Ecology

Themes

Scientific Inquiry From studies in natural history to the development of ecology as a branch of biology, scientists use methods of inquiry to understand interactions in the natural world.

Diversity Tremendous diversity of species results from adaptations to environmental conditions in various biomes.

Energy The flow of energy trapped by photosynthesis sustains life at every trophic level.

Homeostasis Organisms maintain homeostasis by obtaining energy and nutrients from their environments.

Change Succession occurs as a community develops toward a climax stage.

Chapter 2
Principles of Ecology

BIG Idea Energy is required to cycle materials through living and nonliving systems.

Chapter 3
Communities, Biomes, and Ecosystems

BIG Idea Limiting factors and ranges of tolerance are factors that determine where terrestrial biomes and aquatic ecosystems exist.

Chapter 4
Population Ecology

BIG Idea Population growth is a critical factor in a species’ ability to maintain homeostasis within its environment.

Chapter 5
Biodiversity and Conservation

BIG Idea Community and ecosystem homeostasis depend on a complex set of interactions among biologically diverse individuals.

5-Minute UNIT LAUNCH

Facets of Meaning Have students use the word gradual in a sentence.

ASK STUDENTS: What does it mean for a population to grow gradually? It takes some time to increase significantly. What does it mean for a forest to develop gradually? It changes slowly over time, sometimes taking more than a century. Have them make a list in their journals of ways the word is used in this unit.

CAREERS IN BIOLOGY

Wildlife Biologist

As the oystercatcher researchers are doing in this photograph, wildlife biologists perform scientific research to study how species interact with each other and the environment. They protect and conserve wildlife species and also help maintain and increase wildlife populations.

What’s BIOLOGY Got To Do With It?

A professor discusses scientific methods and shark research.
SERVICE LEARNING/COMMUNITY SERVICE

Parks Development  Students can volunteer to work in state or local metropolitan parks and state historical sites doing a variety of activities, such as removing exotic plants, trail building or maintenance, or planting wildflower seeds. Making decisions about their volunteer activities empowers students (Morgan and Streb, 2001).

Research bibliography on pages 36T–38T

Misconceptions

In each section, Clarify a Misconception provides you with the information to dispel a common student misconception. A question will help you elicit the misconception and an explanation will help you correct it.

Below is a preview of misconceptions from each chapter in this unit.

Before studying Chapter 2, students might think that the same molecules of water cycle endlessly through the water cycle. Chapter 2 will explain that not all intact water molecules cycle through living things, but that photosynthesis and respiration break down the water molecules and use the hydrogen and oxygen to make other molecules (p. 46).

Before studying Chapter 3, students might think that deserts are always hot. Chapter 3 will explain that a desert is defined by precipitation, not temperature, and that Antarctica is actually a desert (p. 70).

Before studying Chapter 4, students might think that populations increase indefinitely. Chapter 4 will explain that all populations eventually become limited in size because resources are limited (p. 94).

Before studying Chapter 5, students might think that all members of a population die when their environment is disturbed. Chapter 5 will explain that, in most cases, populations are reduced but do not become extinct, and others might increase because they can withstand or even thrive under the new conditions (p. 126).
# Chapter 2 Organizer: Principles of Ecology

## Section Objectives

### National Science Standards

<table>
<thead>
<tr>
<th>Section 2.1</th>
<th>UCP.1–3; A.1, A.2; C.4, C.5, C.6; F.1, F.3, F.5; G.1,G.2, G.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch Lab</strong>, p. 31: container housing several fruit flies</td>
<td>15 per day</td>
</tr>
<tr>
<td><strong>Demonstration</strong>, p. 38: fallen log or branch with fungi</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2.2</th>
<th>UCP.1–3; A.1, A.2; B.6; C.4, C.5, C.6; D.1; F.3, F.4, F.5; G.1,G.2, G.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demonstration</strong>, p. 42: sod or grass, water with algae in a beaker or jar</td>
<td>5</td>
</tr>
<tr>
<td><strong>MiniLab 2.1</strong>, p. 42: paper, pencils</td>
<td>30</td>
</tr>
<tr>
<td><strong>Demonstration</strong>, p. 43: algae, mosquito larvae, minnows or photos of these items</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2.3</th>
<th>UCP.1–3; A.1, A.2; B.3, B.6; C.4, C.5, C.6; D.1, D.2; F.3, F.4, F.5; G.1,G.2, G.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demonstration</strong>, p. 45: product labels that show nutrition information</td>
<td>10</td>
</tr>
<tr>
<td><strong>Demonstration</strong>, p. 48: fertilizer container with information label</td>
<td>5</td>
</tr>
<tr>
<td><strong>MiniLab 2.2</strong>, p. 48: water samples from different sources, nitrate test kit</td>
<td>30</td>
</tr>
<tr>
<td><strong>Design Your Own BioLab</strong>, p. 51: materials appropriate for the experiment</td>
<td>60</td>
</tr>
</tbody>
</table>

## Materials and Planning

Estimated times include cleanup and disposal, but do not include teacher prep time. For cleanup and disposal guidelines, see page 43T.

## Suggested Time for Each Lesson

<table>
<thead>
<tr>
<th>Class</th>
<th>Chapter Opener</th>
<th>Section 2.1</th>
<th>Section 2.2</th>
<th>Section 2.3</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>45 min</td>
<td>90 min</td>
<td>45 min</td>
<td>45 min</td>
<td>45 min</td>
</tr>
<tr>
<td>General</td>
<td>25 min</td>
<td>100 min</td>
<td>100 min</td>
<td>90 min</td>
<td>45 min</td>
</tr>
<tr>
<td>Honors</td>
<td>5 min</td>
<td>90 min</td>
<td>20 min</td>
<td>45 min</td>
<td>20 min</td>
</tr>
</tbody>
</table>
**BIG Idea**  
Energy is required to cycle materials through living and nonliving systems.

