue around the room until no new words are forthcoming. (Possible words might include species, niche, environment, and food chain.) Tell students they will learn about ecosystems and related concepts when they read this lesson.

Building Science Skills

The activity at the following URL is a good one for introducing students to communities and ecosystems. Students will list familiar organisms found in several different communities, distinguish between producer and consumer organisms in their list, and then examine and identify as many organisms as possible in a soil community.

http://mypages.iit.edu/ smile/bi9115.html

Activity

With the interactive animation at the URL below, students can explore symbiotic relationships in a coral reef ecosystem.

http://www.pbs.org/wgbh/evolution/survival/coral/index.html

Differentiated Instruction

Determining the meanings of unfamiliar words by analyzing word parts is an extremely helpful skill for students to develop. Point out that the word abiotic ("nonliving") means the opposite of the word biotic ("living"). Ask students to infer the meaning of the prefix a- based on this example. (It means "not.") Give students additional examples of words that are negated by adding the prefix a-. (e.g., moral/amoral, symmetric/asymmetric.)

Enrichment

Healthy ecosystems provide several important services, such as providing us with clean water and air and pollinating crops. Interested students can learn more about ecosystem services by reading the article at the first URL below. At the second URL below, you can find two student handouts to accompany the article. Assign one or both handouts. With the first handout, students will create a public service announcement about the importance of ecosystem services. With the second handout, they will investigate how ecosystems provide a particular service. Have students present their finished work to the class.

http://www.actionbioscience.org/environment/esa.html

http://www.actionbioscience.org/environment/lessons/esalessons.pdf

Science Inquiry

Students will analyze and graph population data for predators and prey in the activity at the following URL. The activity will give students a better understanding of the predator-prey relationship and how populations of predators and prey influence each other.

http://www.biologycorner.com/worksheets/predator_prey_graphing.html#.UcYhtoXD-M8

Overcoming Misconceptions

Misconceptions about ecosystems are common. Several are listed below (along with the correct conceptions in parentheses). Use the list as a true/false quiz, and discuss any of the misconceptions that students think are true. An effective way to dispel misconceptions is with examples that counter the misconceptions and show they are false.

1. Varying the population size of a species may not affect an ecosystem because some organisms are not important. (All organisms are important in an ecosystem. Varying a species' population size may not affect all other species equally, but it will affect the ecosystem as a whole.)
2. Ecosystems are not a functioning whole but simply a collection of organisms. (Ecosystems include not just the organisms but also the interactions between organisms and between the organisms and their physical environment.)
3. Ecosystems change little over time. (Ecosystems are always changing. They change to natural hazards, environmental changes, and human activity.)
4. Species coexist in ecosystems because of their compatible needs and behaviors; they need to get along. (Within an ecosystem, species compete for resources and feed on one another. Species live in the same ecosystem because of similar adaptations and environmental needs.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 18.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 18.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is the difference between a population, a community, and an ecosystem?

- [A population is all the members of one species that live in the same area at the same time. All the populations of the all species in an ecosystem make up a community. Besides its community of organisms, an ecosystem includes all of the abiotic factors that the organisms need for survival.]

2. What is the difference between a niche and a habitat?

- [A niche is a species' "job" in an ecosystem. A habitat is the place where a species is well suited to survive. In short, a niche is the way an organism makes its living, and a habitat is where it lives.]

3. Why are the roles in different ecosystems the same but the species that fill them often different?

- [There are only a limited number of roles that species can fill in any ecosystem, such as producer, primary or secondary consumer, or decomposer. All ecosystems have these same roles, but the roles often are filled by different species depending on the climate and other factors. For example, grasses

are the main producers in savanna ecosystems, whereas trees are the main producers in tropical rainforest ecosystems.]

4. Why are there no producers in the deep-sea ecosystem? Without producers, where does the energy come from? What is the ultimate source of the energy?

- [Except at hydrothermal vents, where the producers are microbes that produce food by chemosynthesis, there are no producers in the deep-sea ecosystem because there is no sunlight for photosynthesis. Dead organisms and wastes fall down through the water to the deep sea, and these materials provide energy and nutrients to the organisms that live there. The ultimate source of energy is generally sunlight, because the producers in most marine food webs are phytoplankton that make food by photosynthesis.]

5. Is a predator an herbivore, carnivore, or omnivore? How about a prey?

- [A predator is usually a carnivore, although some may be omnivores. A prey animal can be any of the three.]

6. Biologists have been known to say that bacteria are the most important living things on the planet. Why would this be true?

- [Bacteria are so important because they are the dominant decomposers. If there were no bacteria, most dead organisms and organic wastes would not be broken down, so their nutrients would not be released into the environment. Without nutrient recycling, other organisms could not survive, and life would eventually die out.]

7. Why are you so much more likely to see a rabbit than a lion when you're out on a hike?

- [A lion is a top predator. There are few lions because so little energy reaches such a high trophic level. One lion must eat a lot of rabbits to live, so there are many rabbits but not many lions.]

8. How much energy is available to organisms on the 5th trophic level compared with those on the 1st? How does this determine how long a food chain can be?

- [Only 1/10 of the energy available at a given trophic level is available to the next higher trophic level. Therefore, the 2nd trophic level has 1/10 as much energy available to it as the 1st. The 3rd has 1/100 as much as the 1st. The 4th has 1/1000 as much as the 1st. The 5th has 1/10,000 as much as the 1st. After the 4th or 5th trophic level, there is too little energy left to support more organisms. This limits how long a food chain can be.]

9. Why is a food web a better representation of the feeding relationships of organisms than a food chain?

- [Some organisms feed on multiple organisms, often from more than one trophic level. A food web, but not a food chain, can represent these more complex feeding relationships.]

10. Why is energy transferred only in one way in an ecosystem, but nutrients cycle around?

- [Energy can enter a food web only through the producers. All other organisms in an ecosystem obtain energy from producers, either directly or indirectly. Producers are the bottom trophic level of an ecosystem. At each higher trophic level, only 10 percent of energy is passed on, so energy must be constantly added to the ecosystem. Nutrients, in contrast, cycle around the ecosystem, passing from one organism to another in a food web. Decomposers break down organic matter to release nutrients back into the environment so they can be re-used by producers and repeat the cycle.]

11. Why does a predator kill its prey but a parasite rarely kills its host?

- [A predator is a consumer that eats dead animals, so it kills its prey for food. A parasite is an organism that survives in a symbiotic relationship with another organism, called the host. The parasite needs a living host in order to obtain food, so it rarely kills its host.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What happens if two species attempt to fill the same niche?

- [If two species attempt to fill the same niche, they will compete with each other. One species is likely to out-compete the other species, which may die out in that ecosystem.]

There is at least one exception to the rule that each ecosystem has producers, consumers, and decomposers. Excluding hydrothermal vents, what does the deep-sea ecosystem lack?

- [The deep-sea ecosystem lacks producers.]

Where do humans fit into a food web?

- [Most humans are omnivores who eat at many trophic levels, from producers such as lettuce to high-trophic-level consumers such as large fish.]

Most humans are omnivores, but a lot of what we eat is at a high trophic level. Since ecosystems typically can support only a few top predators relative to the number of lower organisms, why are there so many people?

- [People can raise animals for food in very large numbers rather than depending on prey populations in natural ecosystems. This allows large numbers of people to be supported as top predators.]

18.3 Lesson 18.2: The Carbon Cycle and the Nitrogen Cycle

Key Concepts

- Short-term cycling of carbon
- Long-term cycling of carbon
- Carbon sinks and carbon sources
- Human actions and the carbon cycle
- Importance of the carbon cycle
- The nitrogen cycle

Lesson Objectives

- Describe the short term cycling of carbon through the processes of photosynthesis and respiration.
- Identify carbon sinks and carbon sources.
- Describe short-term and long-term storage of carbon.
- Describe how human actions interfere with the natural carbon cycle.
- Describe the nitrogen cycle.

Lesson Vocabulary

- **carbohydrate:** organic compound that supplies energy to living things; sugar, starch, or cellulose
- **carbon sink:** reservoir for carbon that absorbs more carbon dioxide than it emits
- **carbon source:** reservoir for carbon that emits more carbon dioxide than it absorbs
- **deforestation:** cutting down and/or burning all of the trees in a forested area

Teaching Strategies

Introducing the Lesson

Introduce the carbon cycle by reviewing the element carbon and its properties. Show students the clever animated cartoon about carbon by NPR's Robert Krulwich at the following URL (Episode 1). Tell students they will learn more about carbon and how it cycles through ecosystems when they read this lesson.

http://www.npr.org/news/specials/climate/video/

Demonstration

Demonstrate the carbon cycle to your students by showing students the video "Keeping Up With Carbon" at the URL below. It provides a detailed overview of the carbon cycle and how it is being affected by human actions.

http://www.neok12.com/php/watch.php?v=zX745f736f476a0b58005a5d&t=Carbon-Cycle

Activity

For a deeper understanding of the carbon cycle, have students play the carbon cycle game described at the following URL. By rolling a die, students will simulate a molecule of carbon's movement throughout various sinks and sources within the carbon cycle.

http://www.ctenergyeducation.com//lesson.htm?id=muefmifp

Cooperative Learning

In the "jigsaw" exercise at the URL below, each student is assigned one of five geochemical processes in the carbon cycle to research, fully understand, and then explain to others in groups of five. By the end of the activity, all of the students will know about each of the five processes and have an understanding of the entire carbon cycle.

http://serc.carleton.edu/NAGTWorkshops/climatechange/activities/15162.html

Differentiated Instruction

Pair students who need extra help with other students, and have partners work together to create a simple cycle diagram of the nitrogen cycle. Suggest to students that they keep their cycle diagram in their science notebook.

Enrichment

Direct students who need enrichment to the nitrogen cycle learning module at the URL below. It presents lesson content at a more advanced level and includes a self-scoring quiz that students can take for assessment.

http://www.visionlearning.com/library/module_viewer.php?mid=98&mcid=&l=

Science Inquiry

The activity described in the PDF document below is an inquiry-based approach to investigating the nitrogen cycle in a simplified desktop ecosystem involving aquaria and hydroponically grown plants. Specific learning objectives include identifying biotic and abiotic environmental components, understanding nitrogen cycling, measuring and graphing nutrient levels and plant growth, and generating hypotheses about the impact of nutrients on plant growth.

http://csip.cornell.edu/Curriculum_Resources/CEIRP/Aquaponics.pdf

Language Arts Connection

The activity at the URL below uses creative writing to improve student understanding of the nitrogen cycle. Students begin by self-assessing their knowledge of the nitrogen cycle by drawing a diagram to represent it. Then they research one nitrogen cycle component and choose three or four facts of interest about their component to report to the rest of the class. Small groups of students then use a set of small objects and cards to model a possible nitrogen

cycle, with arrows showing how nitrogen moves through the cycle. Finally, students write a limerick, haiku, or other poem to relate facts about their component of the nitrogen cycle and then share their poem with the class.

http://serc.carleton.edu/NAGTWorkshops/health04/activities/21756.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 18.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 18.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Describe the role of carbon in the process of photosynthesis.

   - [In photosynthesis, plants or other photosynthetic organisms use carbon dioxide and water to make sugar. This requires light energy, and oxygen is released as a waste product. Carbon dioxide from the atmosphere is the source of the carbon in the sugar molecules that are synthesized in this process.]

2. How can carbon cycle very quickly from the atmosphere and then back into the atmosphere?

   - [One way that carbon can cycle very quickly is if a plant takes in carbon dioxide to make food and then is eaten by an animal, which undergoes respiration and breathes out carbon dioxide.]

3. Describe one way that carbon can be stored for a short time in the natural cycle.

   - [Answers may vary. *Sample answer*: Carbon can be stored for a short time in the tissues of living things. When organisms die and decompose, their carbon is released back into the environment.]

4. Describe two ways that carbon can be stored for a very long time in the natural cycle.

   - [Answers may vary. *Sample answer*: Carbon can be stored for a very long time in fossil fuels or ocean floor sediments. The organic material of an organism may be buried and transformed over millions of years into coal, oil, or natural gas. Many ocean creatures use calcium carbonate ($CaCO_3$) to make their shells. When these organisms die, their organic material becomes part of ocean floor sediments, which may stay at the bottom of the ocean for many years.]

5. Describe what makes a carbon sink and what makes a carbon source; give an example of each.

   - [A carbon sink is a reservoir where carbon is stored. A healthy living forest is an example of a carbon sink. A carbon source is a reservoir from which carbon can enter the environment. The mantle is a source of carbon in volcanic gases.]

6. Describe two ways that humans interfere with the natural carbon cycle.

- [Two ways that humans interfere with the natural carbon cycle are by burning fossil fuels and by deforestation. Both actions change carbon sinks to carbon sources and thereby increase the amount of carbon dioxide in the atmosphere.]

7. Describe two important functions for carbon dioxide in the atmosphere.

- [Carbon dioxide in the atmosphere is a greenhouse gas that contributes to the natural greenhouse effect and helps keep Earth's temperature warm enough for living things. Carbon dioxide in the atmosphere is also essential for producers to make sugar by photosynthesis.]

8. The impacts of global warming are being felt and will be felt increasingly in your lifetime. What impacts are likely to be seen in the next few decades?

- [Impacts might include species extinctions, rising sea levels, and increasingly severe weather.]

9. Nitrogen is the most abundant gas in the atmosphere. What needs to happen to nitrogen gas before it can be used by living creatures?

- [Although nitrogen is abundant in the atmosphere, it is not in a form that plants can use. To be useful, nitrogen must be "fixed," or converted into nitrogen compounds such as nitrates or ammonia. Nitrogen is fixed mainly by bacteria in the soil.]

10. What is the role of nitrogen in the creation of a dead zone?

- [Nitrogen in fertilizers runs off the land and ends up in bodies of water. The nitrogen "fertilizes" the water and causes enormous numbers of bacteria to grow. When the bacteria die, their decomposition uses up all the available oxygen. Without oxygen, fish and other larger organisms cannot survive. When this occurs on a large scale, it creates a dead zone.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

18.4 Lesson 18.3: Human Populations

Key Concepts

- Population carrying capacity
- Limits on population growth
- Human population growth
- Humans and the environment

Lesson Objectives

- Describe how changes in a limiting factor can alter the carrying capacity of a habitat.
- Discuss how humans have increased the carrying capacity of Earth for our species and how we may have exceeded it.
- Discuss how human activities such as agriculture and urbanization have impacted the planet.
- Describe sustainable development.

Lesson Vocabulary

- **carrying capacity:** number of individuals of a given species that a particular environment can support
- **Green Revolution:** changes in the way food is produced since World War II that have resulted in enormous increases in production
- **Industrial Revolution:** time when mass production and fossil fuel use started to grow explosively, beginning in the late 1700s in Western Europe
- **invasive species:** species of organism that spreads in an area where it is not native
- **limiting factor:** factor such as a nutrient, water, or space that limits the size of a population in an area
- **over-consumption:** use of resources to a degree that is unsustainable in the long term
- **overpopulation:** situation in which the population of an area exceeds its carrying capacity or does long-term harm to resource availability or the environment
- **pesticide:** chemical that kills a certain pest that would otherwise eat or harm plants that humans want to grow
- **sustainable development:** economic development that helps people out of poverty, uses resources at a rate at which they can be replaced, and protects the environment

Teaching Strategies

Introducing the Lesson

Have students look at the human population graph in the FlexBook® lesson, showing the size of the human population from 10,000 BC through 2000 AD. Challenge students to suggest reasons why the human population

started to increase so dramatically in the recent past. Accept all reasonable responses at this point, and then tell students they will learn how and why the human population has grown when they read this lesson.

Building Science Skills

Carbon emissions from the burning of fossil fuels contribute to global warming. Population growth, along with rapid industrialization over the past two centuries, has increased the world's carbon emissions significantly. By doing the activity at the URL below, students will be able to analyze an online simulation of carbon emissions and population change. They will also graph historical data for global population growth and carbon dioxide emissions. They will discuss the relationship between population growth and carbon dioxide emissions as well as the future implications and responsibilities that come with growing affluence around the world.

http://www.worldof7billion.org/images/uploads/generating_heat.pdf

Activity

In the interactive animation at the following URL, world maps reveal the human footprint on Earth's water, air, climate, forests, and animal habitats. The maps allow students to examine geographical connections between population growth and environmental degradation across the globe in order to answer the question: How do consumption and rapid population growth affect our planet's natural resources?

http://www.pbs.org/wgbh/nova/earth/earth-peril.html

Differentiated Instruction

Suggest that students make a main ideas/details chart for this lesson. Tell them to write at least one main idea for each of the lesson headings. They can write the main ideas on the left side of a sheet of paper, leaving room to fill in important details for each main idea on the right side of the paper.

Enrichment

Challenge one or more students who are especially interested in the issue of human overpopulation to read and write a book review of one of the following books on the issue:

- Life on the Brink: Environmentalists Confront Overpopulation (2012), by Philip Cafaro and Eileen Crist
- Too Many People?: Population, Immigration, and the Environmental Crisis (2011), by Ian Angus et al.
- Full Planet, Empty Plates: The New Geopolitics of Food Scarcity (2012), Lester R. Brown

Science Inquiry

With the activity at the following URLs, students will use the "trendalyzer" program from www.GapMinder.org to construct and interpret dynamic graphs and discuss differences in life expectancy, fertility rates, health, economics, and total population among several different countries. Examining some of the factors related to a country's economic development will help students see connections between population trends and social, environmental, and economic trends throughout the world over time.

http://www.worldof7billion.org/images/uploads/Development_in_Motion1.pdf

Overcoming Misconceptions

As a homework assignment, have students read the article about human population myths at the following URL. The next day, discuss the myths with the class. The article provides numerous examples to counter the myths and explains the faulty reasoning behind them.

http://www.developmenteducation.ie/blog/2012/07/5-myths-about-the-worlds-population/

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 18.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 18.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. If phosphorus is limiting to a species in an ecosystem and the amount of phosphorus is increased, what will happen to the population of that species? What will happen to the carrying capacity?

- [The population of that species is likely to increase in size unless another factor limits the size of the population. The carrying capacity may increase for that species in that environment, although a new limiting factor might impose a new carrying capacity on the population.]

2. Name some factors that could cause a population to increase. Try to include as many types of factors as possible.

- [Answers may vary. *Sample answer*: Some factors that could cause a population to increase include an increase in a limiting factor such as a food source, the extinction or decline of a competing species, a fall in the number of predators, a decrease in the numbers of a disease-causing agent, or the evolution of a new trait that improves adaptation to the environment.]

3. In terms of numbers of births and deaths, explain in detail why you think human population is growing so tremendously.

- [*Sample answer*: Because of the advances in medicine and technology, particularly the green revolution, death rates have fallen for most human populations. However, in many populations, birth rates remain high. The combination of relatively low death rates and high birth rates results in rapid population growth for the human population as a whole.]

4. If all people on Earth were allowed only to replace themselves (that is, each person could only have one child or each couple two children), what would happen to the planet's population in the next decade? Would it decrease, increase, or remain exactly the same as it is now? Why do you say that?

- [The population would increase for at least the next couple of decades. This is because there would already be many people in the population in the young adult and lower age groups. These are the people that would add births to the population and cause it to grow now and over the next generation.]

5. What role has agriculture played in human population and why?

- [Human population has increased with each major advance in agriculture. Agriculture allows people to grow more food and to settle down. When they are settled, they can store food and have it available to them year round. Farmers now can feed many more people than they once could due to advanced technologies.]

6. Discuss the good and bad points about the green revolution.

- [The green revolution has increased the amount of food that can be produced, resulting in less malnutrition and starvation by allowing more people to be fed. On the other hand, the farming techniques of the green revolution have also generated a lot of pollution. For example, some pesticides are toxic, and dead zones are created as fertilizers drain off farmland and introduce nutrients into bodies of water. Although the increase in food allows more people to be fed, people need more than food. For example, they also need clean water, secure shelter, and a place for their wastes. These other needs are not being met for large numbers of people around the world.]

7. In the United States, 17 % of energy is used for agriculture. How is this possible, if plants photosynthesize with sunlight?

- [Modern agricultural practices require a lot of energy. Energy is needed to power farm machines and to transport farm produce to market. Energy is also need to produce fertilizers, pesticides, and other chemicals that today's farmers rely on to produce their crops.]

8. What is more threatening to the future of the planet: overpopulation or over-consumption? How does an increase in the standard of living for people living in poverty affect the planet?

- [Answers may vary. *Sample answer*: At present, over-consumption is a bigger problem because people in the developed nations use far more resources than people in the developing countries of the world, even though there are fewer people in the developed nations. This is because of their over-consumption. An increase in the standard of living for people living poverty would result in greater use of resources and the production of more wastes. On the other hand, women who are lifted out of poverty and who are educated and employed tend to have fewer children. Therefore, increasing the standard of living should eventually result in a smaller human population and reduction in the problems associated with overpopulation.]

9. What evidence is there that humans are exceeding Earth's carrying capacity for our species?

- [Evidence that humans are exceeding Earth's carrying capacity for our species includes the fact that we are using many resources faster than they are being replaced by natural processes. We are also producing tremendous amounts of wastes that are not able to be absorbed by natural processes and are damaging the environment.]

10. What is sustainable development?

- [Sustainable development is economic development that helps people out of poverty, uses resources at a rate at which they can be replaced, and protects the environment.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18. Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How much impact on the planet does an infant born in the United States have during its lifetime, compared with one born in Senegal?

- [An infant born in the United States has a much greater impact on the planet than an infant born in Senegal. Not only is the U.S. infant likely to live longer, but the child is also likely to use far more resources throughout his or her life than the one in Senegal.]

How does consuming less impact global warming?

- [Consuming less reduces the use of fossil fuels that produce carbon dioxide when burned. This, in turn, decreases greenhouse gases and global warming.]

Can ordinary people really make a difference in changing society toward more sustainable living?

- [If enough people work to reduce their consumption of resources and the pollution this causes, then it may be possible to change society toward more sustainable living.]

CHAPTER 19 HS TE Human Actions and the Land

Chapter Outline

19.1 Chapter 19: Human Actions and the Land

Chapter Overview

This chapter discusses how human actions have caused soil erosion and pollution of the land surface, as well as how these problems can be prevented.

Online Resources

See the following Web sites for appropriate laboratory activities:

In the soil erosion lab at the URL below, students will investigate the effect of vegetation removal on soil fertility, analyze common agricultural practices to determine their impact on soil and the environment, and predict possible effects of soil mismanagement.

- http://www.learnnc.org/lp/pages/3701

This lab activity will help students understand how Superfund sites are created. They will learn what activities produce hazardous waste and how contaminants are released into the environment. They will also learn what types of pollution can be cleaned up using Superfund authority and what types are addressed through other laws. In the experimental part of the lab, students will construct a model to observe how contaminants in soil enter and move through groundwater.

- http://www.epa.gov/superfund/students/clas_act/haz-ed/act02.htm

These Web sites may also be helpful:

At the following URL from the Soil Science Society of America, you can find a collection of high school teaching resources pertaining to soil.

- http://www.soils.org/about-soils/lessons/resources

You can find excellent photos and videos of soil erosion, including historical images from the Dust Bowl, at this URL: http://www.soilerosion.net/doc/photos_videos.html.

Two additional soil erosion videos are available here: http://www.ewg.org/losingground/index.html.

At the following URL, you can access Hazed teaching materials from the EPA. The materials include interdisciplinary activities that focus on scientific, technical, and policy issues relating to hazardous waste sites and the Superfund. The materials are designed to help middle and high school students develop skills in critical thinking, problem solving, and decision making. They also increase environmental awareness and encourage an environmental ethic in students.

- http://www.epa.gov/superfund/students/clas_act/haz-ed/hazindex.htm

The EPA's Environmental Response Team Video education program (see URL below) offers eight video-based modules to high school teachers. The free videos highlight real-world environmental clean-up efforts.

- http://www.ertvideo.org/home.html

Pacing the Lessons

TABLE 19.1: short caption

Lesson	Class Period(s) (60 min)
19.1 Loss of Soils	1.5
19.2 Pollution of the Land	1.5

19.2 Lesson 19.1: Loss of Soils

Key Concepts

- The Dust Bowl
- Causes of soil erosion
- Preventing soil erosion

Lesson Objectives

- Explain how human actions accelerate soil erosion.
- Describe ways that we can prevent soil erosion.