<table>
<thead>
<tr>
<th>Chapter 2 Section Resources</th>
<th>Additional Chapter 2 Resources</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST FILE Unit 1 Resources:</td>
<td>FAST FILE Unit 1 Resources:</td>
<td>Teaching Tools:</td>
</tr>
<tr>
<td>Launch Lab Worksheet*</td>
<td>Chapter Diagnostic Test</td>
<td>TeacherWorks™ CD-ROM</td>
</tr>
<tr>
<td>Study Guide (English/Spanish)*</td>
<td>Concept Mapping*</td>
<td>Interactive Classroom CD-ROM*</td>
</tr>
<tr>
<td>Section Quick Check</td>
<td>Real-World Biology</td>
<td>LabManager™ CD-ROM*</td>
</tr>
<tr>
<td>Reading Essentials 2.1</td>
<td>Enrichment</td>
<td>Video Lab DVD*</td>
</tr>
<tr>
<td>Science Notebook 2.1*</td>
<td>Chapter Tests A, B, and C</td>
<td>Virtual Lab CD-ROM*</td>
</tr>
<tr>
<td></td>
<td>Transparencies:</td>
<td>What’s BIOLOGY Got To Do With It?</td>
</tr>
<tr>
<td></td>
<td>Bellringer Transparencies*</td>
<td>StudentWorks™ Plus CD-ROM*</td>
</tr>
<tr>
<td>Lab Resources:</td>
<td>Biology Concepts Transparencies*</td>
<td>Chapter Assessment Tools:</td>
</tr>
<tr>
<td>Laboratory Manual*</td>
<td>Lab Resources:</td>
<td>Interactive Classroom CD-ROM*</td>
</tr>
<tr>
<td>Probeseware Lab Manual*</td>
<td>Lab Resources:</td>
<td>ExamView® Assessment Suite CD-ROM</td>
</tr>
<tr>
<td>Forensics Lab Manual*</td>
<td>Lab Resources:</td>
<td>biologygmh.com</td>
</tr>
<tr>
<td>Open Inquiry in Biology*</td>
<td>Lab Resources:</td>
<td>Online Learning Center:</td>
</tr>
<tr>
<td>Guided Inquiry in Biology*</td>
<td>Lab Resources:</td>
<td>• Concepts in Motion*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Interactive Time Line*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Interactive Tables*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Self-Check Quizzes</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Chapter Tests</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Standardized Test Practice</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Virtual Labs*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Multilingual Glossary*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Vocabulary PuzzleMaker*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Interactive Tutor</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• WebQuests</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Internet BioLabs*</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Study to Go</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Online Student Edition</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Microscopy Links</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Teaching Today</td>
</tr>
<tr>
<td></td>
<td>Lab Resources:</td>
<td>• Additional Teacher Support</td>
</tr>
</tbody>
</table>

While all resources listed are appropriate for English learners, the * indicates resources with a strong visual or hands-on component for EL.

**Teaching strategies and activities have been coded for differentiated instruction.**

| AL Activities for students working above grade level | OL Activities for students working on grade level | BL Activities for students working below grade level | EL Activities for English learners (also ELL) | COOP LEARN Activities designed for small cooperative group work |
**Introduce the Chapter**

**Organism Interactions**

**SAY TO STUDENTS:** The ecosystem shown in the photos is from the Pacific Northwest of the United States.

**ASK STUDENTS:** Where does the energy to keep the organisms alive originally come from? the Sun How do the organisms in the photo get energy? from the food they eat or make This chapter will explain the relationships between organisms and the way in which energy and material flows through ecosystems.

**BIG Idea**

**Information Search** Organize students into pairs and assign approximately the same number of pages from the chapter to each group. Have each pair scan the headings and figure captions of their assigned pages to find new concepts. Have students share their information with the class in the order it appears in the chapter.

**ASK STUDENTS:** What are the main ideas that appear in the chapter? The main ideas emphasized are the relationships among organisms, the transfer of energy in an ecosystem, the diversity of organisms in an ecosystem, and homeostasis.

**Section 1**

**Organisms and Their Relationships**

**MAIN Idea** Biotic and abiotic factors interact in complex ways in communities and ecosystems.

**Section 2**

**Flow of Energy in an Ecosystem**

**MAIN Idea** Autotrophs capture energy, making it available for all members of a food web.

**Section 3**

**Cycling of Matter**

**MAIN Idea** Essential nutrients are cycled through biogeochemical processes.

**BioFacts**

- The Pacific tree frog can change from light colored to dark colored quickly. This could be a response to changes in temperature and humidity.
- The spotted owl nests only in old growth forests and might be in danger of becoming extinct due to the loss of these forests.

**Interactive Classroom**

This CD-ROM is an editable Microsoft® PowerPoint® presentation that includes:

- a premade presentation for every chapter
- additional diagnostic, formative, chapter, and Standardized Test Practice questions
- animations
- image bank
- Glencoe Biology Transparencies
- links to biologygmh.com
Problems in Drosophila world?
As the photos on the left illustrate, what we understand to be the world is many smaller worlds combined to form one large world. Within the large world, there are populations of creatures interacting with each other and their environment. In this lab, you will observe an example of a small part of the world.

Procedure
1. Read and complete the lab safety form.
2. Prepare a data table to record your observations.
3. Your teacher has prepared a container housing several fruit flies (Drosophila melanogaster) with food for the flies in the bottom. Observe how many fruit flies are present.
4. Observe the fruit flies over a period of one week and record any changes.

Analysis
1. Summarize the results of your observations.
2. Evaluate whether or not this would be a reasonable way to study a real population.

Analysis
1. Many flies die as the food runs out. The environment looks polluted as waste and dead flies accumulate.
2. No; materials in the natural world are replenished through ecological cycles that are missing in the fruit-fly jars.
Section 2.1

Organism Interactions

SAY TO STUDENTS: All living things require a supporting environment, including other living things. No organism lives in isolation.

ASK STUDENTS: What evidence do you have that living things require each other? Possible answers: Plants require animals such as butterflies and bees for pollination. Animals eat other animals and plants for survival.

Reading Strategy

Monitor Comprehension

SAY TO STUDENTS: Ask yourselves questions as you read. If you finish a paragraph and you have a question that has not been answered, reread the text where the question may be answered. If you still cannot answer it, write down the question and ask me or another student to help you answer it. This will help you and others in the class understand the concepts. It may be useful to walk through the room and prompt students with questions while they read.

Skill Practice

Visual Literacy

Have students study Figure 2.1.

ASK STUDENTS: Which time line entry do you consider the most significant to ecological discoveries and why? Answers will vary, but encourage students to explain their reasoning.

Organisms and Their Relationships

MAIN Idea Biotic and abiotic factors interact in complex ways in communities and ecosystems.

Real-World Reading Link On whom do you depend for your basic needs such as food, shelter, and clothing? Humans are not the only organisms that depend on others for their needs. All living things are interdependent. Their relationships are important to their survival.

Ecology

Scientists can gain valuable insight about the interactions between organisms and their environments and between different species of organisms by observing them in their natural environments. Each organism, regardless of where it lives, depends on nonliving factors found in its environment and on other organisms living in the same environment for survival. For example, green plants provide a source of food for many organisms as well as a place to live. The animals that eat the plants provide a source of food for other animals. The interactions and interdependence of organisms with each other and their environments are not unique. The same type of dependency occurs whether the environment is a barren desert, a tropical rain forest, or a grassy meadow. Ecology is the scientific discipline in which the relationships among living organisms and their interaction the organisms have with their environments are studied.

Objectives

- Explain the difference between abiotic factors and biotic factors.
- Describe the levels of biological organization.
- Differentiate between an organism’s habitat and its niche.

Review Vocabulary

- species: group of organisms that can interbreed and produce fertile offspring in nature

New Vocabulary

- ecology
- biosphere
- biotic factor
- abiotic factor
- population
- biological community
- ecosystem
- biome
- habitat
- niche
- predation
- symbiosis
- mutualism
- commensalism
- parasitism

- Figure 2.1 Milestones in Ecology

Ecologists have worked to preserve and protect natural resources.

1806 Yellowstone becomes the first national park in the U.S.
1908 Theodore Roosevelt urges the U.S. Congress to set aside over 70 million hectares of land to protect the natural resources found on them.
1971 Marjorie Carr stops the construction of the Cross Florida Barge Canal because of the environmental damage the project would cause.
1967 The government of Rwanda and international conservation groups begin efforts to protect mountain gorillas, due in a large part to the work of Dian Fossey.

Research Citation

Question Educational research indicates that the questioning technique described on this page will help students extend their thinking. Students are challenged to think critically and increase interaction with other students. (Heibert et al., 1997)

Research bibliography on page 36T–38T.

Chapter 2 • Principles of Ecology
Section 1 • Organisms and Their Relationships

The study of organisms and their environments is not new. The word ecology was first introduced in 1866 by Ernst Haeckel, a German biologist. Since that time, there have been many significant milestones in ecology, as shown in **Figure 2.1**.

Scientists who study ecology are called ecologists. Ecologists observe, experiment, and model using a variety of tools and methods. For example, ecologists, like the one shown in **Figure 2.2**, perform tests in organisms’ environments. Results from these tests might give clues as to why organisms are able to survive in the water, why organisms become ill or die from drinking the water, or what organisms could live in or near the water. Ecologists also observe organisms to understand the interactions between them. Some observations and analyses must be made over long periods of time in a process called longitudinal analysis.

A model allows a scientist to represent or simulate a process or system. Studying organisms in the field can be difficult because there often are too many variables to study at one time. Models allow ecologists to control the number of variables present and to slowly introduce new variables in order to fully understand the effect of each variable.

**Reading Check** Describe a collection of organisms and their environment that an ecologist might study in your community.

**Vocabulary**

**Word origin**

Ecology comes from the Greek words oikos, meaning house, and ology, meaning to study.

---

**Skill Practice**

**Visual Literacy** Tell students to study Figure 2.2. Then have them read this page.

**ASK STUDENTS:** What are some locations where you might find ecologists collecting data, and what tools might they use in these locations? Answers will vary, but can include taking water temperature with thermometers at a lake, using a net, or using an identification guide to study birds in a forest.

**Writing Support**

**Journal Writing** Have students respond to the following writing prompt: What I think of when I hear the word ecology. Responses will vary, but might include catastrophes such as forest fires or chemical spills. Allow students to share their journal entries in class.

**Informal Writing** Have students write a short essay explaining how the work of Wangari Maathai helps both the environment and impoverished women and children in Africa.

**Interactive Time Line** Students can interact with the time line at biologygmh.com.

**Develop Concepts**

**Activate Prior Knowledge**

**ASK STUDENTS:** What types of organisms have you ever observed or collected that live near your home? Students may list butterflies, beetles, birds, squirrels, etc.

**ASK STUDENTS:** What are some interesting characteristics of these organisms? Answers will vary.
Develop Concepts

BL OL AL Use Analogies

ASK STUDENTS: If Earth were the size of an apple, what part of the apple would represent the biosphere? the peel of the apple

Writing Support

AL Summary Writing Have students identify and write about the precautions they consider necessary for travel in a spacecraft destined to go beyond the Moon. Encourage students to identify the limits of the conditions inside and outside the craft that would allow travel.