Lesson Vocabulary

- **leaf litter:** layer of organic debris such as dead leaves, bark, and branches that accumulate on a forest floor

Teaching Strategies

Introducing the Lesson

Bring a small sample of soil to class in a closed brown paper bag. Tell students you will give them clues about the material in the bag and they should try to identify it with as few clues as possible. Then read these clues until students correctly identify soil:

- It can take a thousand years to grow an inch.
- There are more than 70,000 kinds of it in the U.S.
- It usually consists of about 25 percent air.
- Its particles come in a range of sizes.
- Five tons of it spread over an acre forms a layer only as thick as a dime.
- Five to ten tons of animal life can live in one acre of it.
- Earthworms eat it.

Tell students they will learn why soil is being lost and how soil loss can be prevented when they read this lesson.

Activity

With the activity at the following URL, students will learn how damaging soil erosion can be to agriculture and the environment. They will also learn how to estimate the rate of soil loss in a field using the universal soil loss equation.

http://www.edu.pe.ca/agriculture/erosion.pdf

Differentiated Instruction

Have students do a think-pair-share activity to help them focus on the most important points in the lesson. First ask them to think about the five questions listed below. Then pair students who need extra help with other students, and ask partners to share and discuss their answers to the questions.

1. What was the Dust Bowl?
2. What caused the Dust Bowl?
3. What are the agents of soil erosion?
4. What human activities increase the chances that soil will be eroded?
5. What can people do to prevent soil erosion?

Enrichment

Ask a small group of students to do the demonstration described at the URL below. They will construct an apparatus to simulate soil erosion by water. Have them use the apparatus to demonstrate how the use of mulch reduces soil erosion. Set aside at least 10 minutes of class time for the students to present the demonstration to the class.

http://soils.usda.gov/education/resources/lessons/experiments/erosion/

Science Inquiry

Do the class demonstration activity in the lesson plan below. Objectives are to demonstrate that less disturbed soils contain more "soil glue" (such as the protein glomalin) so they hold together better than disturbed soils. Students will observe how well different soil samples hold together in water and make inferences about soil type and erosion. They will also conclude why it is important to disturb soil as little as possible.

http://soils.usda.gov/sqi/publications/files/soil_glue_lesson_plan.pdf

Overcoming Misconceptions

Students commonly think that all soil erosion is caused by human actions. To counter this misconception, describe examples or show photos of soil erosion due to natural causes. Explain that the soil lost due to natural erosion is balanced by the natural formation of new soil. However, human activities have increased the rate of soil erosion and thrown the natural system out of balance. You and/or your students can read more about natural causes of soil erosion and human impacts on the causes at this URL: http://www.scienceclarified.com/El-Ex/Erosion.html#ixzz2XY2mVtW3

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 19.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 19.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Many farmers harvest their crops in the fall and then let the leftover plant material stay on the ground over the winter. How does this help prevent erosion?

- [The leftover plant material helps to hold the soil in place and to protect it from wind and driving rains. This helps prevent runoff, wind, and rain from eroding the soil.]

2. Discuss five ways human activity has accelerated soil erosion.

- [Answers may vary. *Sample answer*: Five ways human activity has accelerated soil erosion include agriculture, logging, mining, recreational activities, and building construction. These activities generally remove natural vegetation from soil so that it is more exposed to erosion by water and wind. They also tend to disturb the soil so it doesn't hold together as well.]

3. How do urban areas contribute to soil erosion?

- [Urban areas have a lot of surface areaas roofs, roads, sidewalks, and parking lotsare not permeable to water. This increases runoff and the soil erosion it causes.]

4. What is the connection between poverty and soil erosion in developing countries?

- [When people live in poverty they are more concerned about growing food than protecting the soil. They also may not be able to afford practices, such as planting cover crops or avoiding planting on hillsides, which help reduce soil erosion.]

5. What is one way you can prevent soil erosion when you are hiking?

- [You can prevent soil erosion when hiking by staying on designated trails.]

6. You often see stone barriers or cage-like materials set up along coastal shores and river banks. How do you think these serve to prevent erosion? Why are areas like this prone to erosion?

- [These serve to prevent erosion by preventing flowing water from washing over the shore or river banks. Areas like this are prone to erosion because they are sloped and subject to water flowing over them.]

7. What can people in developed nations do to reduce the likelihood of bad environmental practices being used in developing countries, particularly activities that increase soil erosion?

- [Answers may vary. *Sample answer*: People in developed nations can help educate people in developing countries about the importance of protecting the soil from erosion and practices they might adopt to protect the soil. They also might provide financial help or incentives to people in developing countries so it is economically feasible for them to adopt practices that will reduce soil erosion.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 19. Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why should soil be considered a renewable resource? Why should it be considered a non-renewable resource?

- [Soil should be considered a renewable resource because new soil is constantly forming as rocks weather and organic materials break down. Soil should be considered a non-renewable resource because new soil forms much more slowly than soil is being lost by erosion.]

Could humans live without soil?

- [No; we need soil to grow plants. Without plants, we would not have the food we need to survive.]

What can you do to help to conserve soil?

- [Individuals can do several things to help to conserve soil, such as using drip irrigation instead of overhead sprinkler irrigation to reduce runoff, not riding off-road vehicles on hilly land, and avoiding building on steep slopes.]

19.3 Lesson 19.2: Pollution of the Land

Key Concepts

- Love Canal
- Defining hazardous waste
- Impacts of hazardous waste
- Preventing hazardous waste pollution

Lesson Objectives

- Define hazardous waste and describe its sources.
- Describe some of the impacts of hazardous waste on human health and on the environment.
- Detail some ways that people can control hazardous wastes.

Lesson Vocabulary

- **Superfund Act:** law passed by the U.S. Congress in 1980 that holds companies responsible for cleaning up any sites they have polluted with hazardous wastes
- **Superfund site:** site where hazardous waste has been spilled and that must be cleaned up in accordance with the Superfund Act

Teaching Strategies

Introducing the Lesson

Use the two-part video at the URLs below to introduce the lesson. It is a moving and chilling history of the Love Canal disaster, which opens this FlexBook® lesson.

- http://www.youtube.com/watch?v=PKUyOLXtUsQ
- http://www.youtube.com/watch?v=MXSE9kcBQCI

Activity

Use the exercise described at the following URL when you teach your students about hazardous wastes. Students will collect reports from various media about local and national hazardous waste issues. The activity will help students appreciate the magnitude of the hazardous waste problem. A follow-up discussion allows students to explore how hazardous waste issues affect their community.

http://www.epa.gov/superfund/students/clas_act/haz-ed/news.htm

Building Science Skills

Have students do the activity "The Numbers Game" at the URL below. From the activity, they will gain an appreciation for the parts-per-million and parts-per-billion units that are used to measure contaminant concentrations in the environment. They will learn how to calculate these ratios and then apply them to a sample chemical spill to determine if cleanup action is necessary.

http://www.epa.gov/superfund/students/clas_act/haz-ed/numbers.htm

Differentiated Instruction

Suggest that students make a compare/contrast table of the different types of hazardous wastes (toxic, chemically active, corrosive, and flammable). Tell students to define, and include examples of, each type of hazardous waste in their table.

Enrichment

Have a group of students collaborate to do the role-playing activity at the following URL. They will take on roles and act out a situation that illustrates the process of decision making as it relates to cleaning up a Superfund site. Students will identify the participants in the Superfund decision-making process, make judgments about the potential effect of site cleanup on the characters they portray, and learn that different people have different perspectives on the same cleanup issues. In addition, they will practice writing statements, formulating questions, and articulating their views in a public-meeting setting. Set aside class time for a mock public meeting in which the students present their points of view and role-play the decision-making process.

http://www.epa.gov/superfund/students/clas_act/haz-ed/act09.htm

Science Inquiry

The inquiry activity at the following URL will help students understand some of the reasoning and science involved in choosing technologies for cleaning up hazardous waste sites. Students will analyze the pros and cons of different clean-up methods for specific hazardous waste problems. In their analysis, they will weigh such factors as contaminant-specific requirements, technological limitations, reliability, and cleanup time and cost.

[http://www.epa.gov/superfund/students/clas_act/haz-ed/act08.htm http://www.epa.gov/superfund/students/clas_act/haz-ed/act08.htm

Real-World Connection

Have students do real-world research to identify and locate potential sources of hazardous waste in their neighborhood or community. In the process, they will learn what hazardous waste is and identify the potential threats it poses. The URL below outlines in detail how students should proceed with this real-world activity.

http://www.epa.gov/superfund/students/clas_act/haz-ed/act01.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 19.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 19.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Who was responsible for the tragedy at Love Canal? What was the role of private individuals in fixing the problem? What was the role of government?

- [Answers may vary. *Sample answer*: The chemical company was partly responsible because it produced the hazardous wastes and buried them in the canal. The city was partly responsible because it used the land to build a school and playground and allowed homes to be built on the site. Whoever dug the sewer systems was partly responsible for breaching the impermeable ground so the chemicals could leak out and contaminate the soil. Private citizens called attention to the problem and put pressure on government to fix it. Government passed laws requiring the cleanup of the site and many other like it all across the country by the parties responsible for the hazardous waste contamination.]

2. How does the United States Superfund Act help control hazardous wastes?

- [The Superfund Act helps control hazardous wastes by making companies pay to clean up sites they have polluted with hazardous wastes. This removes hazardous wastes from polluted sites. It also discourages companies from being careless when they use and dispose of hazardous materials.]

3. What is the difference between corrosive and flammable?

- [A substance that is corrosive destroys other things by chemical reactions. A substance that is flammable easily catches on fire and may release dangerous fumes into the air when it burns.]

4. What is often the first indicator that a region has a problem with toxic waste?

- [The first indicator is often a higher-than-normal number of illnesses such as cancers in a region.]

5. Organic farming is a method of growing food crops with natural alternatives to chemical pesticides. How does organic farming help control hazardous wastes?

- [Hazardous chemical pesticides that are applied to crops may pollute the land or nearby bodies of water. Organic farming helps control hazardous wastes because it reduces the amount of hazardous chemicals that are used to control pests.]

6. Why is storing hazardous wastes in barrels and burying them deep in the ground a bad idea? How might that approach be made safer?

- [It is a bad idea to store hazardous wastes in barrels and bury them in the ground because the barrels may eventually leak and pollute the ground with hazardous wastes. The approach might be made safe by using stronger storage containers and taking steps to ensure they are left undisturbed.]

7. What hazardous wastes are common in ordinary households? What can you do to reduce the impact you make on the environment from the use of hazardous wastes?

- [Hazardous wastes that are common in ordinary households include batteries, paints, fertilizers, and pesticides. You can reduce your impact from hazardous wastes by choosing materials that are not hazardous whenever possible. For example, you can clean with vinegar instead of strong cleaning chemicals. If you must use hazardous materials, you can try to use less of them and also safely dispose of any leftover hazardous materials.]

8. Which do you think is easiest and hardest to keep track of: hazardous waste that is present as a gas, liquid, or solid? Why?

- [It is easiest to keep track of solid hazardous waste because it cannot flow away from its container. It is hardest to keep track of gaseous hazardous waste because it can easily escape and drift away into the air.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 19.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What are the best ways to either prevent or safely dispose of hazardous materials?

- [The best way to prevent hazardous wastes is to substitute substances that are not hazardous. For example, you can use compost on a garden instead of fertilizer. The best way to safely dispose of hazardous materials depends on the materials, but most can be safely disposed of at a household hazardous waste collection site.]

What is the effect of hazardous wastes on other living things?

- [Hazardous wastes may make other living things sick or weak or even kill them.]

Is it important for each generation to leave the world a safe place? If one generation doesn't do this, who pays the price?

- [The price is paid by the next generation and possibly by generations after that as well.]

CHAPTER 20 HS TE Human Actions and Earth's Resources

Chapter Outline

20.1 Chapter 20: Human Actions and Earth's Resources

Chapter Overview

This chapter describes the human use of renewable and nonrenewable natural resources, including energy resources. It also explains how resources can be conserved.

Online Resources

See the following Web sites for appropriate laboratory activities:

In the lab activity at the URL below, students will design and carry out a survey of shoppers to determine attitudes about precycling and the use of disposable products. Alternatively, students can use the table of survey results provided at the Web site to complete the lab exercise. The objective of the lab is to assess typical purchasing practices to determine the influence of packaging on consumer choices and whether consumers consider recycling and resource use when making purchasing decisions.

- http://cwmi.css.cornell.edu/TrashGoesToSchool/HowDoOur.html

This document provides specific experiments on bioenergy as well as a useful introduction on how to design and conduct effective science experiments.

- http://www1.eere.energy.gov/biomass/pdfs/highschool_projects.pdf

The lab "Measuring Wind Speed" on pages 168–175 in the following PDF document allows students to investigate the use of wind power for energy. Specifically, students will demonstrate an understanding of the feasibility of using wind as an energy source, construct a device to measure wind speed, calculate average wind speed, and determine whether wind provides sufficient energy to produce electricity in the local area.

- http://www.tvakids.com/teachers/pdf/renewable_high.pdf

These Web sites may also be helpful:

You can find a collection of teacher-reviewed educational games, videos, lessons, puzzles, and quizzes pertaining to natural resources at this URL: http://www.neok12.com/Natural-Resources.htm.

There are additional resources for teaching about natural resources at the URL below.

- http://www.teachervision.fen.com/conservation/teacher-resources/55944.html

For a selection of National Geographic educational content relating to natural resources, go to this URL: http://education.nationalgeographic.com/education/topics/natural-resources/?ar_a=1.

The following URL provides a collection of different types of resources relating to energy use and conservation for high school students and teachers. In addition to activities, the resources include fact sheets, a glossary, and a list of relevant Web sites for educators.

- http://www.tvakids.com/teachers/pdf/renewable_high.pdf

If you go to the URL below, you can download the U.S. Department of Energy's teachers' guide Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education.

- http://www1.eere.energy.gov/education/energy_literacy.html

The documents at the URLs below are the teacher and student pages, respectively, of 11 different activities for middle and high school students that teach students basic concepts of energy use and energy conservation. The hands-on activities allow students to explore energy sources and energy efficiency both at school and at home.

- http://need.org/needpdf/Saving%20Energy%20Teacher%20Guide.pdf
- http://need.org/needpdf/Saving%20Energy%20Student%20Guide.pdf

The teacher's "infobook" at the first URL below contains dozens of fact sheets about the major energy sources, electricity, energy efficiency, energy conservation, transportation, and emerging technologies. The second URL is a companion book of student activities that reinforce vocabulary, concepts, and facts about energy. Answer keys are provided.

- http://www.eere.energy.gov/education/pdfs/basics_secondaryenergyinfobook.pdf
- http://www.eere.energy.gov/education/pdfs/basics_secondaryenergyactivities.pdf

You can find several lesson plans on energy for high school students at this URL: http://www.infinitepower.org/lessonplans.htm.

Pacing the Lessons

TABLE 20.1: short caption

Lesson	Class Period(s) (60 min)
20.1 Use and Conservation of Resources	2.0
20.2 Energy Conservation	1.5

20.2 Lesson 20.1: Use and Conservation of Resources

Key Concepts

- Renewable versus nonrenewable resources
- Common materials we use from Earth
- Resource availability

Lesson Objectives

- Discuss some natural resources used to make common objects.
- Describe some ways to conserve natural resources.

Lesson Vocabulary

- **conserve:** to reduce the use of a natural resource so it will last longer
- **export:** to send a resource or product to another country
- **import:** to receive a resource or product from another country
- **timber:** trees that are cut for wood to be used for building or other purposes

Teaching Strategies

Introducing the Lesson

Introduce resource use by asking students to brainstorm a list of natural resources they typically use each day. Ask a volunteer to record their responses on the board. Tell students they will learn in this lesson how they can use fewer resources in their daily lives.

Activity

With the activity at the URL below, students will learn about the limited supply of natural resources in the world and, by role playing, understand some of the equity issues related to the use of natural resources. Specifically, they will compare lifestyles and consumption habits of rich, middle income, and poor people around the globe.

http://www.uni.edu/ceee/sites/default/files/Education/knowresources.pdf

Discussion

Use the lesson plan outlined at the following URL to teach students about sustainable forestry. Through a combination of lecture, questioning, and class discussion, students will learn the importance of forests as a natural resource, what silviculture is, and how it is used to sustain forests. The Web site includes lecture material and a student worksheet for assessment.

http://ecosystems.psu.edu/youth/sftrc/lesson-plans/forestry/9-12/sustainability

Differentiated Instruction

Suggest that students make a main ideas/details chart to help them focus on the most important ideas and supporting details in the lesson. They should draw a line down the center of a sheet of paper. On the left side of the paper, they should list the main ideas in the lesson, leaving space between each main idea to record supporting details on the right side of the paper. Tell students to include at least one main idea for each heading in the lesson. Caution them against including too many details and show them with an example how to select details that support a main idea.

Enrichment

Challenge a few students to brainstorm unique and creative ways to recycle items that are commonly thrown in the trash. Ask the students to share their ideas with the class.

Science Inquiry

The inquiry activity described below encourages students to think about where the natural resources we use come from and the processes by which these resources are extracted. Students will also consider the environmental, cultural, and human rights issues that are frequently associated with the extraction of natural resources. They will conduct Internet research on specific resources and create presentations to showcase what they have learned.

http://education.nationalgeographic.com/archive/xpeditions/lessons/16/g912/wherefrom.html?ar_a=1

Real-World Connection

Have students write a list of what they ate at their most recent meal. Then have them list the resources that went into making that meal. They should trace each item back to the original resources. For example, for a hamburger, they should trace the meat all the way back to the soil that grew the grass that was eaten by the cow. Students should include any nonfood items used in their lunch, such as paper napkins or aluminum foil wrappers, and identify resources used to make these items as well. After students write their own resource list, have them evaluate as a class which meal used the least amount of resources and which used the most. Wrap up by discussing ways to lessen the impact of food consumption on the environment.

Real-World Connection

In the lesson plan at the URL below, students will examine controversies over the use of public natural areas for economic activities (such as ranching and logging) and efforts to protect natural areas from development for future generations. Students will complete a research project on resource consumption and form their own opinions on the issue.

http://www.pbs.org/americanfieldguide/teachers/natural_areas/natural_areas_sum.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 20.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 20.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. List five general things we get from natural resources.

- [Answers may vary. *Sample answer*: Five general things we get from natural resources are recreational opportunities, energy products such as gasoline, materials such as metals to make electronic appliances, materials for clothing, and food.]

2. Are forests a renewable resource? Are they ordinarily used in a renewable way? How can forests be used more sustainably?

- [Forests are renewable resources because new trees can be planted to replace those that are cut down. Forests are not ordinarily used in a renewable way because they are cut down faster than they can regrow. They can be used more sustainably by using fewer trees and planting more, especially fast-growing species.]

3. Of what value are forests besides for wood? Is there a value to forests that is not a monetary value? How much is that value considered when forests are being used for their resources?

- [Forests are of value for many purposes, including recreation, habitat for many organisms, and a source of natural beauty. These uses of forests do not necessarily have monetary value but they are important to many people. The nonmonetary value of forests is probably not considered that highly when forests are being used for their resources.]

4. How are fish and other wildlife renewable resources? How are they nonrenewable resources?

- [Fish and other wildlife are renewable resources because they can reproduce. They are nonrenewable resources if their habitats are destroyed or they are overused so their reproduction cannot keep pace with their use.]

5. What is overconsumption? How does overconsumption mirror overpopulation?

- [Overconsumption is the use of natural resources above and beyond what people really need. For example, people in the richer nations have many luxury and recreational items and may throw away and replace used items rather than repair or reuse them. Overconsumption mirrors overpopulation because both factors lead to greater resource use and more waste. Both result in pollution that degrades the environment and reduces the availability of natural resources.]

6. If a product is recycled, is anything lost in terms of material or energy?

- [It takes energy to recycle products and make new products with the materials, and some of the materials may not be recyclable and therefore may be lost.]

7. Resource X is scarce except in Nation A. Many nations want to use Resource X. How does politics play into the ability of other nations to get access to the resource?

- [Political relations between nations are likely to affect the ability to import resources from other nations. For example, because of politics, Nation A may refuse to export Resource X to all of the nations that want to use it.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 20.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Could a renewable resource ever become nonrenewable?

- [Yes; a renewable resource could become nonrenewable if people start using it faster than it can be replaced or if they overuse it to the point that it cannot be regenerated.]

What are some of the intangible values that a natural resource might have?

- [Intangible values a natural resource might have could include beauty, uniqueness, or the recreational opportunities it provides.]

Do you think about the material and energy resources you use as you use them?

- [Answers will vary. Most people in the U.S. do not think about material and energy resources as they use them, but this is changing as more people become aware of the environmental problems of overconsumption of resources, especially energy resources and carbon production.]

Which is more sustainable: using renewable resources or nonrenewable resources? Why?

- [It is more sustainable to use renewable resources because they can be replaced as they are used. Nonrenewable resources can be used more slowly but if we keep using them they will eventually be used up.]

20.3 Lesson 20.2: Energy Conservation

Key Concepts

- Obtaining energy
- Energy efficiency
- Energy conservation

Lesson Objectives

- Discuss why it takes energy to get energy and why some forms of energy are more useful than others.
- Describe some ways to conserve energy or to use energy more efficiently.

Lesson Vocabulary

- **energy efficiency:** amount of useful work that is done by a unit of energy
- **net energy:** amount of usable energy that is available from an energy resource
- **net-energy ratio:** ratio between the useful energy present in a fuel and the energy used to extract and process the fuel

Teaching Strategies

Introducing the Lesson

Ask students what the following natural resources have in common: fossil fuels, sunshine, and flowing water. (All of these natural resources can be used to produce energy.) Tell students they will learn more about energy resources when they read this lesson, including how to conserve them.

Activity

The document at the following URL is an educational guide to energy, electricity, consumption, and efficiency. The last page of the document is a home energy survey that students can use to analyze home energy use.

http://www1.eere.energy.gov/education/pdfs/power_to_the_plug_lesson.pdf

Building Science Skills

The teaching module at the URL below focuses on the science behind current and future energy technologies using an inquiry- and application-based framework. Through the use of innovative resource cards that students create themselves, students will weigh the costs and benefits of fossil fuel-based energy resources against those of alternative energy resources, including biomass, solar, geothermal, hydrogen fuel cell, and wind energy. For a final project, students will research an energy source and present it to their classmates. They will then use the information, plus all the content from class lectures and activities, to design a "Planned Community" that is an affordable and eco-friendly place to live. The overall objective is for students to develop a deep understanding not only of the conceptual science of energy but also of the technical and societal issues involved.

http://www1.eere.energy.gov/education/pdfs/acts_butterfield_energybasics_311.pdf

Differentiated Instruction

Suggest that students make an outline of the lesson. This will help them see the organization of the material and how the concepts are related. It will also help them identify the most important ideas and supporting details. Show them how to use the heading structure of the lesson for the main outline entries. They can fill in important details as they read the lesson.

Enrichment

Ask students to use online sources (such as the URLs below) to find the miles per gallon of fuel used by different means of transportation, including automobile, truck, train, plane, and boat transport. Have them make a compare/contrast table to present the results of their research to the class. Ask students to think about how they could use the information to reduce their use of energy when traveling or shipping goods.

- http://truecostblog.com/2010/05/27/fuel-efficiency-modes-of-transportation-ranked-by-mpg/
- http://en.wikipedia.org/wiki/Energy_efficiency_in_transportation

Science Inquiry

At the URL below, you can access inquiry activities in which students will compare two products that have the same function (in this case, providing light) but require different amounts of energy to do their job. Students will research and demonstrate energy efficiency in action and learn how it applies to different technologies. After the activities, students will understand how using less energy helps the environment and how compact fluorescent light bulbs and incandescent light bulbs differ in their efficiency and energy usage. They will also discuss other examples of energy-efficient technologies or energy-saving practices.

http://www1.eere.energy.gov/education/pdfs/efficiency_energyambassadors9-12.pdf

Overcoming Misconceptions

Students may think that the reason we are running out of energy is because energy is destroyed in many processes. Make sure students know that energy is never destroyed (or created); it only changes form. The best way to show students that energy is transformed without being lost is to have them track energy transformations in daily life. The lesson plan at the following URL allows students to track energy transformations in various modes of transportation as an example.

http://www.pbs.org/americanfieldguide/teachers/transportation/transportation_sum.html

Real-World Connection

With the activity at the URLs below, students will work in pairs or small groups to apply knowledge of energy-wise habits to evaluate energy use in their school and make recommendations for improved efficiency. Specifically, students will create an energy audit tool to collect data and present recommendations to their class. Taking their ideas to the school and district levels is encouraged.

- http://www1.eere.energy.gov/education/pdfs/efficiency_energywalkabout.pdf
- http://www.eere.energy.gov/education/pdfs/efficiency_energyauditchecklist.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 20.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 20.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Define net energy.

- [Net energy is the amount of usable energy that is available from an energy resource.]