Reading Strategy

BL OL AL SQ3R This five-step process helps promote active reading. Have students first Survey a portion of text, focusing on the headings. Have students then write Questions about key concepts. Next, have students Read the text, making notes related to the questions. Then, have students Recite the vocabulary and Review for meaning.

The Biosphere

Because ecologists study organisms and their environments, their studies take place in the biosphere. The biosphere (BI uh sfahr) is the portion of Earth that supports life. The photo of Earth taken from space shown in Figure 2.3 shows why the meaning of the term biosphere should be easy to remember. The term bio means “life,” and a sphere is a geometric shape that looks like a ball. When you look at Earth from this vantage point, you can see how it is considered to be “a ball of life.”

Although “ball of life” is the literal meaning of the word biosphere, this is somewhat misleading. The biosphere includes only the portion of Earth that includes life. The biosphere forms a thin layer around Earth. It extends several kilometers above the Earth’s surface into the atmosphere and extends several kilometers below the ocean’s surface to the deep-ocean vents. It includes landmasses, bodies of freshwater and saltwater, and all locations below Earth’s surface that support life.

Figure 2.3 This color-enhanced satellite photo of Earth taken from space shows a large portion of the biosphere.

Reading Check Describe the general distribution of green plants across the United States using Figure 2.4.

The biosphere also includes areas such as the frozen polar regions, deserts, oceans, and rain forests. These diverse locations contain organisms that are able to survive in the unique conditions found in their particular environment. Ecologists study these organisms and the factors in their environment. These factors are divided into two large groups—the living factors and the nonliving factors.

Figure 2.4 This color-coded satellite photo shows the relative distribution of life on Earth’s biosphere based on the distribution of chlorophyll.

Reading Check Green plants are found in higher density in the northern and southeastern parts of the United States. Green plants are found in lower density in the southwestern part of the United States.
Section 1 • Organisms and Their Relationships

Organisms and Their Relationships

Biotic factors The living factors in an organism’s environment are called the biotic factors. Consider the biotic factors in the habitat of salmon shown in Figure 2.5. These biotic factors include all of the organisms that live in the water, such as other fish, algae, frogs, and microscopic organisms. In addition, organisms that live on the land adjacent to the water might be biotic factors for the salmon. Migratory animals, such as birds that pass through the area, also are biotic factors. The interactions among organisms are necessary for the health of all species in the same geographic location. For example, the salmon need other members of their species to reproduce. Salmon also depend on other organisms for food and, in turn, are a food source for other organisms.

Abiotic factors The nonliving factors in an organism’s environment are called abiotic factors. The abiotic factors for different organisms vary across the biosphere, but organisms that live in the same geographic area might share the same abiotic factors. These factors might include temperature, air or water currents, sunlight, soil type, rainfall, or available nutrients. Organisms depend on abiotic factors for survival. For example, the abiotic factors important to a particular plant might be the amount of rainfall, the amount of sunlight, the type of soil, the range of temperature, and the nutrients available in the soil. The abiotic factors for the salmon in Figure 2.5 might be the temperature range of the water, the pH of the water, and the salt concentration of the water.

Organisms are adapted to surviving in the abiotic factors that are present in their natural environments. If an organism moves to another location with a different set of abiotic factors, the organism might die if it cannot adjust quickly to its new surroundings. For example, if a lush green plant that normally grows in a swampy area is transplanted to a dry desert, the plant likely will die because it cannot adjust to abiotic factors present in the desert.

Reading Check Compare and contrast abiotic and biotic factors for a plant or animal in your community.

Critical Thinking

Analyze an Argument

Have students evaluate the following argument: Oxygen is the only abiotic factor that allows life to survive in the classroom, so as long as there is enough oxygen, all life will survive. Although oxygen is one abiotic factor, temperature, humidity, and air pressure are all important for life in the classroom.

Develop Concepts

Activity

Accompany students from the classroom to the school grounds. Have them identify the biotic and abiotic factors they observe. Alternatively, you could hold up magazine photographs of different environments and have students identify the biotic and abiotic factors they observe in each photograph.

Before beginning the exercise, define abiotic and biotic factors. Show students pictures of abiotic factors and biotic factors. Then organize students into small groups. Give each group pictures and have them classify them as showing abiotic or biotic factors.

Reading Check Answers will vary based on community location and student selections, but should accurately note the similarities and differences between abiotic and biotic factors. Be sure students understand that both abiotic and biotic factors are necessary for the survival of every organism.

Caption Question Fig. 2.5 Sample answer: Organisms often depend on other organisms for food and reproduction.
Levels of Organization

The biosphere is too large and complex for most ecological studies. To study relationships within the biosphere, ecologists look at different levels of organization or smaller pieces of the biosphere. The levels increase in complexity as the numbers and interactions between organisms increase. The levels of organization are

- organism;
- population;
- biological community;
- ecosystem;
- biome;
- biosphere.

Refer to Figure 2.6 as you read about each level.

Organisms, populations, and biological communities

The lowest level of organization is the individual organism itself. In Figure 2.6, the organism is represented by a single fish. Individual organisms of a single species that share the same geographic location at the same time make up a population. The school of fish represents a population of organisms. Individual organisms often compete for the same resources, and if resources are plentiful, the population can grow. However, usually there are factors that prevent populations from becoming extremely large. For example, when the population has grown beyond what the available resources can support, the population size begins to decline until it reaches the number of individuals that the available resources can support.

The next level of organization is the biological community. A biological community is a group of interacting populations that occupy the same geographic area at the same time. Organisms might or might not compete for the same resources in a biological community. The collection of plant and animal populations, including the school of fish, represents a biological community.

Ecosystems, biomes, and the biosphere

The next level of organization after a biological community is an ecosystem. An ecosystem is a biological community and all of the abiotic factors that affect it. As you can see in Figure 2.6, an ecosystem might contain an even larger collection of organisms than a biological community. In addition, it contains the abiotic factors present, such as water temperature and light availability. Although Figure 2.6 represents an ecosystem as a large area, an ecosystem also can be small, such as an aquarium or tiny puddle. The boundaries of an ecosystem are somewhat flexible and can change, and ecosystems even might overlap.

The next level of organization is called the biome and is one that you will learn more about in Chapter 3. A biome is a large group of ecosystems that share the same climate and have similar types of communities. The biome shown in Figure 2.6 is a marine biome. All of the biomes on Earth combine to form the highest level of organization—the biosphere.

Reading Check

Infer what other types of biomes might be found in the biosphere if the one shown in Figure 2.6 is called a marine biome.

Reading Check

Other biomes might be terrestrial, atmospheric, and subterranean.

Differentiated Instruction

Below Level

The scaffolding technique described on this page can benefit students working below level. This method of questioning will guide students through their thought processes.

For more tips, see page 14T–15T.
Visualizing Levels of Organization

Purpose
Students will identify levels of the biological hierarchy from individual organism to the biosphere. UCP.1 C.4 C.5

Skill Practice
Visual Literacy
Organize students into groups. Have each group develop a presentation that demonstrates how the levels of organization in Figure 2.6 are related. For example, students might present the information as a triangle, with Organism at the point at the top, Biosphere along the bottom, and the other levels listed between. This illustrates that each level involves more organisms than the one above it.

Interactive Figure
Students can interact with the levels of organization art at biologygmh.com.

Virtual Lab
CD-ROM
In this lab, students will explore and analyze five simplified model ecosystems.

“...The aim of education should be to teach us rather how to think, than what to think—rather to improve our minds, so as to enable us to think for ourselves, than to load the memory with thoughts of other men."

—Bill Beattie
Skill Practice

Visual Literacy Have students read the text under the heading Ecosystem Interactions and review Figure 2.7. Assign students to work in pairs to sketch a different scene containing a biological habitat of their choice. Have them include at least six organisms that live in the habitat. Tell students to list the niche of each organism on the back of their drawings.

BL Have students list four organisms that live in the habitat.

Reading Strategy

Brainstorm Arrange students in groups of two or three.

SAY TO STUDENTS: Read the new vocabulary under the heading Ecosystem Interactions. Brainstorm ideas for the meaning of each word. Write all ideas on the board for students to see. Tell students to write down the words habitat and niche and write what they consider to be the best analogy for each word beside it. For example, students’ habitat might be a school. Their niche would be learners.

Develop Concepts

Discuss The concepts of habitat and niche are often confused with each other.

ASK STUDENTS: How is a habitat different from a niche?
The niche is a characteristic of a species and the niche involves the role an individual organism plays in the community. A habitat is the physical area in which the organism lives. What is an example of a habitat and an individual’s niche in that habitat? Answers will vary, but should distinguish between an organism and its habitat.

Ecosystem Interactions

The interactions between organisms are important in an ecosystem. A community of organisms increases the chances for survival of any one species by using the available resources in different ways. If you look closely at a tree in the forest, like the one shown in Figure 2.7, you will find a community of different birds using the resources of the tree in different ways. For example, one bird species might eat insects on the leaves while another species of bird eats the ants found on the bark. The chance of survival for the birds increases because they are using different resources.

The trees shown in Figure 2.7 also are habitats. A habitat is an area where an organism lives. A habitat might be a single tree for an organism that spends its life on one tree. If the organism moves from tree to tree, its habitat would be a grove of trees.

Organisms not only have a habitat—they have a niche as well. A niche (NIHCH) is the role or position that an organism has in its environment. An organism’s niche is how it meets its needs for food, shelter, and reproduction. The niche might be described in terms of requirements for living space, temperature, moisture, or in terms of appropriate mating or reproduction conditions.

Reading Check Compare and contrast a habitat and a niche.

Community Interactions

Organisms that live together in a biological community constantly interact. These interactions, along with the abiotic factors, shape an ecosystem. Interactions include competition for basic needs such as food, shelter, and mates, as well as relationships in which organisms depend on each other for survival.

Competition Competition occurs when more than one organism uses a resource at the same time. Resources are necessary for life and might include food, water, space, and light. For example, during a drought, as shown in Figure 2.8, water might be scarce for many organisms. The strong organisms directly compete with the weak organisms for survival. Usually the strong survive and the weak die. Some organisms might move to another location where water is available. At times when water is plentiful, all organisms share the resources and competition is not as fierce.

Predation Many, but not all, species get their food by eating other organisms. The act of one organism consuming another organism for food is predation (prih DAY shun). The organism that pursues another organism is the predator, and the organism that is pursued is the prey. If you have watched a cat catch a bird or mouse, you have witnessed a predator catch its prey.

Reading Check A habitat is an area. A niche is the role an organism plays in its environment.

Demonstration

Illustrate a Niche Show the class a fallen log or branch with bracket fungus or other fungi on it.

ASK STUDENTS: How is the fungus using the branch? The log or branch is a habitat for the fungus. What is one example the niche of the fungus? The fungus is a decomposer, taking its nutrients from the wood. Est. time: 5 min
Some insects also prey on other insects. Ladybugs and praying mantises are two examples of insects that are predators. Some insect predators also are called beneficial insects because they are used by organic gardeners for insect control. Instead of using insecticides, organic gardeners use beneficial insects to control other insect populations.

Animals are not the only organisms that are predators. The Venus flytrap, a plant native to some regions of North and South Carolina, has modified leaves that form small traps for insects and other small animals. The plant emits a sweet, sticky substance that attracts insects. When the insect lands on the leaf, the leaf trap snaps shut. Then, the plant secretes a substance that digests the insect over several days.

**Symbiotic relationships** Some species survive because of relationships they have developed with other species. The close relationship that exists when two or more species live together is **symbiosis** (sihm bee OH sus). There are three different kinds of symbiosis: mutualism, commensalism, and parasitism.