2. Why does solar power have a higher net-energy ratio than coal-fired electricity?

- [Solar power has a higher net-energy ratio than coal-fired electricity because sunshine is abundant and does not need to be found, extracted, or transported very far. All of these steps add to the energy cost of obtaining coal for electricity.]

3. Some coal-fired electricity has a net-energy ratio of 2.5. Explain what this means. When is coal a good choice for generating electricity? When is coal not a good choice for generating electricity?

- [A net-energy ratio of 2.5 means that 2.5 times as much usable energy is available than is needed to make the energy available. Coal might be a good choice for generating electricity when it has a high net-energy ratio. This is most likely to occur where the coal does not have to be transported very far. Coal is not a good choice for generating electricity when it has a low net-energy ratio.]

4. What are two ways you can use less energy in your home?

- [Answers may vary. *Sample answer*: Two ways you can use less energy in your home are by using compact fluorescent light bulbs and turning off lights and appliances when not in use.]

5. What are two ways that energy can be conserved?

- [Two ways that energy can be conserved are by using less energy and using energy more efficiently.]

6. Why is it especially important not to waste energy from fossil fuels?

- [It is especially important not to waste energy from fossil fuels because so much of the energy we use comes from fossil fuels and because fossil fuels are nonrenewable resources.]

7. Why are trains much more efficient than trucks for transporting items? Why are boats more efficient than airplanes or cars for travel?

- [Trains are more efficient than trucks for transporting items because a single train engine can pull many train cars full of items, whereas a truck can pull only a single trailer full of items. Boats are more efficient than airplanes or cars for travel because they can carry so much cargo.]

8. If you were to replace a 240 V incandescent bulb with a compact fluorescent bulb with an initial luminous flux of about 1500 lm, how much would you decrease electrical consumption?

- [You would decrease electrical consumption from about 105 W to 20 W, for a savings of about 85 W.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 20.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If it takes energy to get energy, then what are the best choices for types of energy?

- [The best choices for types of energy are those that take the least amount of energy to obtain. Solar energy is a good example. It is abundant and available everywhere so no energy is needed to locate, extract, or transport it.]

Put each of these actions in order from most to least important: choosing a sustainable form of energy, increasing energy efficiency, and conserving energy use. Explain the order you chose.

- [The order will vary depending on the forms of energy used, current level of use, and other considerations. Finding ways to use all three actions will lead to the greatest energy conservation.]

Could everyone in the world use as much energy as a person in the United States does each day? Why or why not?

- [No; if energy consumption were the same worldwide as it is in the United States, there would soon be too little energy to go around. Nonrenewable energy resources would be depleted quickly and renewable energy resources are not well enough developed to provide that amount of energy.]

CHAPTER 21 HS TE Human Actions and Earth's Water

Chapter Outline

21.1 Chapter 21: Human Actions and Earth's Water

Chapter Overview

This chapter describes how we use water and how water is distributed on Earth. It also outlines types and sources of water pollution and how to protect the water supply.

Online Resources

See the following Web sites for appropriate laboratory activities:

At the following URL, you can find both teacher and student lab manuals for testing water quality. Tests include temperature, pH, dissolved oxygen, phosphates, nitrates, and other indicators of water quality. Students may carry out one, some, or all of the testing procedures.

- http://www.chebe.wsu.edu/modules/96modules/bennett/water.html

The URL below provides several labs that allow students to explore water pollution and pollution prevention. For example, students can create and test a watershed model, determine sources of water pollution, test water quality for nutrients and nitrates, and search for nitrate pollution solutions, among other lab activities.

- http://keec.ky.gov/NR/rdonlyres/AE95BAB6-7A2D-46B9-B6CB-2248FBDAECD6/0/5WonderfulCommonwealthHS.pdf

These Web sites may also be helpful:

This Web site provides background information on a wide variety of water topics. It also includes online activities, data tables, maps, and a glossary of terms.

- http://ga.water.usgs.gov/edu/

You can find a world map showing Earth's freshwater supplies by nation (as of 2000) at this URL: http://www.learner.org/courses/envsci/visual/visual.php?shortname=world_freshwater

At the following URL, you can find a variety of resources on water pollution and protection of the water supply.

- http://www.nrdc.org/water/

Pacing the Lessons

TABLE 21.1: short caption

Lesson	Class Period(s) (60 min)
21.1 Humans and the Water Supply	2.0
21.2 Problems with Water Distribution	1.0
21.3 Water Pollution	2.0
21.4 Protecting the Water Supply	1.0

21.2 Lesson 21.1: Humans and the Water Supply

Key Concepts

- Human uses of water
- California water resources

Lesson Objectives

- Discuss how much water is taken up by each water use.
- Explain the difference between consumptive and non-consumptive water uses.
- State the origin of California's fresh water supply.

Lesson Vocabulary

- **aquaculture:** farming in the sea or other body of water to raise fish, seafood, or aquatic plants
- **consumptive water use:** water use in which the water is lost to the ecosystem
- **drip irrigation:** using pipes and tubes with tiny holes in them to deliver small amounts of water directly to the soil at the roots of plants
- **non-consumptive water use:** water use that does not remove water from the ecosystem

Teaching Strategies

Introducing the Lesson

Introduce the lesson by leading the class in a brainstorming session of ways that people use water. Urge students to consider uses of water both inside and outside the home and also industrial and agricultural uses in addition to municipal uses. List their ideas on the board. When no new uses are forthcoming, tell students they will learn more about human uses of water in this lesson.

Activity

With the activity "Tragedy of the Water Commons" on pages 45–49 of the URL below, students will learn about the "tragedy of the commons" as it applies to the water supply. Then they will play a game to simulate use of a common water supply. Following the game, they will discuss how their experiences playing the game relate to how people use and share our common water supply.

http://static.water.org/docs/curriculums/WaterOrg%20HighCurricFULL.pdf

Differentiated Instruction

Have students set up and start filling in a KWL chart before they read the lesson. They should make a three-column chart with the headings "Know," "Want to Know," and "Learned." Before reading, they should list things they know and want to know about humans and the water supply in the first two columns of the chart. As they read or after they complete the lesson, they should add items to the last column. Help students find any information they wanted to learn but didn't learn when they read the lesson.

Enrichment

Suggest that interested students read and analyze the case study "Rising Tensions over the Nile River Basin: A Global Commons Case Study" on pages 38–44 of the following URL. Students will analyze the concept of a global commons as it applies to water by evaluating a primary source document describing a specific case.

http://static.water.org/docs/curriculums/WaterOrg%20HighCurricFULL.pdf

Science Inquiry

An important science inquiry skill is being able to identify possible biases in research literature. Raise students' awareness of the issue by asking them to find online information about farmed vs. wild-caught fish. They might find articles on their nutritional differences, differences in contamination with toxins, and/or impacts on the environment. Tell students to try to find Web sites that present different points of view on the same issue. Then ask them to consider the sources of the information and what if any biases they might have. Use the two URLs below as examples to get them started.

- http://www.paystolivegreen.com/2009/02/wild-salmon-vs-farmed-raised-which-is-better/
- http://www.salmonoftheamericas.com/oceanfarming/aquaculture.php

Overcoming Misconceptions

Because water recycles through the water cycle, students may think that all water is "non-consumed." Point out that consumptive and non-consumptive water use refers to the available water supply and not to all of the world's water, most of which is not available for human use. Elaborate on the differences between consumptive and non-consumptive water use, and give students examples of each type of use to make the differences more concrete. Explain that consumptive water use occurs whenever water taken from the water supply is evaporated, transpired, lost to leakage, incorporated into products or crops, consumed by humans or livestock, transferred to another area, or otherwise removed from the immediate water source. For example, irrigation and livestock water uses are considered to be completely consumptive uses. All of the water withdrawn is evaporated or transpired, incorporated into crops, or consumed by livestock. Then explain that non-consumptive water use occurs whenever water is not removed from the water supply or is returned to the immediate water source unchanged and ready to be used again. For example, swimming and boating are completely non-consumptive uses of water. The water is neither withdrawn nor changed.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 21.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 21.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. List the three water uses that consume the most fresh water.

   - [The three water uses that consume the most fresh water are agricultural, industrial, and municipal uses.]

2. How do farmers grow crops when there is no irrigation?

   - [When there is no irrigation, farmers grow crops by choosing those crops that match the amount of rain that falls in their area.]

3. Describe why some water uses are called consumptive.

   - [Some water uses are called consumptive because they consume, or use up, the water. The water is lost to the ecosystem. For example, the water used in irrigation is consumptive because it is lost to evaporation or runoff, incorporated into plant tissues, or transpired through the leaves of plants.]

4. Describe drip irrigation and why it wastes less water than irrigating with sprinklers.

   - [Drip irrigation is the process of applying water directly to the roots of plants through small holes in pipes or tubes. Drip irrigation wastes less water than irrigating with sprinklers because it uses less water and almost all of the water sinks directly into the soil at the base of plants where it can be taken up by plant roots. When sprinklers are used for irrigation, a lot of water is lost to evaporation or runoff.]

5. Explain why water use by humans has increased dramatically in the past century or so.

   - [Water use by humans has increased because of human population growth and increasing demands for water by agriculture and industry. Also, some water sources have become polluted.]

6. Why do farmers sometimes use more wasteful methods of irrigation than are available?

   - [Farmers sometimes use more wasteful methods of irrigation because they are less expensive to install and because farmers to not have to pay the full cost of their water use.]

7. What are some of the positives of aquaculture? What are some of the negatives?

   - [Positives of aquaculture include increasing our food resources, especially of high-protein sources, and for some species only minimal harm to the environment. Negatives of aquaculture include loss of natural ecosystems to create fish farms and the possible escape of genetically modified farmed fish or their parasites into the wild, where they may cause problems for native fish.]

8. Describe four consequences of water shortages to people.

   - [Answers may vary. Sample answer: Four consequences of water shortages to people are conflicts between people and nations; death of crops and livestock so people go hungry; halting of industrial and economic development, which causes greater poverty; and people dying from thirst.]

9. What is the origin of California's freshwater sources?

- [California's fresh water comes from several sources, including winter snow pack in mountain ranges, which feeds rivers that cross the state; streams with headwaters outside the state, including the Colorado River; and groundwater, especially in the Central Valley.]

10. Describe why droughts are more serious in the arid regions of the world than in wetter regions.

- [Droughts are more serious in the arid regions of the world because these areas already have too little water.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Is fresh water ever more valuable than gold or diamonds?

- [It is if it means the difference between life and death. People can survive only a few days without water, but their lives do not depend on gold or diamonds.]

How can farmers and other people be encouraged to use more efficient irrigation methods?

- [They might be encouraged to use more efficient irrigation methods if they were required to pay in full for all of the water they used or if they were fined for wasting water.]

With such abundant water resources, why do California's planners worry about the state's future water resources?

- [California's water resources are already strained by the state's large population and enormous agricultural needs for water. As the population continues to grow, more water will be needed. At the same time, the water supply is likely to decline because of global warming and other effects of human actions.]

21.3 Lesson 21.2: Problems with Water Distribution

Key Concepts

- World water distribution and supply
- Scarcity of safe drinking water

Lesson Objectives

- Explain why water shortages are increasingly frequent throughout the world.
- Discuss why 1.1 billion people (one-fifth of the people on Earth) do not have access to safe drinking water.

Lesson Vocabulary

- **drought:** long period of lower-than-normal rainfall for a region
- **pathogen:** disease-causing organism

Teaching Strategies

Introducing the Lesson

Call on volunteers to describe a time when they were really thirsty, for example, when they were hiking or playing a sport on a hot day and ran out of water. How did it feel to be thirsty and not be able to quench their thirst? Point out that lack of water can quickly become a serious health issue. Then tell students they will learn in this lesson how common water scarcity is for people around the world.

Activity

Students can gain a deeper appreciation of the global water crisis by creating a "Water Awareness Portfolio" (see pages 23–25 of the PDF document below). Instructions for the activity include numerous sample prompts to guide students' research, writing, and other portfolio entries. Completion of the portfolio will give students knowledge of current water conditions in developing nations, an increased awareness of the need for conservation practices, and a sense of the value of water as a shared global resource.

http://static.water.org/docs/curriculums/WaterOrg%20MidCurricFULL.pdf

Demonstration

When you discuss how water shortages are likely to increase in the future, show students projected freshwater stress areas in 2025 using the map at the following URL. This is similar to a figure in the FlexBook® lesson, but the figure at the URL also shows water stress areas in 1995 for comparison. Point out areas, such as the U.S., that will have to use a greater percentage of their freshwater resources in 2025 than they did in 1995. Discuss human actions that contribute to these changes.

http://www.learner.org/courses/envsci/visual/visual.php?shortname=freshwater_stress

Differentiated Instruction

Pair students with less proficient English language or reading skills with other students, and ask partners to do a think-pair-share activity about water scarcity. First tell individual students to think about and write tentative answers to the questions listed below. Then have partners share and discuss their answers to the questions.

1. How would you define water scarcity?
2. How big a problem is water scarcity worldwide?
3. What are some causes of water scarcity?
4. What are some possible effects of water scarcity?
5. How is water pollution related to water scarcity?

Enrichment

Point out that many rivers, or at least their drainage basins, cross national boundaries so they are located in more than one nation. Suggest that interested students learn about the Helsinki Rules that regulate the use of waters of international rivers. They can start with the URL below. Ask the students to summarize the rules and share their summary with the rest of the class.

http://www.unece.org/fileadmin/DAM/env/water/meetings/legal_board/2010/annexes_groundwater_paper/Annex_II_-Helsinki_Rules_ILA.pdf

Science Inquiry

Divide the class into groups, and ask students within each group to discuss similarities and differences between the global distribution and use of energy on the one hand and the global distribution and use of water on the other hand. Have students debate which problem is worse, more widespread, or more difficult to solve: energy overconsumption and scarcity or water overconsumption and scarcity. After allowing time for in-group discussion, ask groups members to share their ideas with the class.

Overcoming Misconceptions

Students may hold misconceptions about water scarcity, such as those listed below. Refer them to the water facts file from the World Health Organization at the following URL to overcome these and other misconceptions about water scarcity.

http://who.int/features/factfiles/water/water_facts/en/index.html

- Water scarcity occurs only in areas that receive very little rainfall.
- Water scarcity affects only a small percentage of the human population.
- Water scarcity occurs only where water is physically scarce.
- Water scarcity can be dealt with by teaching people how to waste less water.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 21.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 21.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. If most of Earth is covered with water, how can there be water shortages?

- [Only a tiny fraction of a percent of all the water that covers Earth is fresh water that is available for humans to use. Water is also unevenly distributed around the world. Large portions of the world receive very little water from rainfall or rivers relative to their populations. If droughts occur, water shortages may become more widespread or severe. In addition, water pollution contributes to water shortages by making some water sources unfit to use.]

2. Where in the world is there the least amount of water available relative to the human population? Where in North America is there the least amount of water relative to the population?

- [The least amount of water is available relative to the human population in northern Africa and central Asia. In North America, there is the least amount of water available relative to the population in the southwestern U.S.]

3. In 2025, where are the water shortages likely to be?

- [In 2025, water shortages are likely to become more widespread, affecting North Africa, Central Asia, and to a lesser extent most of the nations in the Southern Hemisphere.]

4. Why will there be more regions prone to water shortages in 2025 than there are today?

- [There will be more regions prone to water shortages in 2025 because of a growing human population and because of changing patterns of rainfall and water distribution due to global warming.]

5. How do human activities contribute to the frequency or duration of droughts?

- [Some human activities contribute to more frequent or longer-lasting droughts. For example, deforestation keeps trees from returning water to the atmosphere by transpiration, thus interrupting part of the water cycle.]

6. Why are waterborne diseases more common in less developed countries than developed countries?

- [Waterborne diseases are more common in less developed countries because in these countries many people have no choice but to drink water that has been contaminated by sewage. Unsafe drinking water carries many pathogens and other causes of disease.]

7. Why does the United Nations describe the current water status today as a crisis?

- [The current water status is described as a crisis because many people do not have access to clean water. Sometimes there is just not enough water and sometimes the available water is unclean and unhealthy. This is especially likely in poor nations that cannot afford to treat and purify water in order to make it safe to drink.]

8. How do droughts affect water supplies?

- [Droughts may create or worsen water shortages.]

9. What are the possible consequences of water shortages?

- [Possible consequences of water shortages include loss of crops and livestock, which may result in people going hungry; slowing down or stopping of construction and of industrial and economic development, which can result in nations sinking further into poverty; rising risk of regional conflicts over scarce water resources; and increased death rates from diseases, thirst, or war over scarce water resources.]

10. Give two reasons why water shortages are happening around the world today.

- [Answers may vary. *Sample answer*: Two reasons for water shortages around the world today are overpopulation and overconsumption. Overpopulation means that there are more people than ever in need of water. Overconsumption means that each person uses more water today than ever before. This is especially true in the wealthy nations.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What can we do to help the one-fifth of the people on Earth who do not have access to safe drinking water?

- [Possible solutions include building water infrastructure such as wells and pipelines, providing water treatment facilities, and teaching people about the dangers associated with drinking unsafe water.]

How can we reduce water shortages because of overuse, overpopulation, and drought?

- [We can adopt practices that help to conserve water; slow population growth by educating girls and women; and avoid human activities, such as deforestation, that increase the frequency and severity of drought.]

Water is so valuable that wars have been fought over it throughout history. Could conserving fresh water now help avoid future wars?

- [Finding ways to save fresh water so more is available to all people would reduce international tensions over water. This could help avoid future wars over water.]

21.4 Lesson 21.3: Water Pollution

Key Concepts

- Sources of water pollution
- Municipal water pollution
- Ocean pollution
- Thermal water pollution

Lesson Objectives

- Discuss the risks that water pollution poses to human and environmental health.
- Explain where freshwater and saltwater pollution come from.
- Discuss how pathogen-borne diseases are caused by water pollution.
- Describe why conserving water and protecting water quality is important to human health and the environment.
- Describe how water pollution reduces the amount of safe drinking water available.
- Discuss who is responsible for preventing and cleaning up water pollution.

Lesson Vocabulary

- **thermal pollution:** pollution that raises the temperature of water

Teaching Strategies

Introducing the Lesson

Introduce the class to water pollution with the following facts and figures about the health effects of drinking contaminated water.

- Diseases spread through contaminated water are one of the leading causes of disease and death in the world.
- At any given time, half of the world's hospital beds are occupied by patients suffering from water-related diseases.
- Every 15 seconds, a child dies from a water-related disease.

Tell students they will read more in this lesson about contamination of the water supply and ways to prevent it.

Activity

Students are likely to think that water pollution is caused only by direct discharge of substances into bodies of water. However, bodies of water can also be polluted by acid rain, which is a byproduct of sulfur pollution of the air, mainly by coal-burning power plants. In this activity, students will investigate how even a small input of acid rain can change the acidity of a body of water and negatively affect aquatic life.

http://earthecho.org/images/uploads/wpc_uploads/Acid_Rain_HS.pdf

Differentiated Instruction

Pair English language learners with native English speakers, and ask partners to work together to create a cluster diagram of water pollution. They should draw a circle in the center of a sheet of paper, labeled "Water Pollution," and draw circles around it for each type or source of water pollution, including municipal, industrial, agricultural, ocean-water, and thermal pollution. To each of these surrounding circles, they should add a few key terms or facts about that type or source of pollution.

Enrichment

Have students read and write a book report on the award-winning nonfiction book "A Civil Action" by John Harr (1996). The book is a compelling true account of people in Woburn, Massachusetts, who sought justice when their children developed deadly cancers as a result of contamination of community groundwater resources by two local industries. Students will learn who was responsible for the contamination and how it was resolved in what has been called the "legal thriller of the decade." You can find a summary of the book at this URL: http://serc.carleton.edu/woburn/ACA_summary.html.

Science Inquiry

The activity at the following URL presents student with a real-world problem to solve: the contamination of a fictitious town's drinking water. In the activity, students will make a topographic map, use it to predict groundwater flow, and investigate the most likely source of groundwater contamination.

http://water.epa.gov/learn/kids/drinkingwater/upload/2009_04_29_kids_activity_grades_9-12_trackingpollution_teachersguide.pdf

Overcoming Misconceptions

A common misconception is that most of the pollution that enters water comes from industries dumping toxic wastes into water at a single point. Explain that this type of point-source pollution has been nearly eliminated by the Clean Water Act and other legislation. Instead, the majority of pollution that enters water now comes from non-point source pollution. This type of pollution is caused mainly by runoff rainwater.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 21.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 21.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. How does water pollution contribute to water shortages?

- [Water pollution contributes to water shortages by making some water sources unsafe to use.]

2. How are the major sources of water pollution different between developing and developed countries?

- [In developing countries, the major source of water pollution is raw sewage that is dumped into the same water that people use for drinking and bathing. In developed countries, the main sources of water pollution are inadequately treated sewage and other wastewater from cities and towns; pollutants from factories and hospitals; and runoff from crops, livestock, and poultry farms.]

3. Where are most of the dead zones located?

- [Most of the dead zones are located near the mouths of rivers that drain regions where human population density is high and where crops are grown.]

4. Explain what a dead zone is.

- [A dead zone is a large area of a lake or the ocean without fish or plant life. Dead zones form where decomposition of dead organisms uses up all the dissolved oxygen in the water. Dead zones occur because of excess nutrients that pollute the water and cause it to become clogged with algae and aquatic plants, which eventually die and decompose.]

5. Why are coastal wetlands important and what are the sources of pollution that affect them?

- [Coastal wetlands are important because a large proportion of the fish we rely on for food live in coastal wetlands or lay their eggs there. The sources of pollution that affect coastal wetlands include runoff from farm waste, which often carries waterborne organisms that cause lesions that kill fish.]

6. What is the leading cause of death for children around the world?

- [The leading cause of death for children around the world is waterborne disease caused by unsafe drinking water.]

7. What are the risks of deep-water drilling for petroleum?

- [The risks of deep-water drilling include gas explosions and fires on oilrigs and oil spills that pollute ocean water and coastal regions.]

8. Months after the 2010 Gulf of Mexico oil spill, the amount of oil that was located at the top of the Gulf water and on the shorelines was much less than the amount that was predicted to be in those locations. What happened to the oil? Did it just disappear? Does this mean that the dire predictions made just after the spill were wrong?

- [The long-term effects of oil spills are not well understood. It is likely that oil from the spill will coats rocks and sand beneath the surface along the shorelines. It is known that oil from the 1989 Exxon Valdez spill still coats underlying rocks and sand on many beaches in Alaska.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

How does water pollution reduce the amount of drinking water available for people to use?

- [Water pollution makes water unsafe to drink. Water polluted with sewage or other wastes can make people sick.]

About 50 % of all infectious diseases are caused by water pollution. What can be done to reduce the number of pathogens that reach our freshwater supplies?

- [We can make sure that sewage is treated adequately and kept out of freshwater supplies by the development of effective water-treatment and sanitation systems.]

Ocean pollution harms some of the most productive sources of marine life. How can we change our behaviors to protect marine life?

- [We can take action to reduce pollutants in rivers and other effluent that ends up in the ocean. Individual behaviors we can adopt include properly disposing of motor oil and household chemicals; using lawn, garden, and farm chemicals sparingly and wisely; repairing automobile and boat engine leaks immediately; and keeping litter, pet waste, and grass clippings out of street gutters and storm drains.]

21.5 Lesson 21.4: Protecting the Water Supply

Key Concepts

- Water treatment
- Reducing water pollution
- Controlling ocean pollution
- Conserving water

Lesson Objectives

- Describe several ways water can be conserved.
- Discuss how water is treated to eliminate harmful particles.
- State what governments and international organizations can do to reduce water pollution.

Lesson Vocabulary

- **sewage treatment:** any process that removes contaminants from sewage or wastewater
- **water purification:** any process used to produce safe drinking water by removing contaminants

Teaching Strategies

Introducing the Lesson

Show students the short video at the following URL about waterborne disease known as Guinea worm. The graphic descriptions and images will capture student interest and clearly make the point that the water supply must be protected. Point out in the video how filtering the water removes the Guinea worm. Tell students they will learn in this lesson about other ways water can be treated and purified to make it safe to drink.

http://www.youtube.com/watch?v=BjsquiiYiRU

Activity

Use the lesson at the URL below to raise students' awareness of the importance of water resources and the need to conserve them. In the lesson, students will begin with a water audit pre-lesson to determine their own personal water usage. They will then participate in a class activity to learn how water's physical properties and chemical composition are essential to life on Earth. Once they understand water's importance, they will debate water distribution issues, develop an understanding of the consequences of water scarcity, and come up with ways to conserve water in their own lives.

http://www.eeweek.org/assets/files/EDN%20Water%20Lessons/Amazing_Precious_9-12.pdf

Differentiated Instruction

Suggest that students create a concept map to organize and summarize important lesson concepts. The concept map should be titled "Protecting the Water Supply." Concepts should include water treatment (including sewage treatment and water purification), reducing water pollution (including preventing water pollution and cleaning polluted water), controlling ocean pollution, and conserving water.