**Mutualism** The relationship between two or more organisms that live closely together and benefit from each other is **mutualism** (MYEW chuh wuh lih zum). Lichens, shown in **Figure 2.9**, display an example of a mutualistic relationship between fungi and algae. The tree merely provides a habitat for lichens, allowing it to receive ample sunlight. The algae provide food for the fungi, and the fungi provide a habitat for the algae. The close association of these two organisms provides two basic needs for the organisms—food and shelter.

**Data Analysis Lab 2.1**

**Based on Real Data**

**Analyze the Data**

Does temperature affect growth rates of protozoans? Researchers studied the effect of temperature on the growth rates of protozoans. They hypothesized that increasing temperature would increase the growth rate of the protozoans.

**Data and Observations**

The graph shows the effect of temperature on the growth rate of *Colpidium* and *Paramecium*.

**Think Critically**

1. Describe the differences in population growth for the two species.
2. Evaluate What could be the next step in the researcher’s investigation?

---

**Real-World Connection** The number of symbiotic relationships is enormous. Studies indicate that there might be as many as 50 million species that have some type of symbiotic relationship, instead of the 1.5 million presently known. For example, yeasts, one of the best-studied of all groups of microbes, have many more symbiotic species than the 1,000 presently named. At least 200 species of yeasts were recently found in the guts of beetle species.

---

**About the Lab**

- Some students will need help in reading the graph. Explain that the x-axis shows the three experimental temperatures and the y-axis the growth rate of the protozoans, in hours.

**Think Critically**

1. *Colpidium* grows faster than *Paramecium* at 22°C and 26°C, but *Paramecium* grows faster at 30°C.
2. Sample answer: Test the growth rates for both at 34°C.

---

**Caption Question** Fig. 2.9 In a mutualistic relationship, both species benefit from the relationship. The algae provide food for the fungi and the fungi provide a habitat for the algae.
Abiotic and biotic factors shape an ecosystem and the tree. The lichens benefit from the relationship by gaining more exposure to sunlight, but they do not harm the tree. This type of relationship is commensalism.

Commensalism (kuh MEN suh lih zum) is a relationship in which one organism benefits and the other organism is neither helped nor harmed.

The relationship between clownfish and sea anemones is another example of commensalism. Clownfish are small, tropical marine fish. Clownfish swim among the stinging tentacles of sea anemones without harm. The sea anemones protect the fish from predators while the clownfish eat bits of food missed by the sea anemones. This is a commensal relationship because the clownfish receives food and protection while the sea anemones are not harmed, nor do they benefit from this relationship.

Parasitism A symbiotic relationship in which one organism benefits at the expense of another organism is parasitism (PER us suh tih zum). Parasites can be external, such as ticks and fleas, or internal, such as bacteria, tapeworms, and roundworms, which are discussed in detail in Chapters 18 and 25. The heartworms in Figure 2.10 show how destructive parasites can be. Pet dogs in many areas of the United States are treated to prevent heartworm infestation. Usually the heartworm, the parasite, does not kill the host, but it might harm or weaken it. In parasitism, if the host dies, the parasite also would die unless it quickly finds another host.

Another type of parasitism is brood parasitism. Brown-headed cowbirds demonstrate brood parasitism because they rely on other bird species to build their nests and incubate their eggs. A brown-headed cowbird lays its eggs in another bird’s nest and abandons the eggs. The host bird incubates and feeds the young cowbirds. Often the baby cowbirds push the host’s eggs or young from the nest, resulting in the survival of only the cowbirds. In some areas, the brown-headed cowbirds have significantly lowered the population of songbirds through this type of parasitism.

Formative Assessment Evaluation Have students differentiate between the three categories of symbiosis and give an example of each. The three categories are mutualism, commensalism, and parasitism. Examples will vary.

Remediation Give each student three index cards. Have them write the types of symbiosis explained in this section on one side and make a visual cue on the other side. One helpful way for students to visualize symbiosis is to use plus and minus signs. For example, with mutualism, both organisms benefit, so it can be represented with $+/+$. Parasitism: $+/−$, and commensalism: $+/0$ (0 can represent no effect.) Then allow students to trade cards with the code side up and identify the type of symbiosis. Have students use the cards to quiz each other on these relationships.

**Section 2.1 Assessment**

**Section Summary**
- Ecology is the branch of biology in which interrelationships between organisms and their environments are studied.
- Levels of organization in ecological studies include individual, population, biological community, ecosystem, biome, and biosphere.
- Abiotic and biotic factors shape an ecosystem and determine the communities that will be successful in it.
- Symbiosis is the close relationship that exists when two or more species live together.

**Understand Main Ideas**
1. **MAIN IDEA** Compare and contrast biotic and abiotic factors.
2. Describe the levels of organization of an organism that lives in your biome.
3. List at least two populations that share your home.
4. Differentiate between the habitat and niche of an organism that is found in your community.

**Think Scientifically**
5. Design an experiment that determines the symbiotic relationship between a sloth, which is a slow-moving mammal, and a species of green algae that lives in the sloth’s fur.
6. **WRITING IN BIOLOGY** Write a short story that demonstrates the dependence of all organisms on other organisms.

**Self-Check Quiz**

1. Biotic factors are alive. Abiotic factors are not alive.
2. Answers will vary according to location and student choices. All answers should include the following levels: organism, population, biological community, ecosystem, biome, biosphere.
3. Answers will vary. Sample answer: my family and my dogs.
4. Answers will vary depending on student choices. All answers should clearly distinguish between a habitat (which is an area) and a niche (which is a role).
5. Experiments will vary. Students may try to determine if the green algae provides the sloth with camouflage or the sloth provides the green algae with a habitat.
6. **RUBRIC** Use the modifiable rubric found on your TeacherWorks™ CD-ROM to assess writing assignments. Stories will vary, but students should note a broad range of organisms from all kingdoms.