Enrichment

Ask a few students to interview a water treatment expert in their community, such as the community's environmental services manager or water treatment plant chief operator. The students' objective should be to learn how community water resources are treated and purified to make them safe for drinking. Before the interview, suggest that the students learn more about the processes involved in water treatment at the URL below. After the interview, have the students create a flow chart to show the steps used to treat the local water supply. Give them a chance to explain their flow chart to the rest of the class.

http://www.cdc.gov/healthywater/drinking/public/water_treatment.html

Science Inquiry

In the activity at the URL below, groups of students will use various materials to build a filter that they will then use to try to clean a sample of "wastewater." Each group will try different materials to see which work best to cleanly and quickly filter a given volume of water. In each case, the filtrate will be tested to determine if the filter worked to remove odors, soap, and turbidity. The goal of the activity is to give students an idea of how difficult it is to clean dirty or polluted water.

http://omp.gso.uri.edu/ompweb/doee/teacher/pdf/act14.pdf

Real-World Connection

In 1989, an oil tanker ran aground in Narragansett Bay, Rhode Island, and spilled 200,000 gallons of fuel oil into the bay. Using that spill as a case study, the activity at the first URL below allows students to investigate how to clean up an oil spill. Before starting the activity, you will do a simple demonstration to show students the differences in density of oil and water. Then students will be given a small model of an oil spill and various materials to try to clean up the spill. They will also learn how wind affects oil spills. The document at the second URL is a student worksheet for the activity.

- http://omp.gso.uri.edu/ompweb/doee/teacher/pdf/act13.pdf
- http://omp.gso.uri.edu/ompweb/doee/teacher/pdf/act13.wk.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 21.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 21.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is the purpose of water treatment and purification?

- [The purpose of water treatment is to remove contaminants from water so it is safe for other uses. The purpose of water purification is to treat water so it is safe to drink.]

2. How can governments and international organizations help to reduce water pollution?

- [Governments and international organizations can pass and enforce laws or international agreements to control pollution levels and require polluters to clean up the pollution they create. They can also educate the public to adopt behaviors that reduce pollution. In addition, they can provide more water treatment facilities.]

3. How can ocean pollution be controlled?

- [Ocean pollution can be controlled by reducing pollutants in rivers and other effluent that ends up in the ocean. Governments and international agencies can also pass and enforce laws and provide funding to prevent and clean up ocean pollution.]

4. Name three things that a person could do to reduce pollution.

- [Answers may vary. *Sample answer*: To reduce pollution, a person could properly dispose of motor oil and household chemicals, use lawn and garden chemicals sparingly and wisely, and repair car and boat engine leaks right away.]

5. Name three ways that you could reduce your personal water use.

- [Answers may vary. *Sample answer*: I could reduce my personal water use by taking shorter showers, turning off the tap while brushing my teeth, and sweeping rather than hosing down the sidewalk.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Who is responsible for controlling water pollution?

- [Everyone is responsible for controlling water pollution, from agribusinesses and industries to cities and individuals.]

What can governments and international organizations do to control pollution?

- [They can pass and enforce laws to prevent pollution and require the cleanup water that is already polluted. They can also launch public education campaigns to reduce water pollution by individuals, and they can subsidize water treatment by municipalities.]

It is usually cheaper to dump polluted water without spending money to treat and purify the water. What incentives would convince industry to control water pollution?

- [Incentives might include fines for dumping polluted water and tax breaks for buying and using equipment to treat and purify contaminated water.]

CHAPTER 22 HS TE Human Actions and the Atmosphere

Chapter Outline

22.1 Chapter 22: Human Actions and the Atmosphere

Chapter Overview

This chapter discusses types of air pollution, their causes and effects, and ways to reduce air pollution.

Online Resources

See the following Web sites for appropriate laboratory activities:

The lab at the following URL allows students to investigate exhaust emissions, class car use, and air quality.

- http://www.sciencelearn.org.nz/Contexts/Enviro-imprints/Teaching-and-Learning-Approaches/Air-pollution-activities

With the lab "There's a Hole in My Umbrella" at the following URL, students will gain an understanding of acid deposition and acid rain and the environmental impacts they have both nationally and globally. In the lab, students will investigate the effects of acid deposition on plant growth, the corrosion of copper by acid, and the relationship between prevailing wind direction and areas that receive high levels of acid rain.

- http://www.uni.edu/storm/downloads/highschool/There%27s%20a%20hole%20in%20my%20umbrella.pdf

These Web sites may also be helpful:

This URL lists curriculum resources, activities, materials, and Web sites about air quality.

- http://airnow.gov/index.cfm?action=learning.forteachers

You may want to follow the lesson plan at the following URL when you teach this chapter. In the lesson, students will examine the topic of air pollution, its possible solutions, and the government agencies that are responsible for dealing with it. Specific topics addressed include: ingredients, causes, effects, and solutions of air pollution; individual actions to improve air quality; misuse of the atmosphere; federal laws and agencies that address air quality; stratospheric and tropospheric ozone; and criteria pollutants.

- http://www.dnrec.state.de.us/DNREC2000/Divisions/AWM/aqm/education/airqualityLesson1.pdf

You can find excellent air pollution images as well as background information on air pollution at this URL: http://education.nationalgeographic.com/education/encyclopedia/air-pollution/?ar_a=1.

Pacing the Lessons

TABLE 22.1: short caption

Lesson	Class Period(s) (60 min)
22.1 Air Pollution	2.0
22.2 Effects of Air Pollution	2.0
22.3 Reducing Air Pollution	1.5

22.2 Lesson 22.1: Air Pollution

Key Concepts

- Air quality
- The Clean Air Act
- Primary and secondary air pollutants
- Causes of air pollution

Lesson Objectives

- Describe the different types of air pollutants.
- Discuss what conditions lead some cities to become more polluted than others.
- Describe the sources of air pollutants.

Lesson Vocabulary

- **photochemical smog:** type of air pollution that results from a chemical reaction between certain air pollutants in the presence of sunshine
- **slash-and-burn agriculture:** form of agriculture in which trees are cut down and burned to clear the land for planting crops

Teaching Strategies

Introducing the Lesson

Introduce air pollution by showing the class images of serious air pollution, such as the images at the URLs below. Tell students they will learn about the causes and effects of air pollution, as well as ways it can be controlled, when they read this chapter.

- http://commons.wikimedia.org/wiki/File:SmogNY.jpg
- http://geographyblog.eu/wp/wp-content/uploads/2011/11/Air-pollution-in-London-001-1.jpeg
- http://www.momscleanairforce.org/files/2012/06/GWB_1973_2-580x377.jpg

Activity

Students can study particulates with the lesson plan at the following URL. Using a combination of teacher demonstration, discussion, online work, and hands-on activities, students will construct working definitions of criteria

pollutants and particulate matter, analyze real-time air quality data, and correlate particulate levels with health problems. The document includes background information, extension ideas, and a scoring rubric.

http://www.uni.edu/storm/downloads/highschool/Particulates.pdf

Demonstration

Use the animation at the first URL below to demonstrate to the class how low-level ozone forms. The animation at the second URL will give students more information on particulates.

http://www.epa.gov/airnow/ozone/o3.html

http://www.epa.gov/airnow/pm/pm.html

Differentiated Instruction

Suggest that students create an outline of the information in the lesson. Making an outline can help them organize the information in a reading passage so it is easier to see how concepts are related. It can also help them focus on the most important ideas. In addition, an outline is a very useful tool for reviewing and learning material from a reading passage. One of the main problems people have in writing outlines is writing too much. Tell students to read the following article first in order to learn how to avoid this problem when they create their outline.

http://schooldestroyer.com/outlining-writing-book/

Enrichment

Ask a few students to learn what the Air Quality Index (AQI) is, what it means, how it is calculated, and how it is related to human health. Then have them teach the information to the class. In addition, have the students find and report on the AQI for their local community each day for a week while the class is studying this chapter. At the end of the week, discuss how the AQI for their community affects the health of community members. Also discuss possible factors that contribute to the quality of air in their community.

- http://www.airnow.gov/?action=aqibasics.aqi
- http://www.casadata.org/airqualityindex/aqi/aqicalculated.asp
- http://www.airnow.gov/

Science Inquiry

Students can make an air pollution collector from simple materials, as described in the document below. The document also explains how to use the collector and interpret the results. Students will record observations of visible air pollution and link them with factors such as wind speed. Ask them to write a report on their project.

[http://www.instesre.org/NSFWorkshop/HansenParticulateCollector.pdf http://www.instesre.org/NSFWorkshop/HansenParticulateCollector.pdf

Overcoming Misconceptions

Many people mistakenly think that the creation of ozone is a good thing because it helps repair the ozone hole. Make sure they are aware of the difference between ground-level and stratospheric ozone. The former is the most important secondary air pollutant and never a good thing. The later protects living things from harmful UV radiation and is unrelated to ground-level ozone.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 22.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 22.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is the difference between the type of smog experienced by cities in the eastern United States and that found in Southern California?

- [Eastern cities are often near a lot of industry and coal-burning power plants. Primary pollutants are emitted from these factories and plants. In the arid west, more pollutants are secondary, coming from a combination of auto exhaust and sunshine.]

2. London has suffered from terrible air pollution for at least seven centuries. Why is the city so prone to its famous "London fog?" What did London do to get rid of its air pollution?

- [London has been a major population center for centuries. It was also the starting place for the Industrial Revolution. London is now much cleaner because clean air laws have been passed that require pollution-control measures.]

3. Imagine two cities of the same size with the same amount of industrialization and the same number of motor vehicles. City A is incredibly smoggy most of the time and City B usually has very little air pollution. What factors might go into creating these two different situations?

- [City A may be in a basin surrounded by mountains, which would create frequent temperature inversions that hold polluted air close to the ground. If City A gets little rainfall, precipitation cannot wash pollutants out of the air. Plentiful sunlight would also contribute to the formation of photochemical smog. City B may be in an open area that is not prone to temperature inversions. If City B gets a lot of rainfall, precipitation can wash pollutants out of the air. Another contributing factor could be anti-pollution regulations. City A might be in a nation with few regulations, and City B might be in a nation with strict regulations.]

4. What might be a reason why the city of San Francisco and its metropolitan area is not on the list of smoggiest cities for 2012?

- [A reason that San Francisco is not one of the smoggiest cities might be that it is windier and rainier than other California cities on the list.]

5. Why are naturally occurring substances, such as particulates or carbon dioxide, sometimes considered pollutants?

- [Naturally occurring substances are considered pollutants when human actions cause them to occur in the air at higher-than-natural levels that create problems.]

6. How does ozone form from vehicle exhaust?

- [Ozone forms when nitrogen oxides in vehicle exhaust are broken down in the air by sunlight to form oxygen atoms. The oxygen atoms then combine with oxygen molecules to form molecules of ozone.]

7. What are the necessary ingredients for ozone creation, excluding those that are readily available in the atmosphere? Why could there be a city with a lot of cars but relatively little ozone pollution?

- [Nitrogen oxides in hot exhaust gases and plentiful sunlight are needed for ozone formation. There could be a city with a lot of cars but relatively little ozone pollution if the weather is often cloudy so the city receives relatively little sunlight.]

8. Some people say that we need to phase out fossil fuel use and replace it with clean energy. Why is fossil fuel use becoming undesirable?

- [Fossil fuel use is becoming undesirable because most air pollutants come from the burning of fossil fuels. The burning of fossil fuels also releases carbon dioxide, which is a greenhouse gas that is contributing to global warming.]

9. Mercury is not particularly toxic as a metal but it is very dangerous in its organic form. How does mercury convert from the metal to the organic form?

- [If droplets of liquid mercury fall into sediments, bacteria can convert them to the highly toxic organic compound called methyl mercury.]

10. In what two ways does deforestation contribute to air pollution?

- [Deforestation contributes to air pollution by removing trees that would otherwise absorb carbon dioxide from the air for photosynthesis. The trees are often burned, which releases carbon dioxide and other pollutants into the air.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Despite the Clean Air Act, the air over many regions in the United States is still not clean. Why?

- [The Clean Air Act regulates several but not all air pollutants. Unregulated air pollutants are still being released into the air over the United Sates.]

How do pollutants damage human health?

- [Many air pollutants cause or worsen lung and heart diseases. Heavy metals may cause poisoning and neurological damage.]

In what ways does air pollution harm the environment?

- [Many air pollutants harm living things in the environment. For example, ozone damages some plants. The secondary pollutant acid rain acidifies bodies of water and strips nutrients from soils. It weakens plants and animals and kills fish.]

22.3 Lesson 22.2: Effects of Air Pollution

Key Concepts

- Smog effects on the environment
- Smog effects on human health
- Acid rain
- Ozone depletion

Lesson Objectives

- Describe the damage that is being done by smog.
- Discuss how acid rain is formed and the damage it does.
- Discuss how chlorofluorocarbons destroy the ozone layer.

Lesson Vocabulary

- **acid rain:** rain that has a pH of less than 5 that forms when nitrogen and sulfur oxides in the air dissolve in rainwater
- **alkaline:** having a pH of greater than 7; also called basic
- **bioaccumulation:** accumulation of toxic substances in organisms so that the concentration increases up the food web
- **ozone hole:** region in the stratosphere above Antarctica in which the ozone level is reduced in the spring because of the action of ozone-destroying chemicals
- **pH scale:** scale that measures the acidity of a solution, on which a pH value of 7 is neutral, values of less than 7 are acidic, and values of greater than 7 are basic
- **polar stratospheric clouds (PSC):** clouds that form in the stratosphere when it is especially cold and that are needed for the breakup of chlorofluorocarbon pollutants in the stratosphere

Teaching Strategies

Introducing the Lesson

Most students will be somewhat familiar with asthma and some of them are likely to have asthma themselves. Introduce human health effects of air pollution by focusing on this chronic lung disease. Tell students that asthma is a serious disease of the lungs that causes breathing problems due to a narrowing of the airways, which makes it difficult to get enough oxygen. Attacks are characterized by a tight feeling in the chest, coughing, and wheezing. State that asthma appears to be on the rise in the United States and many other countries. Its prevalence in the

United States, for example, has increased by more than 75 percent since 1980. Point out that children and certain racial groups, especially African Americans, have experienced relatively greater increases in asthma prevalence. Tell students that increases in asthma are just one of several effects of air pollution on human health and they will learn about others when they read this lesson.

Building Science Skills

With the activity "To Burn or Not to Burn" at the URL below, students will investigate the potential health effects of a proposed power plant in a community. They will calculate emissions of various pollutants from the proposed power plant and compare them with EPA air quality standards. Then they will use the data to make an informed decision about the power plant. The document includes teacher notes, links to data, and an assessment rubric.

http://www.uni.edu/storm/downloads/highschool/To%20Burn%20or%20Not%20to%20Burn.pdf

Activity

The purpose of the activity at the following URL is to raise awareness of the negative effects of air pollution, especially for people with asthma. Students will identify some of the sources of air pollution in their school and community and possible ways to improve air quality in these areas.

http://learningtogive.org/lessons/unit483/lesson1.html

Differentiated Instruction

Some students may be confused about ozone and whether it is good or bad. Help avoid this confusion by working with students to make a Venn diagram or compare/contrast table to distinguish the formation and health effects of low-level and stratospheric ozone. You can also have students watch the animation at the URL below.

http://www.epa.gov/airnow/o3gb/o3gb.html

Enrichment

A recent large-scale study documented a suspected link between exposure to air pollution in pregnant women and autism in their children. Refer interested students to one or more of the URLs below to learn about the research. Ask them to summarize the scope and findings of the research and present their summary to the class.

- http://www.rsc.org/chemistryworld/2013/06/air-pollution-diesel-metals-autism
- http://www.bloomberg.com/news/2013-06-18/autism-tied-to-air-pollution-brain-wiring-disconnection.html
- http://www.livescience.com/37510-autism-air-pollution.html

Science Inquiry

Use the lesson plan at the following URL so students can investigate the health effects of different air pollutants. This lesson contains three activities that focus on symptoms caused by specific pollutants. Students will engage in a game in which they analyze a series of case studies. The goal is to ask questions that clarify the patient's symptoms and then deduce the probable cause of the symptoms. Seven such cases are included on "Symptom Scenario" cards. Although based on fictional characters, the cases are realistic examples of well-documented health effects of exposure to specific pollutants.

http://www.dnrec.state.de.us/DNREC2000/Divisions/AWM/aqm/education/airqualityLesson7.pdf

Overcoming Misconceptions

Students may think that people who are healthy and don't have asthma are not adversely affected by air pollution. Point out research that shows even a healthy person can suffer ill effects from air pollution. You can use the research described at the URL below or find other research to share with students.

http://www.epa.gov/region07/air/quality/health.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 22.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 22.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Why is visibility so reduced in the United States?

   - [Particulates in the air are the main reason for reduced visibility.]

2. Why do health recommendations suggest that people limit the amount of tuna they eat?

   - [Tuna are predators near the top of their food chains, so they have bioaccumulated high levels of pollutants such as mercury.]

3. Why might ozone pollution or acid rain change an entire ecosystem?

   - [Ozone pollution might change an entire ecosystem by damaging the plants that other organisms depend on for food. Acid rain might change an entire ecosystem by stripping soils of nutrients so plant growth is curtailed. Acid rain also might make aquatic ecosystems to acidic that many organisms are damaged or killed.]

4. Why does air pollution cause problems in developing nations more than in developed ones?

   - [Developed nations have laws and regulations to limit the amounts of many pollutants that are allowed to enter the air. Many developing nations lack such laws and regulations.]

5. Why are children more vulnerable to the effects of air pollutants than adults?

   - [Sample answer: Children are more vulnerable because they are still growing and developing. Children also take in more air for their body weight than adults. In addition,

children generally spend more time outside and may be more likely to breathe hard because they are actively playing.]

6. Describe bioaccumulation.

- [Bioaccumulation is the accumulation of toxic substances in organisms so that the concentration increases from the bottom to the top of a food chain.]

7. How does pollution indirectly kill or harm plants?

- [Pollutants such as ozone kill or harm plants by weakening them so they are more likely to be damaged by frost or killed by a pest. Acid rain can indirectly kill or harm plants by stripping the soil of nutrients that plants need. Particulates can reduce the amount of sunlight available to plants for photosynthesis.]

8. What do you think the effect is of jet airplanes on global warming?

- [The contrails of jet airplanes add particulates to the atmosphere that reduce the amount of sunlight that reaches the surface. This slightly lowers Earth's temperature, which might reduce global warming.]

9. Why is air pollution a local, regional, and global problem?

- [Some pollutants affect only a local region like a city. Most of the smog that harms Los Angeles stays in L.A. Acid rain is an example of a pollutant that affects a larger region. The acids may travel hundreds of miles before they fall to the ground in rain. Ozone depletion and global warming are global problems caused by air pollution. CFCs are emitted in the developed nations, but most ozone depletion occurs in the polar regions and affects all of earth. Carbon dioxide and other greenhouse gases also enter the atmosphere in the populated parts of the world but global warming affects the entire planet.]

10. How do CFCs deplete the ozone layer?

- [CFCs in the stratosphere are broken apart by sunlight to form free chlorine atoms, which break down ozone molecules to oxygen.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Since mercury bioaccumulates and coal-fired power plants continue to emit mercury into the atmosphere, what will be the consequence for people who like to eat tuna and other large predatory fish?

- [The fish will continue to bioaccumulate mercury. If people continue to eat the fish, they will also bioaccumulate mercury because they are the top predators in the food chain.]

What are the possible causes of rising asthma rates in children?

- [Possible causes of rising asthma rates in children include greater exposure to air pollution.]

A ban has been imposed on CFCs and some other ozone-depleting substances. How will the ozone hole change in response to this ban?

- [Following a short period when CFC levels remained high, the ozone hole has started to shrink in response to this ban.]

22.4 Lesson 22.3: Reducing Air Pollution

Key Concepts

- Reducing air pollution from vehicles
- Reducing industrial air pollution
- Reducing ozone destruction
- Reducing greenhouse gases

Lesson Objectives

- Describe the major ways that energy use can be reduced.
- Discuss new technologies that are being developed to reduce air pollutants, including greenhouse gases.
- Describe the difference between placing caps on emissions and reducing emissions.

Lesson Vocabulary

- **biofuel:** fuel made from living things, usually crop plants such as corn or soybeans
- **cap-and-trade:** system of caps, or upper limits, on carbon dioxide emissions in which nations can trade allowances for emissions
- **carbon sequestration:** removal of carbon dioxide from the atmosphere so it does not act as a greenhouse gas and contribute to global warming
- **carbon tax:** tax placed on energy sources that emit carbon dioxide when burned in order to discourage their use and to raise funds for researching alternative energy sources
- **catalyst:** substance that increases the rate of a chemical reaction but is not used up in the reaction
- **catalytic converter:** device on modern motor vehicles that uses a catalyst to break down pollutants in exhaust before they can leave the vehicle and enter the atmosphere
- **fuel cell:** energy cell in which chemical energy is converted to electrical energy
- **gasification:** technology that changes solid coal to a gas that burns more efficiently and produces fewer emissions than solid coal
- **hybrid vehicle:** very efficient vehicle that is powered by a combination of an internal combustion engine and an electric motor with a rechargeable battery

Teaching Strategies

Introducing the Lesson

Briefly explain to the class that an international agreement called the Montreal Protocol was signed by many nations, including the U.S., in 1987. The purpose of the agreement was to limit the production and use of CFCs, which break

down stratospheric ozone. Ask students if they think the Montreal Protocol was a success. Tell them they will find out when they read the lesson.

Activity

The activity at the URL below is designed to introduce students to the field of engineering with a focus on air pollution control. Students will learn basic information about one of the most commonly used air pollution control devices used in industry, known as the baghouse. Then they will use math to determine the efficiency of simulated baghouses they create using simple items available from a hardware store.

http://tbpmindset.org/modules/GatorTRAX/Environmental/Baghouse_Module.pdf

Differentiated Instruction

Have students make a KWL chart for the lesson to help them focus their reading. The three-column chart should have the headings "Know" (K), "Want to Know" (W), and "Learned" (L). Tell students to fill in the K and W columns before they read the lesson and the L column after they read the lesson. Discuss as a class anything students wanted to know but didn't learn when they read the lesson.

Enrichment

Encourage interested students to learn more about fuel cell technology and fuel cell vehicles. They should find out how they work and why they don't create air pollution. They should also learn about constraints on the design of fuel cell vehicles and problems in developing them for large-scale use. Suggest to the students that they start their research with this URL: http://www.fueleconomy.gov/feg/fuelcell.shtml.

Science Inquiry

Show the excellent film "AirSearch for One Clean Breath" at the first URL below. Then use the lesson plan that accompanies the film (see second URL). In the lesson, students will solve an air pollution mystery using a variety of evidence. This will allow students to appreciate that many disciplines of study and areas of interest can contribute to solving a public health problem. It will also increase their awareness of past air pollution disasters. Students will learn that public awareness and activism can prevent or minimize air pollution tragedies.

http://www.vcapcd.org/AirTheFilm/index.htm

http://www.vcapcd.org/AirTheFilm/pubs/AirPollutionTragedyLessonPlan.pdf

Overcoming Misconceptions

Many people think that catalytic converters solve all the air pollution problems created by motor vehicles by removing pollutants from the exhaust before they exit the tail pipe. This is incorrect for two reasons. Point out that a catalytic converter works only when it is very hot. The heat comes from the exhaust and until the car engine heats up, the exhaust is too cool for the converter to work. This means that the car releases air pollutants from the tail pipe at the start of each trip until the car warms up. Also explain that a catalytic converter changes air pollutants other gases. One of these other gases is carbon dioxide. Although carbon dioxide is harmless to human health, it is a significant cause of global warming.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 22.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 22.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Since the Clean Air Act was passed in 1970, why is the air still not clean?

- [There are many more vehicles, factories, and power plants than ever before. These have increased the number of polluters, even if the amount of pollution that comes from each one is less. Also, scientists have identified substances that weren't known to be pollutants in 1970. These include CFCs, which are greenhouse gases and ozone destroyers.]

2. What are some ways that you can conserve energy?

- [Answers may vary. *Sample answer*: You can conserve energy, and thus reduce your use of fossil fuels, by riding a bike or walking instead of driving, buying a car with greater fuel efficiency, turning off lights and appliances when not in use, and using more energy-efficient light bulbs and appliances.]