40 Chapter 2 • Principles of Ecology
Flow of Energy in an Ecosystem

**Main Idea** Autotrophs capture energy, making it available for all members of a food web.

**Real-World Reading Link** When you eat a slice of pizza, you are supplying your body with energy from the Sun. You might be surprised to learn that the Sun is the original source of energy for your body. How did the Sun’s energy get into the pizza?

**Energy in an Ecosystem**

One way to study the interactions of organisms within an ecosystem is to follow the energy that flows through an ecosystem. Organisms differ in how they obtain energy, and they are classified as autotrophs or heterotrophs based on how they obtain their energy in an ecosystem.

**Autotrophs** All of the green plants and other organisms that produce their own food in an ecosystem are primary producers called autotrophs. An autotroph (AW tuh trohf) is an organism that collects energy from sunlight or inorganic substances to produce food. As you will learn in Chapter 8, organisms that have chlorophyll absorb energy during photosynthesis and use it to convert the inorganic substances carbon dioxide and water to organic molecules. In places where sunlight is unavailable, some bacteria use hydrogen sulfide and carbon dioxide to make organic molecules to use as food. Autotrophs are the foundation of all ecosystems because they make energy available for all other organisms in an ecosystem.

**Heterotrophs** A heterotroph (HE tuh roh trohf) is an organism that gets its energy requirements by consuming other organisms. Therefore, heterotrophs also are called consumers. A heterotroph that eats only plants is an herbivore (HUR buh vor) such as a cow, a rabbit, or grasshopper. Heterotrophs that prey on other heterotrophs, such as wolves, lions, and lynxes, shown in Figure 2.11, are called carnivores (KAR nuh vorz).

**Differentiated Instruction**

**Hearing Impaired** When students with hearing difficulties are in the classroom, be sure that the lighting is adequate. Good lighting will allow students to see your lips and facial expressions clearly, which will help with their understanding.

For more tips, see pages 14T–15T.

**Caption Question** Fig. 2.11 carnivore and herbivore

**BL OL AL**

**Organisms Need Energy**

**ASK STUDENTS:** What is the process by which autotrophs convert light energy into chemical energy? Photosynthesis In Section 2, students will learn how energy flows in one direction through an ecosystem. Have students read carefully to learn the reason why energy cannot be recycled through a system.

**Reading Strategy**

**OL AL** Activate

**Background Vocabulary**

**SAY TO STUDENTS:** Four of the vocabulary words for this section end in the suffix –vore. This suffix comes from the Latin word vorare, meaning “eat” or “devour.”

**ASK STUDENTS:** How can this help you understand the meaning of these words? Each has something to do with eating. Lead a discussion in which students try to work out the meanings of each of the new vocabulary terms.

**Critical Thinking**

**AL Evaluate** Have students evaluate the benefits of being an autotroph or heterotroph. Autotrophs can produce their own food, so they do not rely on other organisms for food sources. Heterotrophs rely on other organisms for food, including autotrophs and other heterotrophs.
In addition to herbivores and carnivores, there are organisms that eat both plants and animals, called omnivores (AHM nih vorz). Bears, humans, and mockingbirds are examples of omnivores.

The detritivores (duh TRYD uh vorz), which eat fragments of dead matter in an ecosystem, return nutrients to the soil, air, and water where the nutrients can be reused by organisms. Detritivores include worms and many aquatic insects that live on stream bottoms. They feed on small pieces of dead plants and animals. Decomposers, similar to detritivores, break down dead organisms by releasing digestive enzymes. Fungi, such as those in Figure 2.12, and bacteria are decomposers.

All heterotrophs, including detritivores, perform some decomposition when they consume another organism and break down its body into organic compounds. However, it is primarily the decomposers that break down organic compounds and make nutrients available to producers for reuse. Without the detritivores and decomposers, the entire biosphere would be littered with dead organisms. Their bodies would contain nutrients that would no longer be available to other organisms. The detritivores are an important part of the cycle of life because they make nutrients available for all other organisms.

Models of Energy Flow
Ecologists use food chains and food webs to model the energy flow through an ecosystem. Like any model, food chains and food webs are simplified representations of the flow of energy. Each step in a food chain or food web is called a trophic (TROH fik) level. Autotrophs make up the first trophic level in all ecosystems. Heterotrophs make up the remaining levels. With the exception of the first trophic level, organisms at each trophic level get their energy from the trophic level before it.

Construct a Food Web

**How is energy passed from organism to organism in an ecosystem?** A food chain shows a single path for energy flow in an ecosystem. The overlapping relationships between food chains are shown in a food web.

**Procedure**
1. Read and complete the lab safety form.
2. Use the following information to construct a food web in a meadow ecosystem:
   - Red foxes feed on raccoons, crayfishes, grasshoppers, red clover, meadow voles, and gray squirrels.
   - Red clover is eaten by grasshoppers, muskrats, red foxes, and meadow voles.
   - Meadow voles, gray squirrels, and raccoons all eat parts of the white oak tree.
   - Crayfishes feed on green algae and detritus, and they are eaten by muskrats and red foxes.
   - Raccoons feed on muskrats, meadow voles, gray squirrels, and white oak trees.

**Analysis**
1. **Identify** all of the herbivores, carnivores, omnivores, and detritivores in the food web.
2. **Describe** how the muskrats would be affected if disease kills the white oak trees.

---

**Caption Question** Fig. 2.12
Decomposers are important to ecosystems because they break down dead organisms and detritus so that producers can reuse the nutrients stored there.

**Demonstration**
**BL QL AL Autotrophs** Bring in a piece of sod or grow some grass in a pot. Pet grass can also be purchased at pet stores. Also, place a jar or beaker containing pond water with algae at the front of the room.