3. How does reducing air pollutants, as described in the Clean Air Act of 1970, affect greenhouse gas emissions?

- [Some air pollutants regulated by the Clean Air Act of 1970, such as nitrogen oxides, are greenhouse gases, so regulating them reduces emissions of these greenhouse gases. However, other greenhouse gases, including carbon dioxide, are not regulated by the Clean Air Act. In 1970, carbon dioxide was not known to cause environmental problems.]

4. What has to be done before alternative energy sources can replace fossil fuels?

- [Before alternative energy sources can replace fossil fuels, technologies for using them must improve and become less expensive.]

5. What are catalytic converters?

- [Catalytic converters are devices on motor vehicles that break down nitrous oxides, carbon monoxide, and VOCs in exhaust into other gases, including harmless oxygen and nitrogen gases.]

6. Why are hybrid vehicles more energy efficient than regular vehicles powered by internal combustion engines?

- [Hybrid vehicles are more energy efficient because they run on a combination of gas and electricity. Energy that would be lost during braking in a regular vehicle is used to charge a battery, which can then run the car.]

7. Why aren't fuel-cell vehicles widely available yet?

- [Fuel-cell vehicles aren't widely available yet because technology has to advance to make them practical.]

8. How does a cyclone reduce particulate pollution?

- [A cyclone sets up a rotating funnel of air like a cyclone storm. Heavy particles move to the outside of the cyclone. When they hit the sides of the container the particles fall to the base and are then easily removed. As the cyclone gets smaller in diameter, smaller particles are able to be removed.]

9. How can coal power be made so that it has nearly zero carbon contribution to the atmosphere?

- [Gasification can be used to create syngas from coal. Compared to coal, when syngas is burned it releases about 80 percent less pollution and also less greenhouse gas.]

10. Why is it that the ozone hole will not be healed for several decades?

- [The ozone hole will not be healed for several decades because CFCs take many years to reach the stratosphere and they can remain there a long time before they break down.]

11. Many people think that biofuels are the solution to a lot of the problems of climate change, but others disagree. What requirements would biofuels have to meet if they were to be really effective at replacing gasoline in motor vehicles?

- [To be really effective at replacing gasoline, biofuels would have to be made from crops that require less fossil fuel to grow, do not replace food crops, and produce more usable oil than crops such as corn.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why is it important to reduce air pollution?

- [It is important to reduce air pollution because it can harm human health and the environment.]

What can you do in your own life to reduce your impact on the atmosphere?

- [You can conserve energy, because most energy is produced from fossil fuels. You can also use alternative energy resources that do not produce air pollution.]

Why is a worldwide effort needed to reduce the threat of global climate change?

- [A worldwide effort is needed because air pollution from any given nation circulates in the atmosphere and because air pollution problems such as acid rain and global warming affect the entire planet.]

CHAPTER 23 HS TE Observing and Exploring Space

Chapter Outline

23.1 Chapter 23: Observing and Exploring Space

Chapter Overview

This chapter begins with a discussion of electromagnetic radiation, types of telescopes, and ways of gathering information from our universe. It provides information about early space exploration and concludes with a description of recent and current space exploration.

Online Resources

See the following Web sites for appropriate laboratory activities:

The virtual space travel lab at the following URL (Lesson 4) will help students appreciate the difficulties involved in human exploration of space. It will also develop their technological design skills. In the lab, students will design helmets to protect space travelers on different planets, including Mars, Saturn, and Pluto. Each helmet must address different conditions and meet different requirements. The document includes design sheets adapted from NASA.

- http://www.msnucleus.org/membership/html/jh/earth/spaceexplore/jhspaceexpl.pdf

Another technological design lab can be found at the URL below. In the lab, students will demonstrate how reaction wheels (also known as momentum wheels) take advantage of Newton's third law to control a spacecraft's orientation. This is an important function, especially when an orbiting spacecraft is collecting data from a planet or other celestial body.

- http://saturn.jpl.nasa.gov/files/Spinning_World.pdf

These Web sites may also be helpful:

The following interactive Web site provides an in-depth exploration of the telescope, including its history and the science behind it. The site is a useful adjunct to the first lesson in this chapter for you and/or your students.

- http://amazing-space.stsci.edu/resources/explorations/groundup/

Students can explore space and take telescopic images with the Harvard-Smithsonian Center for Astrophysics' MicroObservatory network of automated telescopes. The telescopes can be controlled over the Internet. You can learn more about the program at this URL: http://mo-www.harvard.edu/OWN/about.html

At the URL below, you can find links to a wide variety of educational resources on astronomy.

- http://www.astrosociety.org/education/educational-resources/

This URL has links to many Web sites that offer information and activities relating to multi-wavelength astronomy.

- http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/activities.html

You can find a detailed interactive space exploration timeline at the following URL. It covers space exploration for the 50-year period 1957–2007.

- http://science.nationalgeographic.com/science/space/space-exploration-timeline/

Go the URL below for a collection of space exploration videos.

- http://www.neok12.com/Space-Exploration.htm

Pacing the Lessons

TABLE 23.1: short caption

Lesson	Class Period(s) (60 min)
23.1 Telescopes	2.5
23.2 Early Space Exploration	2.0
23.3 Recent Space Exploration	2.0

23.2 Lesson 23.1: Telescopes

Key Concepts

- Electromagnetic radiation and the speed of light
- Optical, radio, and space telescopes
- Observations made with telescopes

Lesson Objectives

- Explain how astronomers use the whole electromagnetic spectrum to study the universe beyond Earth.
- Identify different types of telescopes.
- Describe historical and modern observations made with telescopes.

Lesson Vocabulary

- **astronomer:** scientist who studies the universe beyond Earth
- **catadioptric telescope:** type of optical telescope that uses a combination of mirrors and lenses to collect and focus light
- **constellation:** group of stars that appear from Earth to form a recognizable pattern
- **electromagnetic (EM) radiation:** energy transmitted through space as waves
- **electromagnetic spectrum:** full range of wavelengths of electromagnetic radiation
- **frequency:** number of waves that pass a given point each second
- **gamma ray:** penetrating type of electromagnetic radiation that has the shortest wavelengths
- **infrared light:** type of electromagnetic radiation with wavelengths between radio waves and visible light
- **light-year:** distance that light travels in one year; equal to 9.5 trillion kilometers
- **microwave:** type of radio waves with the shortest wavelengths
- **planet:** space object that orbits a star and has cleared its orbit of smaller objects
- **radio telescope:** type of telescope that collects radio waves
- **radio wave:** type of electromagnetic radiation that has the longest wavelengths
- **reflecting telescope:** type of optical telescope that uses mirrors to gather and focus visible light
- **refracting telescope:** type of optical telescope that uses convex lenses to gather and focus visible light
- **space telescope:** telescope that orbits Earth above Earth's atmosphere
- **spectrometer:** device that breaks light into different wavelengths, or colors
- **ultraviolet (UV) light:** type of electromagnetic radiation with wavelengths between visible light and X-rays that can harm living things
- **visible light:** type of electromagnetic radiation that has wavelengths between infrared and ultraviolet light and that can be detected by the human eye
- **wavelength:** horizontal distance between corresponding points on adjacent waves, such as the distance between two crests or two troughs
- **X-ray:** type of electromagnetic radiation with wavelengths between ultraviolet light and gamma rays

Teaching Strategies

Introducing the Lesson

Play a word association game with the class. Go around the room from one student to the next, and ask each student to say the first word that comes to mind when they hear the term space. After no new words are forthcoming, discuss how some of the most pertinent words are related to space or space exploration. Then tell students they will learn about space exploration in this chapter.

Activity

Students can use the telescope simulator at the following URL to better understand how a telescope works and how to use it to bring distant objects into focus.

http://astro.unl.edu/classaction/animations/telescopes/telescope10.html

Building Science Skills

Many students have trouble envisioning how relatively thin a layer Earth's atmosphere is and where space begins. Use the activity at the URL below to help them get a better idea of the relative sizes and locations of the atmosphere and space. In the activity, students will construct a scale model and use it to see where things such as airplane flights, the Hubble space telescope, and the beginning of space are located.

http://www.astrosociety.org/edu/activities/I11_How_High_Space.pdf

Activity

Students can explore the electromagnetic spectrum using a variety of interactive Internet resources and hands-on activities that are described at the following URL.

http://can-do.com/uci/ssi2001/emspectrum.html

Differentiated Instruction

Pair any differential learners with other students, and ask partners to make a Venn diagram comparing and contrasting refracting and reflecting telescopes.

Enrichment

Interested students can extend the Science Inquiry Activity below by learning how Galileo's discoveries with this telescope relate to the Copernican Revolution. Ask the students to create a PowerPoint presentation to share what they learn with the rest of the class.

Science Inquiry

In the inquiry activity at the URL below, students will undertake a simplified version of Galileo's pioneering observations of Jupiter's moons. Specifically, they will examine data showing the positions of Jupiter's moons over several nights. This will allow them to follow the motion of each moon and determine its orbital period around Jupiter. The focus of the activity is on the scientific process and the steps in that process.

http://www.astrosociety.org/edu/slooh/footsteps.pdf

Real-World Connection

Astronomy is an interesting subject to many people, and many companies take advantage of that interest by naming their products after astronomical objects. Have students make a list of such products (e.g., Mercury and Saturn cars, Milky Way candy bars, Starburst candies, Moon pies, Comet cleanser, and the Gemini roller coaster). Then have students think about other astronomy terms that might be used in the future to name new products. The activity will help students appreciate the influence of astronomy outside of science, increase their familiarity with astronomical terms, and develop their creative thinking skills.

http://www.astrosociety.org/edu/publications/tnl/08/stars2.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 23.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 23.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Betelgeuse is around 640 light-years from Earth. Light travels 9.5 trillion kilometers in one year. How far away is Betelgeuse in kilometers?

- [The distance is 640 light-years x 9.5 trillion km/light-year = 6,080 trillion km.]

2. Identify four regions of the electromagnetic spectrum that astronomers use when observing objects in space.

- [Astronomers use the entire electromagnetic spectrum to observe objects in space, including radio waves, microwaves, visible light, and ultraviolet light.]

3. List the three main types of optical telescopes, and describe their differences.

- [The three main types of optical telescopes are refracting, reflecting, and catadioptric telescopes. Refracting telescopes use convex lenses to focus light. Reflecting telescopes use curved mirrors to focus light. Catadioptric telescopes use a combination of lenses and mirrors to focus light.]

4. Explain the advantages of putting a telescope into orbit around Earth.

- [Putting a telescope into orbit around Earth allows the telescope to gather radiation from space before the radiation passes through, and is distorted by, Earth's atmosphere.]

5. Describe two observations that Galileo was the first to make with his telescope.

- [Answers may vary. *Sample answer*: Two observations that Galileo was the first to make include the observation that the moon has craters and that Jupiter has orbiting moons.]

6. List three things that an astronomer can learn about a star by studying its spectrum.

- [Answers may vary. *Sample answer*: From its spectrum, an astronomer can learn the composition, temperature, and speed of a star.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Radio waves are used for communicating with spacecraft. A round-trip communication from Earth to Mars takes anywhere from 6 to 42 minutes. What challenges does this present for sending unmanned spacecraft and probes to Mars?

- [Scientists on Earth might not be able to react quickly enough to deal with any emergencies involving the spacecraft.]

The Hubble space telescope is a very important source of data for astronomers. The fascinating and beautiful images from the Hubble also help to maintain public support for science. However, the Hubble is growing old. Missions to service and maintain the telescope are extremely expensive and put the lives of astronauts at risk. Do you think there should be another servicing mission to the Hubble?

- [Students may or may not think that there should be another servicing mission to the Hubble. With the cessation of the shuttle program in 2011, no additional servicing missions can be made. The Hubble is expected to cease operation sometime between about 2014 and 2020.]

23.3 Lesson 23.2: Early Space Exploration

Key Concepts

- Rockets
- Satellites
- The Space Race
- Reaching the moon
- Exploring other planets

Lesson Objectives

- Explain how a rocket works.
- Describe different types of satellites.
- Outline major events in early space exploration, including the Space Race.

Lesson Vocabulary

- **low-Earth orbit:** orbit of satellites that stay relatively close to Earth
- **orbit:** circular or elliptical path of one object around another
- **rocket:** vehicle propelled by high-speed gas particles flying out one end of it
- **satellite:** natural or human-made object that orbits another object
- **space probe:** spacecraft that is sent without a crew to collect data by flying near or landing on a distant object in space
- **thrust:** forward force produced by gases escaping from a rocket engine in the opposite direction

Teaching Strategies

Introducing the Lesson

Ask students if they have ever heard the expression, "It's not rocket science." Have them explain what the expression refers to and also what it infers about the actual science of rockets. (The expression refers to something that is not especially difficult. It infers that the actual science of rockets is very difficult.) Tell students that the basic science behind rockets is not as difficult as many people think, as they will learn when they read this lesson.

Activity

Students can apply basic principles of rocket science to build and launch a model transport rocket. You can find all the information needed for this project on pages 74–76 of the following document. Students will predict and then test how much weight their rocket can carry.

http://www.nasa.gov/pdf/265386main_Adventures_In_Rocket_Science.pdf

Differentiated Instruction

Have visual learners draw and label a sketch to show how a rocket works. Putting pencil to paper to create a labeled sketch will focus their knowledge of rocketry on the most crucial aspects of the rocket and the science behind it.

Enrichment

Have students who need extra challenges do the satellite image-interpretation activity at the URL below. The activity has three parts. Parts I and II providethen quiz students onbasic information they need in order to interpret visible and infrared satellite images. Answers to the questions are provided. Part III asks students to apply this knowledge to a variety of actual satellite images and interpret what they see in the images.

http://funnel.sfsu.edu/satlab/

Science Inquiry

Students can use microsets of NASA satellite data to study the relationship between Earth's surface temperature and tropospheric ozone levels. The purpose of the study is to analyze changes in tropospheric ozone and then hypothesize about the consequences of these changes. In the process, students will learn how to use satellite images and other data as well as gain an appreciation of the value of using satellites to gather data about Earth. The URL below provides a lesson plan for the activity. The Web site includes instructions for accessing the satellite data. The lesson plan itself includes background information, the procedure, and ideas for extension. Teacher notes are also provided.

http://mynasadata.larc.nasa.gov/lesson-plans/lesson-plans-hs-educators/?page_id=474?&passid=16

History Connection

Describe to students some of the social effects of the Space Race on people in the U.S. For example, shortly after the Soviet Union launched Sputnik 1, greater emphasis was placed on teaching math and science in schools, including greater government funding for math and science teacher training and public school math and science classes. You and/or your students can learn more by reading the excellent article at this URL: http://www.nebraskastudies.org/0900/frameset_reset.html?http://www.nebraskastudies.org/0900/stories/0901_0105.html.

Reinforce and Review

Lesson Worksheets=

Copy and distribute the Lesson 23.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 23.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Use Newton's third law to explain how a rocket moves.

   - [Newton's third law states that for every action there is an equal and opposite reaction. In a rocket, fuel is ignited in a chamber, which causes an explosion of gases. The explosion creates pressure that forces the gases out of the rocket. As these gases rush out the end of the rocket, the rocket moves in the opposite direction, as predicted by Newton's third law of motion. The movement of the gases is the action, and the movement of the rocket in the opposite direction is the reaction.]

2. List the three great pioneers of rocket science and their contributions.

   - [The three great pioneers of rocket science are Tsiolkovsky, Goddard, and Oberth. Tsiolkovsky came up with the ideas of using liquid fuel and multiple stages, but he never actually built a rocket. Goddard came up with the same ideas as Tsiolkovsky and also designed a system for cooling the gases that escape from a rocket, which increases rocket efficiency. Goddard built rockets to test his ideas, including the first rocket to use liquid fuel. Oberth came up with the same ideas as Tsiolkovsky and Goddard and also built and launched a liquid-fuel rocket. In addition, he designed a rocket for the German military that played a major role in World War II. This rocket was launched to an altitude of 176 km, making it the first human-made object to travel into space.]

3. What is the difference between a rocket and a satellite? How are they related?

   - [A rocket is a vehicle that launches from Earth's surface. A satellite is an object that orbits Earth. Satellites are launched into orbit by rockets.]

4. What is the name of Earth's natural satellite?

   - [Earth's natural satellite is the moon.]

5. Explain why a satellite in polar orbit can take pictures of all parts of Earth over time.

   - [A satellite in polar orbit keeps circling the globe in a path perpendicular to the direction of Earth's rotation. Because Earth rotates beneath the rocket, the rocket eventually passes over all parts of the globe.]

6. Describe three different types of orbits.

   - [Three different types of orbits are low-Earth orbits, medium-Earth orbits, and geostationary orbits. Low-Earth orbits pass over the poles, perpendicular to Earth's spin. They have the lowest orbits, closest to the surface. Geostationary orbits are the highest orbits, farthest from Earth's surface. A satellite in a geostationary orbit travels in the same direction and at the same speed that Earth spins, so the satellite is always in the same position over Earth's surface. Medium-Earth orbits are in between low-Earth and geostationary orbits in their distance from the surface.]

7. What event launched the Space Race?

   - [The Space Race was launched by Sputnik 1, which was the first artificial satellite ever put into orbit. It was launched by the USSR in 1957.]

8. What goal did John F. Kennedy set for the United States in the Space Race?

- [Kennedy set the goal for the United States of landing a man on the moon and returning him back safely to Earth.]

9. What are the advantages of a multi-stage rocket instead of a single-stage rocket?

- [A multi-stage rocket allows empty fuel containers to drop away. This reduces the mass of the rocket so it can fly higher.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

The Space Race and the United States' desire to get to the moon brought about many advances in science and technology. Can you think of any challenges we face today that are, could be, or should be a focus of science and technology?

- [There are many challenges but arguably the most important is global climate change.]

If you were in charge of NASA, what new goals would you set for space exploration?

- [Exploring other planets or even other solar systems with probes that do not require human crews are among the possible goals NASA has already set for space exploration.]

Do you think that a space program is a good use of government funding?

- [Some people think that scientific knowledge gained from the space program is worth the money. Other people think that the money could be better spent solving people's problems here on Earth.]

23.4 Lesson 23.3: Recent Space Exploration

Key Concepts

- Space stations
- Space shuttles
- Recent space missions

Lesson Objectives

- Outline the history of space stations and space shuttles.
- Describe recent developments in space exploration.

Lesson Vocabulary

- **orbiter:** main part of the space shuttle that has wings like an airplane
- **space shuttle:** reusable spacecraft capable of carrying large pieces of equipment or parts of a space station
- **space station:** large spacecraft that orbits Earth and on which humans can live for extended periods of time

Teaching Strategies

Introducing the Lesson

Show students some of the amazing images at the following URL. They are pictures of Saturn and its moons taken by the Cassini spacecraft. Tell students they will learn about the Cassini and other recent and current space missions when they read this lesson.

http://www.nasa.gov/mission_pages/cassini/multimedia/gallery/gallery-index.html

Discussion

Point out that research projects on the International Space Station (ISS) are projects that require the conditions of a low-Earth orbit, such as weightlessness. Have students brainstorm possible research questions that might be addressed in which weightlessness is a factor. Suggest that they think about research questions in human biology, space medicine, life science, physical science, astronomy, and/or meteorology. After students have come up with their own ideas, you can describe some of the research that actually takes place on the ISS. To learn more, go to these URLs:

- http://en.wikipedia.org/wiki/Scientific_research_on_the_International_Space_Station

- http://www.nasa.gov/mission_pages/station/research/experiments_category.html

Differentiated Instruction

Have students do a gallery walk for space shuttles and space stations. Post a large sheet of paper or poster board on two different walls of the classroom. Label one "Space Shuttles" and label the other "Space Stations." Divide the class into several groups, including any differential learners in groups with other students. Give each group a chance to add notes to each poster, expressing what they know about each type of spacecraft. They should also add comments about the ideas expressed by other groups. After the activity, read aloud the most important points made by the groups, and identify and discuss any misconceptions.

Enrichment

If students want to learn more about NASA's planned future missions, advise them to go to the Web site below. Encourage them to summarize what they learn and share it with the other students in class.

http://science.nationalgeographic.com/science/space/space-exploration/future-spaceflight/

Science Inquiry

Through Mars Exploration Student Data Teams (MESDT), students can get involved in authentic Mars research. As team members, they will work with scientists, mission planners, and educators on the collection and analysis of data as it is downloaded from instruments currently orbiting Mars. To see how your students can join this free program, go to this URL: http://marsed.mars.asu.edu/mesdt-home.

Overcoming Misconceptions

Many people think that there is no gravity in space. This misconception may come from the images people see of astronauts floating around in the International Space Station (ISS). Explain to students that neither the astronauts nor their spacecraft are ever free of gravity because there is gravity everywhere in the universe. In fact, for near-Earth missions like the ISS, astronauts are subject to a force of gravity that is almost as strong as it is on Earth's surface. The only reason they seem weightless (and therefore not subject to gravity) is that they are falling around Earth at the same rate as the spacecraft is falling around Earth. This makes them weightless relative to the things around them.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 23.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 23.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Which space station was built and launched by the United States alone?

- [The space station named Skylab was the space station built and launched by the United States alone.]

2. How many years was the Mir space station in orbit?

- [The Mir space station was in orbit for nearly 10 years.]

3. Which space station was the first to involve several countries working together?

- [The International Space Station was the first to involve several countries.]

4. Describe two ways in which space shuttles were an improvement over the spacecraft used for the Apollo missions?

- [Unlike the spacecraft used for the Apollo missions, space shuttles could carry a lot of cargo and be reused.]

5. Name the five fully functional space shuttles that the United States built. Which of these were destroyed?

- [The five space shuttles were Columbia, Challenger, Discovery, Atlantis, and Endeavor. Columbia and Challenger were destroyed.]

6. Describe the space shuttle Columbia disaster, including its cause.

- [The space shuttle Columbia lost a small piece of insulating foam off the fuel tank during takeoff. The foam smashed into the front edge of one wing of the orbiter and damaged a heat-shield tile. When Columbia returned to Earth, it could not withstand the high temperature with the missing tile and broke apart.]

7. Describe two recent or ongoing space missions.

- [Answers may vary. *Sample answer*: Several rovers have landed on Mars and explored the Martian surface. They include Sojourner, Spirit, Opportunity, and Curiosity. The Cassini mission has been studying Saturn, including its rings and moons.]

8. Is a space shuttle more like a rocket or a plane? Explain your answer.

- [Answers may vary. *Sample answer*: A space shuttle is like both a rocket and a plane. It has three main parts: the orbiter, which has wings and looks and flies like a plane; a large fuel tank; and on either side of the fuel tank two large booster rockets. The booster rockets provide extra power to get the orbiter out of Earth's atmosphere. When they are done, they parachute down into the ocean so they can be recovered and used again. When the fuel tank is empty, it also falls away, but it burns up in the atmosphere. When the orbiter returns to Earth, it glides down to the surface and is landed on a runway.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

To date, a total of 22 people have died on space missions. In the two space shuttle disasters alone, 14 people died. However, space exploration and research have led to many great discoveries and new technologies. Do you think sending people into space is worth the risk? Why or why not?

- [Some people think that what we can learn from space travel is worth the risk. Other people think that it is not worth risking human lives to explore space.]

In the past several years, private companies have been developing vehicles and launch systems that can take people into space. What applications can you think of for such vehicles? What advantages and disadvantages are there to private companies building and launching spacecraft?

- [Such vehicles might be used to take space tourists into space or to extract minerals from other planets or moons and return them to Earth. Advantages of private companies building and launching spacecraft might include the money the government would save and be able to spend on more urgent needs on Earth. Disadvantages might include private companies launching spacecraft to make money for themselves rather than to do research.]

CHAPTER 24 HS TE Earth, Moon, and Sun

Chapter Outline

24.1 Chapter 24: Earth, Moon, and Sun

Chapter Overview

This chapter describes the basic properties and motions of Earth, the moon, and the sun, including tides and eclipses. It also describes the sun's layers and solar activity.

Online Resources

See the following Web sites for appropriate laboratory activities:

Students can do the investigation "Impact Craters" (pages 61–70 in the document below) to learn more about the formation of craters on the lunar surface. They will experiment to determine the factors affecting the appearance of impact craters and ejecta. They will use marbles, ball bearings, or similar spheres as impactors dropped onto a prepared "lunar surface." Using these materials, they will investigate how mass and velocity of the impactors affect crater size.

- http://www.nasa.gov/pdf/58199main_Exploring.The.Moon.pdf

In the classroom lab activity at the following URL, students will calculate the velocity and acceleration of a coronal mass ejection based on its position in a series of images taken by NASA's SOHO mission. This is a good lab to involve students in actual space research. It will develop both observational and mathematics skills.

- http://sohowww.nascom.nasa.gov/classroom/cme_activity.html

These Web sites may also be helpful:

At the following URL, you can access an excellent resource from NASA, "Exploring the Moon," which is a teacher's guide with activities for Earth and space science for grades 4–12. In addition to the activities, the document includes extensive background information, fact sheets, and links to other resources.

- http://www.nasa.gov/pdf/58199main_Exploring.The.Moon.pdf

Another excellent resource from NASA is available at the URL below. It covers the SOHO mission, which is exploring the sun from space. You and/or your students can learn more about the sun and how it is being studied. The site also has wonderful solar images and a variety of educational materials.

- http://sohowww.nascom.nasa.gov/home.html

The following Web site provides a collection of multi-disciplinary, interactive exercises and activities based on the sun and solar science, most geared to grades 4-12.

- http://solar-center.stanford.edu/teachers/

At the URLs below, you can find a diversity of educational resources on solar eclipses, including teacher-reviewed videos.

- http://www.exploratorium.edu/eclipse/index.html
- http://www.neok12.com/Eclipse.htm

Pacing the Lessons

TABLE 24.1: short caption

Lesson	Class Period(s) (60 min)
24.1 Planet Earth	1.5
24.2 Earth's Moon	1.0
24.3 The Sun	1.5
24.4 The Sun and the Earth-Moon System	2.0

24.2 Lesson 24.1: Planet Earth

Key Concepts

- Earth's shape
- Earth's magnetism
- Earth's rotation
- Earth's revolution

Lesson Objectives

- Recognize that Earth is a modified sphere (oblate spheroid), and describe the evidence for this conclusion.
- Explain what causes Earth's magnetism and the effects that magnetism has on Earth.
- Describe Earth's rotation on its axis.
- Describe Earth's revolution around the sun.

Lesson Vocabulary

- **axis:** imaginary line that runs between the North and South Poles through the center of Earth
- **ellipse:** oval-like shape of the orbits of Earth and the other planets
- **hemisphere:** half of a sphere, such as half of planet Earth
- **revolution:** orbital movement of one object around another, such as the moon around Earth or Earth around the sun
- **rotation:** spinning of an object such as Earth on its axis

Teaching Strategies

Introducing the Lesson

Play a game to get students thinking about Earth the planet. Tell students you are going to give them clues about a natural object in space (Earth), and they have to try to guess the identity of the object with as few clues as possible. You can use these clues:

- It has a diameter of 12,756 km.
- It has a mass of 5.97×10^{24} kg.
- It formed 4.6 billion years ago.
- Its average distance from the sun is about 150 million km.
- The temperature at its center is about 5500 degrees Celsius.

- The temperature on its surface ranges from about -90 to 57 degrees Celsius.

After they guess, or you tell them, that the object is Earth, say they will learn more about our planet when they read this lesson.

Activity

Use the lesson "Foucault's Pendulum" at the following URL so students can learn more about Foucault's pendulum experiment and how it provided evidence for Earth's rotation. By working through the lesson, they will have a better understanding of how Foucault used Newton's first law of motion to prove that Earth spins on its axis. The activity includes links to related resources, a student worksheet, a written assessment, and ideas for extension.

http://sciencenetlinks.com/lessons/foucaults-pendulum/

Differentiated Instruction

Pair any students who are struggling with those who excel in science. Ask the students who excel to create an unlabeled diagram that shows how the tilt of Earth on its axis causes Earth's seasons. Then have the other student in each pair correctly label the diagram. This is a good activity for visual and English language learners.

Enrichment

Ask interested students to learn more about Earth's magnetic field and how it shields the planet form harmful solar radiation. The resources at the following URLs are useful for this purpose. Have the students explain this function of Earth's magnetic field to the rest of the class. Tell them to include illustrations in their presentation. They should also explain and use the terms magnetosphere and Van Allen radiation belts.

- http://www.universetoday.com/27005/earths-magnetic-field/
- http://www.windows2universe.org/glossary/plasmaspheric_gain.html
- http://www.windows2universe.org/glossary/radiation_belts.html

Science Inquiry

Show the class the photograph of a partial lunar eclipse at the URL below. Tell students that the picture shows the moon passing through Earth's shadow. Ask students to explain how this provides evidence for Earth's spherical shape. (The curvature of Earth is apparent from the shape of the shadow it casts on the moon.)

http://upload.wikimedia.org/wikipedia/commons/8/8e/Rhys400D_-_Lunar_Eclipse_Half_Moon_(by).jpg

Overcoming Misconceptions

Students are likely to have misconceptions about Earth's magnetic field. For example, they are likely to think that the magnetic pole in the Northern Hemisphere is the north magnetic pole and that Earth's magnetic alignment is always the same. Explain why each of these potential misconceptions is false. The north magnetic pole attracts the north pole of a bar magnet and so is in a physical sense actually a south magnetic pole. Also, the orientation of Earth's magnetic field (and that of other planets) can flip, so that magnetic north becomes magnetic south and vice versa. This is known as geomagnetic reversal, and it has happened repeatedly throughout Earth's geologic history.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 24.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 24.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. When you watch a tall ship sail over the horizon of Earth, you see the bottom part of it disappear faster than the top part. Why does this happen?

- [The bottom of the ship disappears first as the ship starts to go over the curvature of the planet.]

2. Why are we able to use magnets to determine north-south directions on Earth?

- [Magnets have a north and south pole like Earth's magnetic poles, and they always align with Earth's magnetic field.]

3. Describe the difference between Earth's rotation and its revolution.

- [Earth's rotation is its spinning on its axis. Its revolution is its movement in its orbit around the sun.]

4. What is the force that keeps Earth and other planets in their orbital paths?

- [Gravity keeps Earth and other planets in their orbital paths.]

5. In its elliptical orbit around the sun, Earth is closest to the sun in January. If Earth is closest to the sun in January, why is January winter in the Northern Hemisphere?

- [The seasons are not caused by distance from the sun. It is winter in the Northern Hemisphere in January because the Northern Hemisphere is tilted away from the sun at that time of year. As a result, it receives less direct and less intense solar radiation then.]

6. Where on Earth would Foucault's pendulum appear not to be moving? Where would it appear to be moving the most?

- [Foucault's pendulum would appear not to be moving at the equator. It would appear to be moving the most at the poles.]

7. The planet Jupiter is about 778,570,000 kilometers from the sun; Earth is about 150,000,000 kilometers from the sun. Does Jupiter take more or less time to make one revolution around the sun? Explain your answer.

- [Jupiter takes more time to make one revolution around the sun because its orbit is longer so it has to travel farther in each revolution than Earth.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What type of experiment could you create to prove that Earth is rotating on its axis?

- [You could set a pendulum in motion and observe how it appears to move because Earth is rotating under it.]

If you lived at the equator, would you experience any effects because of Earth's tilted axis?

- [No; the lengths of day and night would be about the same year-round and temperatures would also be much the same year-round. Therefore, there would be no seasons (except in some places wet and dry seasons).]

If Earth suddenly increased in mass, what might happen to its orbit around the sun?

- [If Earth suddenly increased in mass, its gravity would be stronger so its orbit might move closer to the sun.]

Would life on Earth be impacted if Earth lost its magnetic field?

- [Yes; some organisms use Earth's magnetic field for orientation, so if Earth lost its magnetic field they might lose their sense of direction.]

Why are the inner planets spherical?

- [The inner planets are spherical because they have enough gravity to pull their matter into a rounded shape.]

24.3 Lesson 24.2: Earth's Moon

Key Concepts

- Lunar characteristics
- Surface of the moon
- Interior of the moon

Lesson Objectives

- Explain how scientists think the moon formed.
- Describe the features of the moon.

Lesson Vocabulary

- **crater:** bowl-shaped depression on the surface of the moon caused by the impact of a meteorite
- **lunar:** of or relating to the moon
- **maria:** dark-colored flat areas on the moon's surface that are made up of ancient basaltic lava
- **terrae:**light-colored highlands on the moon's surface

Teaching Strategies

Introducing the Lesson

At the URL below, you can find exciting new discoveries about the moon made by NASA's Lunar Reconnaissance Orbiter. Share some of the most interesting discoveries with students, and then tell them they will learn more about the moon when they read this lesson.

http://www.space.com/21-10-coolest-moon-discoveries.html

Activity

Students can learn more about the lunar surface and the Apollo Mission by doing the activity "Apollo Landing Sites" at the following URL (pages 43–46). In the activity, students will learn about the locations and geology of the six Apollo landing sites. The URL includes both student and teacher pages, with background information, an Apollo landing sites data chart, and ideas for extension.

http://www.nasa.gov/pdf/58199main_Exploring.The.Moon.pdf

Differentiated Instruction

Suggest that students make a Venn diagram to compare and contrast the near and far sides of the moon. They might compare them in terms of surface features, thickness of the crust, and visibility from Earth.

Enrichment

Encourage students to view and write a review of the award-winning science fiction film "Moon," which was directed by Duncan Jones (2009). The movie is set on the moon. For the look of the lunar exteriors, the filmmakers relied on the amazing collection of NASA photos from the Apollo missions, which show the moon both from space and from its surface.

Science Inquiry

In the activity "Moon Anomalies" on pages 91–98 in the following document, students will develop hypotheses to explain four anomalies of the moon. They will be expected to prepare written and oral presentations. Then, using a forum format, students will debate the merits of each hypothesis.

http://www.nasa.gov/pdf/58199main_Exploring.The.Moon.pdf

Overcoming Misconceptions

There are several common misconceptions about the moon. Some of them are listed below. Read each misconception aloud, and call on students to state whether it is true or false. Call on other students to restate each misconception so it is true and then explain why each misconception is false. You can click on links to learn more about each misconception at this URL: http://moon.nasa.gov/moonmisconceptions.cfm

Misconception: The moon goes around Earth in a single day.
- **Reality**: It takes about a month for the moon to orbit Earth (27.3 days to complete a revolution, but 29.5 days to change from new moon to new moon).

Misconception: The moon makes its own light (the same way the sun does).
- **Reality**: The moon reflects the light of the sun, just as the planets do.

Misconception: The moon does not rotate.
- **Reality**: The moon does rotate, completing a rotation once every 27.3 days. The confusion may be caused by the fact that it also takes about the same amount of time for the moon to orbit the Earth. As a result, the same side of the moon always faces Earth.

Misconception: The same half of the moon is in darkness all the time, that is, there is a dark side of the moon.
- **Reality**: The moon has no side that is constantly dark. The moon's entire surface is eventually lit by the sun as the moon rotates on its axis. It's just that one side is always turned away from Earth. This side is more accurately called the far side because it is farther from Earth than the side we can see.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 24.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 24.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Compare the composition of the moon's surface with the composition of Earth's surface.

- [The moon's surface is composed of igneous rock. Earth's surface is composed of all three major types of rock, including sedimentary and metamorphic rock in addition to igneous rock.]

2. Why is there no weather on the moon?

- [There is no weather on the moon because the moon lacks an atmosphere.]

3. Rusting is a process that happens when oxygen reacts chemically with iron in the presence of water. Can rusting occur on the moon? Explain your answer.

- [No; rusting cannot occur on the moon because the moon does not have an atmosphere with oxygen in it.]

4. What is the difference between maria and terrae?

- [Maria are dark-colored flat areas on the moon's surface that are made up of ancient basaltic lava. Terrae light-colored highlands on the moon's surface.]

5. How does the moon's interior differ from Earth's?

- [The moon's interior actually resembles Earth's. Like Earth, the moon has a distinct crust, mantle, and core. The moon's core also consists mostly of iron like Earth's core.]

6. How much do landscape features on the moon change over time compared to landscape features on Earth? Explain your answer.

- [Landscape features on the moon remain unchanged for very long periods of time, whereas landscape features on Earth are constantly changing. The difference is due mainly to Earth's atmosphere, which causes weather and weathering. Weathering is always changing Earth's surface. Without an atmosphere, there is no weather on the moon and no weathering to change its surface. Earth is also geologically active, with volcanoes and other tectonic activities that change its landscape. The moon is no longer geologically active.]

7. Why is the force of gravity on your body weaker on the moon than on Earth?

- [The force of gravity is weaker on the moon than on Earth because the moon has less mass than Earth.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

What things would be different on Earth if Earth did not have a moon?

- [If Earth did not have a moon, its tides would be influenced only by the sun's gravity, so they would be weaker. There would also be no moonlit nights when reflected light from the moon lights up Earth's landscape.]

If the moon rotated on its axis once every 14 days, would we see anything different than we do now?

- [We would see the moon's entire surface. There would no longer be a far side of the moon that is always turned away from Earth.]

How do we know that the moon has been geologically inactive for billions of years?

- [We know the moon has been geologically inactive for billions of years because all the maria are older than that and they resulted from geologic activity.]

24.4 Lesson 24.3: The Sun

Key Concepts

- Layers of the sun
- Sunspots, solar flares, and solar prominences
- Solar Dynamics Observatory

Lesson Objectives

- Describe the layers of the sun.
- Describe the surface features of the sun.

Lesson Vocabulary

- **chromosphere:** thin layer of the sun's atmosphere that lies directly above the photosphere and glows red
- **convection zone:** layer of the sun that surrounds the radiative zone and through which energy moves by convection
- **corona:** outermost layer of the sun's atmosphere that consists of plasma and extends millions of kilometers into space
- **nuclear fusion:** nuclear reaction in which nuclei of atoms fuse to form a heavier element and release a huge amount of energy; source of the sun's energy
- **photon:** particle of light
- **photosphere:** visible surface of the sun
- **plasma:** high-energy, high-temperature state of matter that consists of charged ions instead of atoms
- **radiative zone:** layer of the sun surrounding the core where energy moves slowly by electromagnetic waves away from the core
- **solar flare:** violent explosion on the sun's surface
- **solar prominence:** plasma loop flowing between sunspots

Teaching Strategies

Introducing the Lesson

Use the short video at the URL below to introduce students to the sun and how it has been studied, starting with ancient observations of sunspots and continuing through current NASA missions such as SOHO that are studying the sun from space. Tell students they will learn more about the sun and what scientists have learned about it when they read this lesson.

http://www.jpl.nasa.gov/video/index.php?id=828

Demonstration

Students will have a better understanding of how the sun's magnetic field creates surface features on the sun if they watch the brief animation at the following URL. Using actual images of the sun from the SOHO mission, the animation shows how the sun's magnetic field winds up and loops out.

http://sohowww.nascom.nasa.gov/gallery/Movies/dynamo/dynamo_snd.mov

Activity

With the activity at the URL below, students will acquire solar images and record coordinates of sunspots. They will calculate and plot the apparent movement of sunspots and describe their shapes. They will determine whether sunspots are features on the surface of the sun as Galileo proposed when he first discovered sunspots, or objects in orbit around it as the early German astronomer Christoph Scheiner claimed. The latter view was more consistent with religious ideas about the infallibility of God and his creations. This activity is a good way to expose students to relationships between science and society and how scientific interpretations may be biased by the belief systems of scientists.

http://solar-center.stanford.edu/activities/galileo-sunspots.html

Differentiated Instruction

Use the visuals in the FlexBook® lesson to teach important lesson concepts to students with limited English or reading proficiency. Call students' attention to the relevant images as you discuss the sun's layers, atmosphere, and surface features. You can find additional useful images for this purpose at this URL: http://sohowww.nascom.nasa.gov/gallery/.

Enrichment

Ask one or more students to learn about the relationships among solar wind, Earth's magnetosphere, and the aurora that can often be viewed from Earth's surface. Then have them present an explanation for the relationship to the class. The excellent NASA animation at the first URL below is a good visual for them use when they give their presentation.

http://sohowww.nascom.nasa.gov/gallery/Movies/animation/Solarwind.mpg

Science Inquiry

With the inquiry activity at the URL below, students can use real NASA images to observe and track sunspots. Then they can use the sunspot data to determine the rate of the sun's rotation.

http://sohowww.nascom.nasa.gov/classroom/docs/Spotexerweb.pdf

Overcoming Misconceptions

Some people think that recent global warming is caused by the sun. Tell the class that scientists know the sun is not responsible for global warming. How do they know? The output of energy from the sun has been monitored by satellites for thirty years and has not increased during this period of rapid global warming.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 24.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 24.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. In what way does the sun support all life on Earth?

   - [The sun provides light that virtually all producers need for photosynthesis, the process in which producers produce food for themselves and all other organisms.]

2. Which two elements make up the sun almost in entirety?

   - [The sun is made up almost entirely of the two elements hydrogen and helium.]

3. Which process is the source of heat in the sun and where does it take place?

   - [Nuclear fusion is the source of heat in the sun. It takes place in the sun's core.]

4. Why would human astronauts on a trip to Mars need to be concerned about solar wind? What is solar wind?

   - [Astronauts would need to be concerned about solar wind because it consists of high-speed protons and electrons that fly through the solar system from the sun. Solar wind extends millions of kilometers out into space and could reach astronauts on a trip to Mars. In a spaceship beyond Earth's magnetic field, the astronauts would not be protected from the harmful high-speed particles in solar wind.]

5. Describe how movements in the convection zone contribute to solar flares.

   - [In the convection zone, hot material from near the radiative zone rises, cools at the sun's surface, and then plunges back down to the radiative zone. As heat and electrically charged particles reach the Sun's surface, they can flow along lines of the Sun's magnetic field. If those lines of force snap and break, it produces a solar flare.]

6. Do you think fusion reactions in the sun's core will continue forever and go on with no end? Explain your answer.

   - [Answers may vary. *Sample answer*: I think that the fusion reactions will come to an end when all of the lighter elements in the sun have fused to form heavier elements so there is no fuel left for continued fusion reactions.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

If something were to suddenly cause nuclear fusion to stop in the sun, how would we know? When would we know?

- [We would know because the sun would stop producing radiation. However, we would not know for millions of years because it takes that long for energy from nuclear fusion to reach the surface of the sun.]

Are there any types of dangerous energy from the sun? What might be affected by them?

- [The sun gives off energy in all wavelengths of the electromagnetic spectrum, including dangerous UV radiation, X-rays, and gamma rays. Living things on Earth would be harmed by these types of energy from the sun were it not for Earth's atmosphere, which absorbs most of the harmful radiation. Solar wind is also dangerous energy from the sun. It consists of streams of high-energy particles from solar flares. It can damage spacecraft and harm astronauts. It can even cause damage on Earth. For example, it can knock out entire power grids and disturb radio, satellite, and cell phone communications.]

If the sun is made of gases such as hydrogen and helium, how can it have layers?

- [The layers differ in terms of energy and how it travels but do not have distinct borders.]

24.5 Lesson 24.4: The Sun and the Earth-Moon System

Key Concepts

- Day-night cycle
- Earth's seasons
- Solar eclipses
- Lunar eclipses
- Phases of the moon
- Earth's tides

Lesson Objectives

- Describe how Earth's movements affect seasons and cause day and night.
- Explain solar and lunar eclipses.
- Describe the phases of the moon and explain why they occur.
- Explain how movements of Earth and the moon affect Earth's tides.

Lesson Vocabulary

- **crescent moon:** phase of the moon in which the near side of the moon appears to be less than half lit; occurs between the new moon and the first or third quarter
- **gibbous moon:** phase of the moon in which the near side of the moon appears to be more than half lit; occurs between the full moon and the first or third quarter
- **lunar eclipse:** event in which Earth casts a shadow on the moon so the moon cannot be seen from anywhere on Earth
- **penumbra:** outer part of a shadow where light is only partly blocked
- **shadow:** darkness that occurs where a light source is blocked
- **solar eclipse:** event in which the moon casts a shadow on Earth so the sun cannot be seen from the area on Earth's surface where the shadow falls
- **umbra:** inner part of a shadow where light is completely blocked

Teaching Strategies

Introducing the Lesson

Write the term harvest moon on the board, and ask students if they know what it means. (They are unlikely to know the precise definition if they have any idea at all of its meaning.) Explain that the harvest moon occurs each fall

and is defined as the full moon closest to the autumnal equinox. In the Northern Hemisphere, it usually occurs in September or sometimes in October. Add that around the time of the harvest moon, there is a shorter-than-usual time between moonrises for several days in succession. This means shorter periods of complete darkness between sunset and moonrise. The harvest moon no doubt gets its name from the days before artificial lighting when the light of the harvest moon helped farmers harvest their crops. Tell students they will learn more about the full moon and other phases of the moon when they read this lesson.

Demonstration

Use the teen-oriented video from NASA at the following URL to explain to students how solar eclipses occur.

http://www.neok12.com/php/watch.php?v=zX767b534f7e076a05736267&t=Eclipse

Differentiated Instruction

Use the short video at the first URL below to show students how a lunar eclipse occurs. This is a good way to explain the phenomenon to visual learners, less proficient readers, and English language learners. Following the video, have students label the interactive lunar eclipse diagram at the second URL to assess their comprehension.

http://www.neok12.com/php/watch.php?v=zX027e52507b754877644063&t=Eclipse

http://www.neok12.com/diagram/Eclipse-01.htm

Enrichment

Challenge a few creative students to make a three-dimensional model of the sun-Earth-moon system and use it to explain to the rest of the class what causes the monthly cycle of moon phases.

Science Inquiry

In the activity at the following URL, students will learn how the moon and the sun affect ocean tides. They will also use the Internet to gather current regional tidal information, graph the tidal data, and interpret the graphs.

http://www.sitesalive.com/oil/tg/private/oiltgtides.html

Overcoming Misconceptions

A common misconception is that the moon appears in different phases in different parts of the world on the same day. Explain to students that everyone on Earth sees the same phases of the moon at the same time. Draw a simple sketch on the board to be sure students understand why this is the case, or use the diagram at this URL: http://www.windows2universe.org/the_universe/uts/moon2.html.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 24.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 24.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. The globe is divided into time zones, so that any given hour of the day in one time zone occurs at a different time in other time zones. For example, New York City is in one time zone and Los Angeles is in another time zone. When it is 8:00 a.m. in New York City, it is only 5:00 a.m. in Los Angeles. Explain how Earth's motions cause this difference in times.

- [Earth's rotation on its axis explains why places that are far apart are in different time zones. The sun comes up over the horizon earliest on the East Coast, and as Earth rotates, the sun comes up over the horizon farther and farther west.]

2. Explain how Earth's tilt on its axis accounts for seasons on Earth.

- [During summer in the Northern Hemisphere, the Northern Hemisphere is tilted toward the sun, so the sun's rays strike the surface more directly and temperatures are warmer than at other times of year. In the Southern Hemisphere at that time, the opposite is happening. The Southern Hemisphere is tilted away from the sun, so the sun's rays strike the surface less directly and temperatures are cooler than at other times of years. Therefore, it is winter in the Southern Hemisphere when it is summer in the Northern Hemisphere.

3. Explain how the positions of Earth, the moon, and the sun vary during a solar eclipse and a lunar eclipse.

- [A solar eclipse occurs when the moon passes between the sun and Earth and casts a shadow on Earth. A lunar eclipse occurs when Earth passes between the sun and the moon and casts a shadow on the moon.]

4. Draw a picture that shows how Earth, the moon, and the sun are lined up during the new moon phase.

- [Pictures may vary. However, the moon should be located directly between the sun and Earth, and the near side of the moon should appear black from Earth.]

5. Why are neap tides less extreme than spring tides?

- [Neap tides occur when the moon is in the first or third quarter phase and at right angles to the axis between the sun and Earth. This causes the moon and the sun to pull on Earth's waters at right angles to each other. The result is tides that have the least difference between high and low tides. Spring tides occur when the moon is new or full and lined up on the same axis as the sun and Earth. This causes the moon and the sun to pull on Earth's water in the same direction. The result is tides that have the greatest difference between high and low tides.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Why don't eclipses occur every single month at the full and new moons?

- [Eclipses occur only when the sun, the moon, and Earth are all in the same plane, called the ecliptic, which is the plane of Earth's orbit around the sun. This doesn't occur every single month.]

The planet Mars has a tilt that is very similar to Earth's. What does this produce on Mars?

- [This produces seasons on Mars. When it is summer in the Northern Hemisphere on Mars, it is winter in the Southern Hemisphere, and vice versa.]

Venus comes between Earth and the sun. Why don't we see an eclipse when this happens?

- [Earth is too far from Venus for Venus to cast a shadow on Earth's surface.]

CHAPTER 25 HS TE The Solar System

Chapter Outline

25.1 Chapter 25: The Solar System

Chapter Overview

This chapter discusses the motion of the planets and the formation of the solar system. It also describes the inner and outer planets, dwarf planets, meteoroids, asteroids, and comets.

Online Resources

See the following Web sites for appropriate laboratory activities:

The simulation lab at the following URL focuses on gravity and planetary orbits. It is a virtual inquiry lab that will help students gain an intuitive understanding of how planetary orbits are affected by orbital velocity and the presence of other gravity-producing objects besides the sun.

- http://phet.colorado.edu/en/contributions/view/3260

In the lab "Looking Inside Planets" (see Lesson 3 in the PDF document below), students will make scale models of the interiors of the planets and compare them. They will see that the structures of the four inner planets are similar to each other, as are the structures of the four outer planets. They will also discover that the outer planets have rocky cores that are similar in size to Earth.

- http://solarsystem.nasa.gov/docs/modelingsolarsystem_20070112.pdf

In the lab at the following URL, students will observe the differences in thermal behavior between similar materials having different physical properties by making a series of temperature measurements and plotting the results. This will allow students to understand how scientists remotely determine the composition of an object in outer space, in particular how they learn about distant planets in the solar system through remote sensing of thermal properties.

- http://solarsystem.nasa.gov/educ/docs/Sand_Or_Rock.pdf

These Web sites may also be helpful:

The following URL is an excellent series of more than 80 PowerPoint slides that you can use throughout the teaching of this chapter. It covers all of the planets and other objects in the solar system.

- http://www.lpi.usra.edu/education/resources/s_system/solar_sys_overview.ppt

Links to several recommended videos about the solar system can be found at the first URL below. Links to several exceptional Web sites with information, images, and other resources about the solar system can be found at the second URL below. The third URL is a large collection of three-dimensional images of planets and moons that were taken from NASA spacecraft.

- http://www.lpi.usra.edu/education/skytellers/solar_system/audio_video.shtml

- http://www.lpi.usra.edu/education/skytellers/solar_system/web_sites.shtml
- http://www.lpi.usra.edu/publications/slidesets/3dsolarsystem/3d_index.shtml

You can find several solar system activities at this URL: http://hea-www.harvard.edu/ECT/the_book/Chap5/Chapter5.html.

You can access many teacher-reviewed videos about the solar system and individual planets at this URL: http://www.neok12.com/Solar-System.htm.

Pacing the Lessons

TABLE 25.1: short caption

Lesson	Class Period(s) (60 min)
25.1 Introduction to the Solar System	2.0
25.2 Inner Planets	2.0
25.3 Outer Planets	1.5
25.4 Other Objects in the Solar System	1.5

25.2 Lesson 25.1: Introduction to the Solar System

Key Concepts

- Geocentric and heliocentric models
- Exoplanets
- Planetary orbits
- Formation of the solar system

Lesson Objectives

- Describe historical views of the solar system.
- Name the planets, and describe their motion around the sun.
- Explain how the solar system formed.

Lesson Vocabulary

- **geocentric model:** early model of the universe that placed Earth at the center and placed other celestial bodies in spheres surrounding Earth
- **heliocentric model:** model proposed by Copernicus that placed the sun at the center of the solar system and placed Earth and the other planets in orbits around the sun
- **moon:** celestial object that orbits a planet
- **nebula:** interstellar cloud of gas and dust
- **nebular hypothesis:** hypothesis that the solar system formed from a spinning cloud of dust and gas
- **solar system:** star such as the sun and all of the planets and other objects that revolve around it due to gravity

Teaching Strategies

Introducing the Lesson

Introduce the solar system with the short video about the solar system at the following URL. After the video, tell students they will learn more about the solar system when they read this chapter.

http://www.neok12.com/php/watch.php?v=zX54554e5c047a4e7d077d41&t=Solar-System

Demonstration

Use the excellent series of PowerPoint slides at the URL below when you teach students about the formation of the solar system. It include vivid visuals from NASA and offers a detailed explanation of how the solar system formed.

http://www.lpi.usra.edu/education/resources/s_system/solar_sys_formation.ppt

Building Science Skills

The interactive animation at the following URL shows two important features of orbits: shape and size. Students will experiment with the shape and size of a hypothetical planet's orbit and in the process learn about ellipses, including eccentricity and semi-major axes.

http://www.windows2universe.org/physical_science/physics/mechanics/orbit/orbit_shape_interactive.html

Differentiated Instruction

Students can reinforce their knowledge of the names and order of planets in the solar system with the drag-and-drop activity at the following URL. This is a good exercise for kinesthetic and visual learners.

http://scoilnet.magicstudio.ie/interactive/view/11630?from=search&return_to=%2Frepository%2Fbrowse%3Fsearch_-text%3Dsun

Enrichment

Students may be surprised to learn that ideas about extrasolar planets extend back to ancient Greece. They can learn more about the history of these ideas, as well as the long quest for extrasolar planets, with the interactive animated timeline at the first URL below. At the second URL, students can create their own extrasolar planet with the interactive activity "Extreme Planet Makeover."

http://planetquest.jpl.nasa.gov/system/interactable/2/timeline.html

http://planetquest.jpl.nasa.gov/system/interactable/1/index.html

Science Inquiry

Have students do the activity "Modeling Planets," which is Lesson 2 at the URL below. Students will learn the relative sizes and order of the planets while making a scale model of the solar system using common food items. They will also calculate gravity on planetary surfaces and determine the densities of planets. In addition, they will learn how the density of planets relates to the proportions of different components they contain.

http://solarsystem.nasa.gov/docs/modelingsolarsystem_20070112.pdf

Overcoming Misconceptions

Students commonly think that the solar system is crowded, that is, that planets are much closer together than they actually are. In fact, the distance between planets and between planets and the sun is tremendous. The best way to overcome this misconception is to relate interplanetary distances to distances with which students are familiar. Tell them, for example, that if Earth were the size of a baseball, the distance between Earth and the sun would be about half a mile.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 25.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 25.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What does geocentric mean?

- [Geocentric means "Earth-centered."]

2. Describe the geocentric model and heliocentric model of the universe.

- [The geocentric model was an early model of the universe. In this model, Earth is at the center of the universe, and other celestial bodies are located on spheres surrounding Earth. The heliocentric model was proposed by Copernicus. In this model, the sun is at the center of the solar system, and Earth and the other planets in orbit around it.]

3. How was Kepler's version of the heliocentric model different from Copernicus'?

- [In Kepler's version, the orbits of the planets are elliptical. In Copernicus' version, the orbits are circular.]

4. Name the eight planets in order from the sun outward. Which are the inner planets and which are the outer planets?

- [From the sun outward, the eight planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The first four planets are the inner planets, and the remaining four planets are the outer planets.]

5. Compare and contrast the inner planets and the outer planets.

- [All of the inner planets are relatively small. They are also solid, dense, and rocky. None has rings or many moons. The outer planets are farther from the sun than the inner planets and also much larger. They are made mostly of gases, and all of them have rings and numerous moons.]

6. What object used to be considered a planet but is now considered a dwarf planet? What are the other dwarf planets?

- [Pluto used to be considered a planet but is now considered a dwarf planet. Other dwarf planets are Ceres, Makemake, Eris, and Haumea.]

7. What keeps planets and moons in their orbits?

- [Gravity keeps planets and moons in their orbits.]

8. How old is the solar system? How old is Earth?

- [The solar system and Earth are about 4.6 billion years old.]

9. Use the nebular hypothesis to explain why the planets all orbit the sun in the same direction.

- [According to the nebular hypothesis, the sun, planets, and other objects in our solar system formed from a nebula. A nebula is a spinning cloud of gas and dust. The planets formed from clumps of dust circling around the sun in the center. This would explain why the planets all orbit the sun in the same direction.]

{{Todo | DANA - Comment from JB for question 6: The SE lesson says there are only three dwarf planets: Ceres, Pluto, and Eris.

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Would you expect all the planets in the solar system to be made of similar materials? Why or why not?

- [If the solar nebular hypothesis is correct, then all of the objects in the solar system formed from the same spinning cloud of gas and dust. Therefore, you would think that all of the planets would be made of similar materials. However, the planets closest to the sun were more affected by its gravity and formed from heavier elements such as the metal iron, whereas the more distant planets were less affected by its gravity and formed mainly from hydrogen and helium gases.]

The planets are often divided into two groups: the inner planets and the outer planets. Which planets do you think are in each of these two groups? What do members of each group have in common?

- [The inner planets are the four planets closest to the sun: Mercury, Venus, Earth, and Mars. All of the inner planets are relatively small. They are also solid, dense, and rocky. None has rings or many moons. The outer planets are the remaining four planets: Jupiter, Saturn, Uranus, and Neptune. The outer planets are farther from the sun than the inner planets and also much larger. They are made mostly of gases, and all of them have rings and numerous moons.]

25.3 Lesson 25.2: Inner Planets

Key Concepts

- Earth
- Mercury
- Venus
- Mars

Lesson Objectives

- Describe key features of each of the inner planets.
- Compare each of the inner planets to Earth and to one another.

Lesson Vocabulary

- **day:** amount of time it takes for a planet to complete one rotation on its axis
- **inner planet:** one of the four planets closest to the sun; Mercury, Venus, Earth, or Mars
- **terrestrial planet:** Earth or any of the other three Earth-like planets (Mercury, Venus, or Mars) that are solid, dense, and rocky
- **year:** amount of time it takes for a planet to complete one revolution around the sun

Teaching Strategies

Introducing the Lesson

Introduce the inner, or terrestrial, planets by asking students to recall from the previous chapter ("Earth, Moon, and Sun") some of the most salient characteristics of planet Earth. Encourage a diversity of responses and list on the board any characteristics they name that are shared with the other inner planets. Tell students they will learn in this lesson about the planets in the solar system that resemble Earth in these ways.

Cooperative Learning

Students can collaborate to learn more about the inner planets by creating an illustrated booklet about them. Divide the class into four groups and assign each group one of the four inner planets. Within groups, each student should assume responsibility for finding one category of information (e.g., size, mass, and distance from the sun; atmosphere and temperature range; interior layers and composition; surface features; unique properties; and so on), as well as related images, about that planet. Then students within the group should collaborate to assemble all of the

information and images and create their booklet. Arrange a display of the booklets in the classroom, and encourage students to examine the booklets created by other groups. Some suitable sources for information and images include:

- http://nineplanets.org/
- http://www.neok12.com/Solar-System.htm
- http://airandspace.si.edu/research/resources/rpif/index.cfm

Activity

Have students do the activity "Find that Planet!" at the URL below. By doing the activity, they will learn about the celestial coordinate system that astronomers use to identify the locations of objects in space. Students will use the instructions provided to determine the position of a planet at a certain time and date. Then they will plot that position on an appropriate sky map, choosing from a set provided. The final step is for students to actually find the planet in the night sky using the sky map.

http://cse.ssl.berkeley.edu/SegwayEd/lessons/FindPlanets/Find-hmpg2.html

Differentiated Instruction

The four inner planets share certain similarities, but they also differ from one another in many important ways. To help students sort out the similarities and differences, have them make a compare/contrast table for the inner planets. They might compare them in terms of size, mass, distance from the sun, moons, atmosphere, temperature, and other properties.

Enrichment

Mars has been the object of several space missions, in part because it seems to be the most suitable planet in our solar system for life to have evolved. Suggest that students who want to learn more about Mars missions go to the URL below. They will find a plethora of information about Mars and its exploration, ranging from Mars in pop culture to the technology behind the Mars rovers. Encourage them to share the most interesting information they learn from the site with the rest of the class in a brief oral report.

http://mars.jpl.nasa.gov/

Science Inquiry

Have students do the inquiry activity "Search for a Habitable Planet," which is Lesson 4 in the following PDF document. Students will define the life requirements of a variety of organisms and learn that these relate to measurable characteristics of planets the organisms might inhabit. By evaluating these characteristics, students will discover that Earth is the only natural home for us in our solar system and that Mars is the next most likely home for life as we know it.

http://solarsystem.nasa.gov/docs/modelingsolarsystem_20070112.pdf

Overcoming Misconceptions

Students commonly think that planets are too far away or too dim to be visible from Earth without a telescope. In fact, five planets (other than Earth) are visible with the unaided eye: Mercury, Venus, Mars, Jupiter, and Saturn. These planets are visible in our sky because they reflect sunlight and shine with a steadier light than distant twinkling stars. In fact, the five planets tend to be quite bright. Tell students to read the article and view the images at the following URL to see how clearly visible the planets can be.

http://earthsky.org/astronomy-essentials/visible-planets-tonight-mars-jupiter-venus-saturn-mercury#visible-planet

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 25.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 25.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Name the inner planets from the sun outward. Then name them from smallest to largest.

- [From the sun outward, the inner planets are Mercury, Venus, Earth, and Mars. From smallest to largest, they are Mercury, Mars, Venus, and Earth.]

2. Why do the temperatures on some planets vary widely? Why are some temperatures much less variable?

- [Planets with an atmosphere have a greenhouse effect that makes temperatures less variable. Planets without an atmosphere or with a very thin atmosphere do not have a greenhouse effect to moderate temperatures. On these planets, temperatures are much more variable.]

3. Why does Venus have higher temperatures than Mercury?

- [Venus has higher temperatures than Mercury because it has a very thick atmosphere and a strong greenhouse effect. Mercury is closer to the sun than Venus so it is very hot during the day. However, Mercury has very little atmosphere to hold in heat at night, so it gets very cold on the side turned away from the sun.]

4. How are maps of Venus made?

- [Maps of Venus are made using radar to penetrate the thick atmosphere.]

5. Name two major ways in which Earth is unlike any other planet.

- [Earth is unlike any other planet in having oxygen in its atmosphere and liquid water on its surface.]

6. Why is Mars red?

- [Mars is red because of large amounts of iron oxide in its soil.]

7. Suppose you are planning a mission to Mars. Identify two places where you might be able to get water on the planet. Why is this important?

- [You might be able to get water at a pole by melting ice from the polar ice cap. You also might be able to find liquid water beneath the surface. This is important because it means that life possibly could have evolved on Mars.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

The first humans may reach Mars sometime in the next few decades. What conditions will they face? Why do you think we are going to Mars instead of Mercury or Venus?

- [On Mars, humans will face a cold, dry planet. They will need to protect themselves from the cold. They will also need protection from dangerous solar radiation because the atmosphere is thin. The atmosphere has low pressure and consists mainly of carbon dioxide, so humans will need oxygen tanks to help them breathe. We are going to Mars because it is most similar to Earth in many ways and one of the most likely places in the solar system for life to have evolved.]

Why are the four inner planets called terrestrial planets? What might a planet be like if it weren't a terrestrial planet?

- [The four inner planets are called terrestrial planets because they are similar to Earth and terrestrial means "Earth-like." For example, they are all small and made of solid rock. If a planet weren't a terrestrial planet, it might be large and made of gas.]

25.4 Lesson 25.3: Outer Planets

Key Concepts

- Jupiter
- Saturn
- Uranus
- Neptune

Lesson Objectives

- Describe key features of the outer planets and their moons.
- Compare the outer planets to each other and to Earth.

Lesson Vocabulary

- **Galilean moons:** Jupiter's four largest moons, which were discovered by Galileo
- **gas giant:** one of the four outer planets, which are composed mainly of the gases hydrogen and helium
- **Great Red Spot:** enormous, oval-shaped, long-lasting storm visible on Jupiter
- **outer planet:** one of the four planets that are located beyond the asteroid belt in the solar system; Jupiter, Saturn, Uranus, or Neptune
- **planetary ring:** ring of dust, rock, and/or other materials encircling a planet in a thin plane

Teaching Strategies

Introducing the Lesson

Introduce the outer planets by playing a guessing game called "Which planet am I?" Give students the following facts about Jupiter and challenge them to guess which planet it is. After the game, tell students they will learn more about Jupiter and the other outer planets when they read this lesson.

- I am the fastest-spinning planet in the solar system.
- I have rings that surround me.
- If you were to stand on my surface, you would weigh 14 times as much as you do on Earth.
- I have 63 moons, including one that is the largest moon in the solar system.
- I have been visited seven times by spacecraft from Earth.
- You can see me from Earth without a telescope.
- I am 2.5 times as massive as all of the other planets in the solar system combined.

Cooperative Learning

Have students do a collaborative, outer planets four-page Web site project to learn about the four planets that are farthest from the sun. Divide the class into four groups, and assign each group one of the four outer planets. Students within each group should work together to create an informative, illustrated Web page about their planet, including its unique features. These URLs are useful resources for this project:

- http://nineplanets.org/
- http://www.neok12.com/Solar-System.htm
- http://airandspace.si.edu/research/resources/rpif/index.cfm

Differentiated Instruction

Students will have a better understanding of what sets the outer planets apart from the inner planets if they make a Venn diagram comparing and contrasting the two sets of planets.

Enrichment

Suggest that students who are interested in space exploration learn about the Cassini Mission to Saturn. Cassini was designed to explore the Saturnian system from orbit: the planet and its atmosphere, rings and magnetosphere, and its moons, particularly Titan and the icy satellites. Cassini also carried Europe's Huygens probe to its rendezvous with Titan. Students can learn more about the Cassini Mission at the following URLs. After their research, ask them to share what they learn in a PowerPoint presentation to the class.

- http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Cassini
- http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Cassini&Display=ReadMore
- http://saturn.jpl.nasa.gov/

Science Inquiry

In the inquiry activity at the URL below (which was written for high school students in addition to middle school students), students will investigate how the density of Jupiter's moons is related to their diameter and their distance from Jupiter.

http://lasp.colorado.edu/education/outerplanets/lessons/grades6-8/The%20Moons%20of%20Jupiter.pdf

Science Inquiry

Another inquiry activity about Jupiter's moons is available at the following URL. In this activity, students will apply the scientific method and do a simplified version of Galileo's pioneering observations of Jupiter's moons. They will look at data showing the positions of the moons of Jupiter over nine nights and follow the motions of each moon to determine its orbital period around Jupiter.

http://www.astrosociety.org/edu/slooh/footsteps.pdf

Overcoming Misconceptions

Students may erroneously think that the gas giants are nothing but balls of gas so a spacecraft could fly right through them. Make sure students realize that the gas giants actually have rocky cores of heavier elements. Only their outer layers consist of gas. A good way to overcome the misconception is by sharing the diagram at the URL below, which

shows the layers of the gas giants. The diagram also shows how large the gas giants are compared with planet Earth (in the upper right corner of the diagram). Point out how the inner cores of the two largest gas giants are similar in size to Earth.

http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=166

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 25.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 25.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Name the outer planets a) in order from the sun outward, b) from largest to smallest by mass, and c) from largest to smallest by size.

- [a) From the sun outward, the outer planets are Jupiter, Saturn, Uranus, and Neptune; b) from largest to smallest by mass, they are Jupiter, Saturn, Neptune, and Uranus; c) from largest to smallest by size, they are Jupiter, Saturn, Uranus, and Neptune.]

2. Why are the outer planets called gas giants?

- [The outer planets are called gas giants because they are much larger in diameter than the inner planets and are composed mainly of gases rather than solid rock like the inner planets.]

3. How do the Great Red Spot and Great Dark Spot differ?

- [Jupiter's Great Red Spot is an enormous storm that has existed for at least 300 years. Neptune's Great Dark Spot is thought be to a gap in Neptune's methane clouds that lasted less than a decade.]

4. Name the Galilean moons, and explain why they have that name.

- [The Galilean moons are Io, Europa, Ganymede, and Callisto. They are called Galilean moons because they were discovered by Galileo.]

5. Why might Europa be a likely place to find extraterrestrial life?

- [Europa may have an ocean of liquid water beneath its surface ice. It also has a constant source of energy. It is heated by changes in its shape due to tidal forces from Jupiter.]

6. What causes gaps in Saturn's rings?

- [Gaps in Saturn's rings were cleared out by the gravity of moons inside the rings or by the competing gravity of Saturn and its moons outside the rings.]

7. Why are scientists interested in the atmosphere of Saturn's moon Titan?

- [Scientists are interested in Titan's atmosphere because they think it is like Earth's atmosphere before life evolved on Earth.]

8. What liquid is found on the surface of Titan?

- [Lakes of liquid methane and ethane are found on Titan's surface.]

9. Why is Uranus blue-green in color?

- [Uranus is blue-green in color because clouds of methane filter out red light when sunlight reflects off Uranus.]

10. What is the name of Neptune's largest moon?

- [Neptune's largest moon is named Triton.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

The inner planets are small and rocky, while the outer planets are large and gaseous. Why might the planets have formed into these two groups?

- [The inner planets are closer to the sun, so they experienced greater gravity from the sun and formed from heavier elements such as the metal iron. Lightweight helium and hydrogen gases were not pulled as close by the sun's gravity and formed the more distant outer planets.]

We have discussed the sun, the planets, and the moons of the planets. What other objects can you think of that can be found in our solar system?

- [Other objects in our solar system include meteoroids, asteroids, comets, and dwarf planets.]

25.5 Lesson 25.4: Other Objects in the Solar System

Key Concepts

- Asteroids
- Meteoroids
- Comets
- Dwarf planets

Lesson Objectives

- Locate and describe the asteroid belt.
- Explain where comets come from and what causes their tails.
- Differentiate between meteors, meteoroids, and meteorites.

Lesson Vocabulary

- **asteroid:** small, irregularly shaped rocky body that orbits the sun, typically in a belt of asteroids located between the orbits of Mars and Jupiter
- **asteroid belt:** region between the orbits of Mars and Jupiter where the majority of asteroids are located
- **comet:** small icy, dusty object with a bright tail that orbits the sun
- **dwarf planet:** celestial body orbiting a star that meets all the criteria of a planet except that it has not cleared its orbit of other objects
- **Kuiper belt:** region of the solar system beyond the orbit of Neptune that contains millions of frozen objects
- **meteor:** chunk of rock from space that burns up as it passes through Earth's atmosphere
- **meteor shower:** event in which many meteors fall through the atmosphere because Earth passes through a cluster of meteoroids
- **meteoroid:** small rock in interplanetary space that has not entered Earth's atmosphere

Teaching Strategies

Introducing the Lesson

Show students the animation at the following URL without telling them what it represents. Ask them if they can identify what it shows. (They are likely to recognize the sun and the nearly circular orbit of a terrestrial planet such as Earth, but they may not recognize the highly elliptical orbit of the comet.) Point out the tail of the comet when it is close to the sun, and tell students this is a strong hint as to what it is. If need be, tell them that the object represents a comet orbiting the sun. Add that they will learn in this lesson about comets and other non-planetary objects that orbit the sun.

http://www.st-andrews.ac.uk/ bds2/ltsn/ljm/JAVA/COMETORB/orbit.gif

Cooperative Learning

Divide the class into groups, and assign each group one of the non-planetary objects that orbits the sun: meteoroids, asteroids, comets, and the individual dwarf planets. Tell students within groups to become "experts" on their orbiting bodies. Then have each group create an illustrated poster to share their expert knowledge. Urge them to make their posters eye-catching and creative and to include information beyond what is found in the FlexBook® lesson. Give each group an opportunity to present its poster to the class, and then display the posters in the classroom.

Differentiated Instruction

Give students copies of a simple solar system diagram showing only the sun and planets (see URLs below for samples). Then ask students to add labeled sketches to the diagram to represent the following: asteroid belt (between Mars and Jupiter), Kuiper belt (beyond Neptune's orbit), and Oort cloud (beyond the Kuiper belt). They should also add a few words to each sketch to indicate the type of orbiting bodies found there.

- http://upload.wikimedia.org/wikipedia/commons/0/0c/Quad-solarsystem_BD%E2%88%9222_5866.jpg
- http://amazingspacepictures.info/diagram-of-the-solar-system.html

Enrichment

Ask students who are especially interested in space exploration to learn about careers in space science. The following URLs are good sources of information. They should address such questions as: What are some specific careers in space science? What types of work do space scientists do? Where are space scientists employed? What educational background is required? Have the students choose the career that most interests them and report on it to the class. Ask them to explain why they are most interested in that career.

- http://www.nasa.gov/audience/forstudents/postsecondary/career/
- http://jobs.lovetoknow.com/Careers_in_Space_Science
- http://sciencenetlinks.com/blog/snl-educator/careers-space-science-not-just-astronauts/

Science Inquiry

Have students do the inquiry activity "Comparing Comets" at the following URL. In the activity, students will play the role of cometary scientist by observing and comparing the surfaces of two comet nuclei. They will propose possible causes for the differences between the two nuclei and list questions they have about them.

http://epoxi.umd.edu/pdfs/Comparing_Comets_SA.pdf

Overcoming Misconceptions

Students may have the misconception that when a meteor shower occurs, meteors pour out of the sky like raindrops. Explain that a meteor shower is nothing like this. In a typical meteor shower, you are unlikely to see more than a few dozen meteors per hour. During the best meteor displays, the maximum rate of meteors might be about one per minuteexactly a downpour!

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 25.4 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 25.4 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. Arrange the following from smallest to largest: asteroid, star, meteoroid, planet, dwarf planet.

   - [In general, from smallest to largest the bodies are meteoroid, asteroid, dwarf planet, planet, and star.]

2. Where are most asteroids found?

   - [Most asteroids are found in the asteroid belt, which is located between the orbits of Mars and Jupiter.]

3. What is the difference between a meteor, a meteoroid, and a meteorite?

   - [A meteoroid has not yet entered Earth's atmosphere. A meteor is burning up as it passes through Earth's atmosphere. A meteorite is what's left of a meteor that doesn't burn up completely and has struck Earth's surface.]

4. Why are meteorites extremely valuable to scientists?

   - [Meteorites provide clues about our solar system because many come from asteroids that formed when the solar system formed.]

5. What objects would scientists study to learn about the composition of the Oort cloud?

   - [To learn about the composition of the Oort cloud, scientists would study long-period comets because they originate in the Oort cloud.]

6. Why is Pluto no longer considered a planet?

   - [Pluto is no longer considered a planet because it has not cleared its orbit of other objects. It is now considered a dwarf planet.]

7. Name the four known dwarf planets in our solar system.

   - [In addition to Pluto, dwarf planets include Ceres, Makemake, Eris, and Haumea.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.4 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

In 2006, astronomers changed the definition of a planet and created a new category of dwarf planets. Do you think planets, dwarf planets, moons, asteroids, and meteoroids are clearly separate groups?

- [Some of these categories are well defined. For example, planets and dwarf planets are clearly separate groups because they share the same criteria except that planets must have cleared their orbits of other bodies. If they haven't, they are dwarf planets. The distinction between moon and dwarf planet isn't so clear. For example, Pluto and its moon Charon are almost the same size, and some astronomers think they should be called double dwarf planets.]

What defines each of these groups, and what do objects in these different groups have in common? Could an object change from being in one group to another? How?

- [Planets are spherical bodies that orbit stars and have cleared their orbits. Dwarf planets are the same as planets except they haven't cleared their orbits. Moons are bodies that orbit planets. Asteroids and meteoroids are irregularly shaped rocky bodies that are smaller than planets or moons, and meteoroids are smaller than asteroids. All of these objects orbit the sun. One way an object could change from one group to another is for an asteroid to change to a meteoroid. This could happen if an asteroid was struck by another asteroid and broke into smaller pieces.]

We have learned about many different kinds of objects that are found within our solar system. What objects or systems of objects can you think of that are found outside our solar system?

- [Outside our solar system, there are billions of other stars, solar systems, galaxies, nebulae, star clusters, pulsars, quasars, black holes, and dark matter.]

CHAPTER 26 HS TE Stars, Galaxies, and the Universe

Chapter Outline

26.1 Chapter 26: Stars, Galaxies, and the Universe

Chapter Overview

This chapter describes constellations and the classification of stars. It explains show stars produce energy and how stars evolve. Also included are multiple star systems, types of galaxies, black holes, the Big Bang Theory, and dark matter and dark energy.

Online Resources

See the following Web sites for appropriate laboratory activities:

The star lab at the URL below is divided into six investigations that can be done and evaluated separately. Each section has a combination of linked Internet sites to engage students and content questions they are to answer by visiting the linked sites. Most sections have a self-scored online quiz, and the last section has a Java applet for students to arrange stars of various temperatures in correct order on a Hertzsprung-Russell diagram of Luminosity vs. Temperature.

- http://cse.ssl.berkeley.edu/SegwayEd/abtstellar.html

In the interesting lab activity at the following URL, students estimate the number of civilizations in the Milky Way Galaxy by first estimating the number of craters on the moon and then by performing estimates of multiple-variable systems, culminating in the use of the Drake Equation.

- http://btc.montana.edu/ceres/html/DrakeEquation/Drake.htm

In the virtual spectroscopy lab at the URL below, students will use an online virtual spectroscope to examine the spectrum from a galaxy and determine whether it is moving toward or away from Earth and how quickly it is moving.

- http://www.cfa.harvard.edu/seuforum/galSpeed/

These Web sites may also be helpful:

You can find numerous links to useful star and galaxy Web sites at this URL: http://www.lpi.usra.edu/education/skytellers/galaxies/web_sites.shtml.

Go to this URL for recommended videos on galaxies, including the Milky Way Galaxy: http://www.lpi.usra.edu/education/skytellers/galaxies/audio_video.shtml.

At the URL below, you can find a long list of frequently asked questions and answers in cosmology. http://www.astro.ucla.edu/ wright/cosmology_faq.html

NASA provides more information about chapter topics at these URLs:

- Stars: http://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve/
- Galaxies: http://science.nasa.gov/astrophysics/focus-areas/what-are-galaxies/

- The Big Bang: http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/
- Black holes: http://science.nasa.gov/astrophysics/focus-areas/black-holes/
- Dark matter and dark energy: http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/

This booklet from NASA provides extensive background information and several activities on black holes for high school students.

- http://imagine.gsfc.nasa.gov/docs/teachers/blackholes/imagine/imagine_book.pdf

Pacing the Lessons

TABLE 26.1: short caption

Lesson	Class Period(s) (60 min)
26.1 Stars	2.0
26.2 Galaxies	1.5
26.3 The Universe	1.5

26.2 Lesson 26.1: Stars

Key Concepts

- Constellations
- Nuclear fusion in stars
- Classification of stars
- Lifetime of stars
- Measuring star distances
- Parallax

Lesson Objectives

- Define constellation.
- Describe the flow of energy in a star.
- Classify stars based on their properties.
- Outline the life cycle of a star.
- Use light-years as a unit of distance.

Lesson Vocabulary

- **asterism:** group of stars that appear from Earth to be close together in the sky
- **black hole:** super-dense core left after a supergiant star explodes as a supernova
- **main sequence star:** star that is actively fusing hydrogen atoms to form helium; considered to be a star in the main portion of its "life"
- **neutron star:** remnant of a massive star after it explodes as a supernova
- **nuclear fusion:** nuclear reaction that releases a huge amount of energy when two nuclei fuse to form a larger nucleus, such as two hydrogen nuclei fusing to form a helium nucleus
- **parallax:** method used by astronomers to calculate the distance to nearby stars, using the apparent shift of the star relative to more distant stars
- **red giant:** stage in a star's "life" when the inner helium core contracts and the outer hydrogen layers expand
- **star:** glowing sphere of gases that produces light through nuclear fusion reactions in its core
- **supernova:** tremendous explosion that occurs when the core of a star is mostly iron
- **white dwarf:** small- to mid-sized star that has collapsed

Teaching Strategies

Introducing the Lesson

Show students images of constellations that are clearly visible in your part of the world. (Pictures of some well-known constellations can be found at the URLs below.) Point out that constellations are patterns of stars as they appear from Earth. Ask students if they can identify the constellations in one or more of the images. Identify the constellations if students cannot name them, and explain how they got their names. For example, the constellation in the image at the first URL below is Orion, which is one of the most recognizable constellations all over the world. Orion is named for a hunter in Greek mythology. Point out the stars in Orion's "belt," which holds his dagger. Explain that constellations are important for stargazers because they can help them locate particular stars in the night sky. Tell students they will learn more about constellations and stars in this lesson.

- http://en.wikipedia.org/wiki/File:OrionCC.jpg
- http://en.wikipedia.org/wiki/File:UrsaMajorCC.jpg
- http://en.wikipedia.org/wiki/File:CassiopeiaCC.jpg

Activity

The activity "Life Cycle of Stars" has students first analyze characteristics of the human life cycle and then apply them to various NASA pictures of stars to synthesize patterns of stellar life cycles. Specifically, students will sequence pictures of human beings by age, describe the observational characteristics used to determine a life cycle, observe NASA images of stars at various life cycle stages, synthesize a stellar life cycle based on observations, contrast their star life sequence with that of astronomers, and create a star life cycle concept map.

http://btc.montana.edu/ceres/html/LifeCycle/stars1.html

Building Science Skills

In the activity "A Case of the Wobbles: Finding Extra-Solar Planets" at the following URL, students will plot and analyze NASA data to determine the period of an invisible planet orbiting a wobbling star.

http://btc.montana.edu/ceres/html/Wobble/Wobbles.htm

Differentiated Instruction

Work with students to create a flow chart that shows the sequence of stages through which stars pass during their "lifetime." The chart will have branches to allow for different stages for small and large stars. Suggest that students keep their flow chart in their science notebook.

Enrichment

Assign the short and very entertaining article at the following URL. It is a good extension for the Building Science Skills activity above. The article describes the real-life discovery of a planet around the most famous star system in the sky, Alpha Centauri, which is the star system closest to our sun. The planet was detected by its gravitational effect on the stars in the system.

http://blogs.discovermagazine.com/badastronomy/2012/10/16/alpha-centauri-has-a-planet/

Science Inquiry

With the inquiry activity at the following URL, students will download NASA Hubble Space Telescope (HST) views of star-forming regions in nebulae and look for evidence of planetary systems forming beyond our own solar system. Specifically, students will hypothesize about mysterious objects in NASA HST images, systematically search NASA images of the Orion nebula for proplyds, and study star charts to find night-sky locations of other planetary systems.

http://btc.montana.edu/ceres/html/Disks/disks1.html

Overcoming Misconceptions

Because most stars appear to observers on Earth as tiny points of twinkling light, some people erroneously believe that all stars are the same distance from Earth. Prove to students that this is not the case by giving them the distances from Earth of several different stars. You can use the stars below as examples. Tell students that all of the stars in the list are found in our own galaxy, the Milky Way Galaxy, so most stars are much farther from us than these.

- Proxima Centauri (star nearest to our sun): 4.2 light-years
- Polaris (also known as the North Star): 323 light-years
- Atlas (in the Pleiades constellation): 434–446 light-years
- Deneb (most distant star in the Milky Way galaxy that is visible with the unaided eye): 1400–3230 light-years

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 26.1 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 26.1 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What distinguishes a nebula and a star?

   - [A nebula is a spinning cloud of gas and dust. It is not hot enough to undergo nuclear fusion. A star forms from a nebula that has become very dense and hot enough for nuclear fusion to begin.]

2. What kind of reactions provide a star with energy?

   - [Nuclear fusion reactions provides a star with energy.]

3. Stars are extremely massive. Why don't they collapse under the weight of their own gravity?

   - [The energy from fusion reactions in the core pushes outward to balance the inward pull of gravity.]

4. Of what importance are particle accelerators to scientists?

   - [Scientists use particle accelerators to simulate the nuclear fusion that takes place in the cores of stars. It also simulates the conditions that allowed the first helium atom to be form from the collision of two hydrogen atoms very early in the formation of the universe.]

5. Which has a higher surface temperature: a blue star or a red star?

- [A blue star has a higher surface temperature.]

6. List the seven main classes of stars, from hottest to coolest.

- [From hottest to coolest, the seven main classes of stars are O (blue), B (blue-white), A (white), F (yellowish-white), G (yellow), K (orange), and M (red).]

7. What is the main characteristic of a main sequence star?

- [A main sequence star is a star that is fusing hydrogen to form helium.]

8. What kind of star will the sun be after it leaves the main sequence?

- [After the sun leaves the main sequence, it will be a red giant star.]

9. Suppose a large star explodes in a supernova, leaving a core that is 10 times the mass of the sun. What would happen to the core of the star?

- [The core of the star would become a black hole.]

10. Since black holes are black, how do astronomers know that they exist?

- [Astronomers can detect black holes by the effects of their gravity on objects near them in space and by the radiation that leaks out around their edges.]

11. What is a light-year?

- [A light-year is the distance that light travels in a year.]

12. Why don't astronomers use parallax to measure the distance to stars that are very far away?

- [Parallax can be used to measure the distance to stars only if they are relatively close to us. If stars are too far away, the shift due to parallax would be too small to detect.

For more distant stars, astronomer use indirect evidence such as star brightness to measure the distance to stars.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 26.1 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Although stars may appear to be close together in constellations, they are usually not close together out in space. Can you think of any groups of astronomical objects that are relatively close together in space?

- [Planets in the same solar system and stars in the same galaxy are relatively close together in space.]

Most nebulas contain more mass than a single star. If a large nebula collapsed into several different stars, what would the result be like?

- [The result might be a star system.]

26.3 Lesson 26.2: Galaxies

Key Concepts

- Star systems and star clusters
- Types of galaxies
- Milky Way Galaxy

Lesson Objectives

- Distinguish between star systems and star clusters.
- Identify different types of galaxies.
- Describe our own galaxy, the Milky Way Galaxy.

Lesson Vocabulary

- **binary stars:** system of two stars that orbit a common center of mass
- **dwarf galaxy:** small galaxy containing a few million to a few billion stars
- **elliptical galaxy:** oval-shaped galaxy with older stars and little gas and dust
- **galaxy:** group of millions or billions of stars held together by gravity
- **globular cluster:** group of tens to hundreds of thousands of stars tightly held together by gravity
- **irregular galaxy:** galaxy that is neither spiral nor elliptical in shape
- **Milky Way Galaxy:** spiral galaxy in which Earth and our solar system are located
- **open cluster:** group of up to a few thousand stars loosely held together by gravity
- **spiral arm:** region of gas, dust, and young stars that wind outward from the central bulge of a spiral galaxy
- **spiral galaxy:** rotating galaxy with a central bulge and spiral arms
- **star cluster:** group of thousands of stars held together by gravity
- **star system:** small group of stars that are close together

Teaching Strategies

Introducing the Lesson

Define galaxy and tell students that our solar system is located in the Milky Way Galaxy. Share the following impressive facts and figures about galaxies with students, and then tell them they will learn more about galaxies in this lesson.

- The name of our galaxy as well as the term galaxy itself refers to the appearance of our galaxy as a milky or cloudy area in the sky when viewed from Earth without a telescope.

- There are as many as 200 billion stars in the Milky Way Galaxy and it has a diameter of 100,000 light-years.
- It takes the solar system about 200 million years to complete one revolution around our galaxy's center.
- The largest known galaxy is almost 80 times wider than the Milky Way, with a diameter of about 5.6 million light-years.
- The galaxy nearest the Milky Way is more than 70,000 light-years from Earth.
- The most distant galaxy is nearly 13.2 billion light-years from Earth.

Building Science Skills

Students can learn more about galaxies and how they are studied as well as develop knowledge and skills in statistics with the activity "Online Exploration: Galaxy Hunter" (see URL below). The activity uses real data from the Hubble Space Telescope. Students will investigate bias in sampling techniques and determine optimal sample size based on variability of different-sized samples. They will also use statistical data to make conjectures about the universe. Teaching tips and background information on statistics are included.

http://amazing-space.stsci.edu/resources/explorations/ghunter/home.html

Demonstration

The interactive video at the following URL shows how galaxies evolve through collisions with other galaxies. It outlines the eventual fate of our own galaxy, the Milky Way Galaxy, which is expected to collide with the Andromeda Galaxy. The video also introduces the expanding universe, which students will learn more about in the next lesson.

http://hubblesite.org/explore_astronomy/cosmic_collision/cosmic_collision.swf

Differentiated Instruction

Suggest that students may a three-way Venn diagram to compare and contrast spiral, elliptical, and irregular galaxies.

Enrichment

Encourage interested students to learn more about multiple star systems and their orbits. They can see animations of different types of multiple star orbits at the first URL below. The second URL describes different types of multiple star systems.

- http://www.atlasoftheuniverse.com/orbits.html
- http://orionatlas.wikia.com/wiki/Multiple_Star_Systems

Science Inquiry

In the inquiry activity "Galactic Inquiry" at the URL below, students will view NASA images of galaxies and develop a galaxy classification scheme. Then they will compare and contrast their classification scheme with that developed by Edwin Hubble. Specific learning objectives of the activity include understanding that galaxies take a variety of forms and developing and applying a galactic classification scheme.

http://btc.montana.edu/ceres/html/Galaxy/gal1.html

Overcoming Misconceptions

A recent study of students' misconceptions about astronomy found the misconceptions about galaxies listed below. Use these misconceptions as a true/false quiz with your students to identify which misconceptions they believe to

be true. Then explain why each identified misconception is false and provide evidence to support the explanation. You can learn more about the study at this URL: http://blogs.physicstoday.org/thedayside/2012/07/analyzing-students-misconceptions-about-galaxies/

- The Milky Way is the only galaxy.
- The solar system is not in the Milky Way (or any other) Galaxy.
- All galaxies are spiral.
- The Milky Way is the center of the universe.
- The sun is at the center of the Milky Way Galaxy.
- The sun is at the center of the universe.
- There are only a few galaxies.
- Galaxies are randomly distributed throughout the universe.
- We can see all the stars that are in the Milky Way Galaxy.
- All galaxies are the same in size and shape.
- The Milky Way is just starsgas and dust.
- New planets and stars are not still forming today.

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 26.2 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 26.2 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents.

1. What is a binary star?

- [A binary star is a system of two stars that orbit a common center of mass.]

2. Compare globular clusters with open clusters.

- [Globular clusters are groups of many thousands of stars tightly held together by gravity. Their stars tend to be red in color, and they do not contain much dust. Open clusters are groups of up to a few thousand stars that are loosely held together by gravity. Their stars tend to be blue in color, and they often contain glowing gas and dust.]

3. Name the three main types of galaxies.

- [The three main types of galaxies are spiral, elliptical, and irregular galaxies.]

4. List three main features of a spiral galaxy.

- [A spiral galaxy rotates; it has a bulge in the middle and spiral arms extending from it; and it contains lots of young stars, gas, and dust.]

5. Suppose you see a round galaxy that is reddish in color and contains very little dust. What kind of galaxy is it?

- [The galaxy is an elliptical galaxy.]

6. What galaxy do we live in, and what kind of galaxy is it?

- [We live in the Milky Way Galaxy. It is a spiral galaxy.]

7. What is the evidence that the galaxy we live in is this type of galaxy?

- [Evidence that our galaxy is a spiral galaxy includes its shape as we see it; the velocities of stars and gas, which show rotational motion; and the gases, color, and dust, which are typical of spiral galaxies.]

8. Describe the location of our solar system in our galaxy.

- [Our solar system is located within one of the spiral arms of the Milky Way Galaxy, a little more than halfway out from the center of the galaxy to the edge.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 26.2 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

Objects in the universe tend to be grouped together. What forces or factors do you think cause objects to form and stay in groups?

- [Object form and stay in groups because of gravity.]

Some people used to call galaxies "island universes." Are they really universes?

- [No; the universe is expanding outward in all directions and contains all of space and time, whereas individual galaxies do not expand and are only a small part of the universe.]

Can you think of anything, either an object or a group of objects, that is bigger than a galaxy?

- [The entire universe is far bigger than a galaxy. In fact, it contains an estimated hundred billion galaxies.]

26.4 Lesson 26.3: The Universe

Key Concepts

- Hubble's contribution to knowledge of the universe
- Expansion of the universe
- Big Bang Theory
- Dark matter and dark energy

Lesson Objectives

- Explain the evidence for an expanding universe.
- Describe the formation of the universe according to the Big Bang Theory.
- Define dark matter and dark energy.

Lesson Vocabulary

- **Big Bang Theory:** theory that all matter and energy were at one time compressed into a very small volume and exploded in a "big bang" that started everything expanding outward and formed the universe
- **cosmology:** study of the universe
- **dark energy:** as yet undiscovered form of energy that we cannot detect
- **dark matter:** matter in the universe that we cannot see because it does not emit light
- **Doppler effect:** change in the frequency of a wave that is apparent to an observer who is moving relative to the source of the wave
- **redshift:** shift of wavelengths of light toward the red end of the spectrum that occurs as a light source moves away from the observer
- **universe:** everything that exists; all matter, energy, space, and time

Teaching Strategies

Introducing the Lesson

Introduce students to the universe with the excellent 6-minute video "The Known Universe" from the American Museum of Natural History. The video will impress them with the incredible vastness of the universe. It will take them from Earth's surface through our atmosphere and the inky black of space to the afterglow of the Big Bang. The film was created as part of an exhibition entitled "Visions of the Cosmos."

http://www.youtube.com/watch?v=17jymDn0W6U

Building Science Skills

Have students do the activity "Online Exploration: No Escape: The Truth About Black Holes" at the following URL. The activity provides an opportunity for students to research the fascinating topic of black holes and to examine the concepts of escape velocity, gravity, mass, and the speed of light as they apply to black holes. Dramatic illustrations and spectacular Hubble Space Telescope images illustrate the activity and provide data that the students will use to hunt for black holes in the centers of galaxies.

http://amazing-space.stsci.edu/resources/explorations/blackholes/lesson/

Differentiated Instruction

This lesson covers some difficult content, such as an expanding universe, black holes, and dark matter. Suggest that students make a main ideas/details chart of the lesson to help them organize the material and reduce it to the most important points. Tell students that a general rule of thumb is to have at least one main idea per heading or sub-heading in the lesson and to include only the most important details that support each main idea.

Enrichment

Suggest to your more advanced students that they explore the theoretical foundations of the big bang, including Einstein's theory of general relativity and the cosmological principle. They can start with these URLs:

- http://map.gsfc.nasa.gov/universe/bb_theory.html
- http://map.gsfc.nasa.gov/universe/bb_concepts.html

Science Inquiry

In the inquiry activity "The Expanding Universe" (see URL below), students will gain a deeper understanding of cosmology. They will develop authentic models and gather evidence supporting the Big Bang Theory. The activity uses observations, interactive media, and scientific models.

http://btc.montana.edu/ceres/html/Universe/uni1.html

Overcoming Misconceptions

The excellent article at the following URL discusses some common misconceptions about the expanding universe and Big Bang Theory. Reading the article may help you become aware of possible misconceptions in your students and ways to overcome them.

http://space.mit.edu/ kcooksey/teaching/AY5/MisconceptionsabouttheBigBang_ScientificAmerican.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the Lesson 26.3 worksheets in *CK-12 Earth Science for High School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions at the end of Lesson 26.3 in *CK-12 Earth Science for High School*. The answer key can be found in the Resource tab above the Table of Contents. 1. What is redshift, and what causes it to occur? What does redshift indicate?

- [Redshift is a shift in wavelengths of light toward the red end of the spectrum. It occurs because the light source is moving away from the observer. Redshift indicates that other galaxies are moving away from us.]

2. What is Hubble's law?

- [Hubble's law states that the farther away a galaxy is, the faster it is moving away from us.]

3. What is the cosmological theory of the formation of the universe called?

- [The cosmological theory is called the Big Bang Theory.]

4. How old is the universe, according to the Big Bang Theory?

- [According to the Big Bang Theory, the universe is about 13.7 billion years old.]

5. Describe two different possibilities for the nature of dark matter.

- [One possibility is that dark matter is just ordinary matter that does not emit radiation, like black holes and neutron stars. Another possibility is that dark matter is much different from ordinary matter. For example, it might include particles that have gravity but don't otherwise interact with other particles.]

6. What makes scientists believe that dark matter exists?

- [Scientists believe that dark matter exists because its gravity affects the motion of objects around it. Strong gravitational lensing also supports the existence of dark matter. More matter than is observed must be present for strong gravitational lensing to occur.]

7. What observation caused astronomers to propose the existence of dark energy?

- [The observation is that the rate at which the universe is expanding is increasing. To explain this, some scientists have proposed the existence of energy that cannot be detected.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 26.3 Quiz in *CK-12 Earth Science for High School Quizzes and Tests*.

Points to Consider

The expansion of the universe is sometimes modeled using a balloon with dots marked on it, as described earlier in the lesson. In what ways is this a good model, and it what ways does it not correctly represent the expanding universe? Can you think of a different way to model the expansion of the universe?

- [An expanding balloon with dots on its surface is a good model of the universe because as the balloon is inflated, the dots move away from each other, like the galaxies in the expanding universe. On the other hand, the surface of a balloon is two-dimensional, whereas space is three-dimensional. Also, the dots on the surface of the balloon expand as the balloon is inflated, whereas galaxies in the universe do not expand. Only the space between galaxies expands, causing the galaxies to grow farther apart. A classic model of the expansion of the universe is a lump of raisin bread dough. As the dough rises and expands, the raisins move farther away from each other but don't get any bigger.]

The Big Bang theory is currently the most widely accepted scientific theory for how the universe formed. What is another explanation of how the universe could have formed? Is your explanation one that a scientist would accept?

- [One explanation would be a creationist explanation that the universe was created as it currently is by a god or other supernatural force. This explanation would not be accepted by a scientist because it is not supported by evidence.]