**ASK STUDENTS:** What do the grass and the algae have in common? Answers will vary. Sample answer: Grass and some algae are green. Moreover, they are both autotrophic organisms that carry on photosynthesis. Discuss with students how these producers provide energy for different ecosystems. Est. time: 5 min

**Est. Time** 30 min

**Safety Precautions** Approve lab safety forms before work begins.

**Teaching Strategy** Students could work on this lab individually or in small groups.

**Analysis**
1. Herbivores: grey squirrels, grasshoppers, meadow voles, crayfishes; carnivores: none; omnivores: raccoons, red foxes, muskrats; detritivores: crayfishes
2. Sample answer: Removing the white oak from the system would force other animals, such as meadow voles, to eat the red clover, so there would be less clover for the muskrats to eat. Furthermore, raccoons would no longer have white oak to eat, so they may increase their consumption of muskrats.
Food chains. A food chain is a simple model that shows how energy flows through an ecosystem. Figure 2.13 shows a typical grassland food chain. Arrows represent the one-way energy flow which typically starts with autotrophs and moves to heterotrophs. The flower uses energy from the Sun to make its own food. The grasshopper gets its energy from eating the flower. The mouse gets its energy from eating the grasshopper. Finally, the snake gets its energy from eating the mouse. Each organism uses a portion of the energy it obtains from the organism it eats for cellular processes to build new cells and tissues. The remaining energy is released into the surrounding environment and no longer is available to these organisms.

Food webs. Feeding relationships usually are more complex than a single food chain because most organisms feed on more than one species. Birds, for instance, eat a variety of seeds, fruits, and insects. The model most often used to represent the feeding relationships in an ecosystem is a food web. A food web is a model representing the many interconnected food chains and pathways in which energy flows through a group of organisms. Figure 2.14 shows a food web illustrating the feeding relationships in a desert community.

Develop Concepts

BL OL AL Discuss

SAY TO STUDENTS: In the previous section, you learned about predatory relationships.

ASK STUDENTS: What kind of animal is a predator? Students may say that predators are carnivores. A few might be less specific and say consumers. If students say all consumers are predators, point out that herbivores and scavengers are consumers that are not predatory. Can an animal be a predator and not be a carnivore? Yes, some omnivores might be predatory at least part of the time.

Develop Concepts

OL Clarify a Misconception

ASK STUDENTS: Does a food chain have an end? Answers will vary. Explain the important conservation law of physics: that both matter and/or energy are neither created nor destroyed over time—they merely change form, and their sum remains the same. Students will learn more about recycling of nutrients in the next section.

BI Show students examples of food chains and food webs before asking the question.

Interactive Figure. Students can interact with the food web art at biologygmh.com.

Demonstration

Food Chains. Using available living materials such as algae, mosquito larvae, and minnows, or using photos that have been cut from magazines, show students a food chain that contains at least three links. Est. time: 10 min.

Food chains

Food webs

Figure 2.13. A food chain is a simplified model representing the transfer of energy from organism to organism.

Figure 2.14. A food web is a model of the many ways in which energy flows through organisms.
Energy moves through an ecosystem. As shown in the pyramid shown in Figure 2.15, numbers compare and contrast a food chain and a food web. Draw an ecological pyramid models used to represent trophic levels in ecosystems.

**Ecological pyramids** Another model that ecologists use to show how energy flows through ecosystems is the ecological pyramid. An ecological pyramid is a diagram that can show the relative amounts of energy, biomass, or numbers of organisms at each trophic level in an ecosystem. Notice in Figure 2.15 that in a pyramid of energy, approximately 90 percent of all energy is not transferred to the level above it. This occurs because most of the energy contained in the organisms at each level is consumed by cellular processes or released to the environment as heat. Usually, the amount of biomass—the total mass of living matter at each trophic level—decreases at each trophic level. As shown in the pyramid of numbers, the relative number of individuals at each trophic level also decreases because there is less energy available to support organisms.

### Section 2.2 Assessment

#### 1. Autotrophs and heterotrophs both require energy, but autotrophs collect energy from sunlight or from inorganic substances to produce food. Heterotrophs get energy by consuming other organisms.

#### 2. Sample answer: grass → zebra → lion

#### 3. A family dog is a heterotroph. A dog is also an omnivore because commercial dog food contains both animal and plant products.

#### 4. Sample answer: As the Sun produced less and less energy, the producers would have less and less energy to capture. Consumers would have fewer producers to eat, and the available producers would be small. Carnivores would have fewer consumers to eat. When the Sun burned out, the system would stop.

#### 5. Answers will vary, but all food webs should include producers, herbivores, carnivores, and detrivores.

#### 6. The pyramid should show grass (100 percent available energy) at the lowest level, followed by caterpillar (10 percent available energy), tiger beetle (1 percent available energy), lizard (0.1 percent available energy), snake (0.01 percent available energy), and roadrunner (0.001 percent available energy) at the top.
Nutrients are cycled through the biosphere through organisms. In this ecosystem, the green grass—to consumers. Decomposers return the nutrients to the cycle at every level.

The cycling of nutrients in the biosphere involves the biotic and abiotic parts of the environment. The exchange of matter through the biosphere is called the biogeochemical cycle. As the name suggests, these cycles involve living organisms (bio), geological processes (geo), and chemical processes (chemical).

Reading Check Explain why it is important to living organisms that nutrients cycle.

Nutrients Show product labels from a variety of cereal boxes, soup cans, and other food. Point out on the labels where the nutrient content of the food is listed, and indicate which nutrients are biological, such as carbohydrates and protein, and which are biogeochemicals, such as calcium and phosphorus. Est. time: 10 min
The water cycle Living organisms cannot live without water. Hydrologists study water found underground, in the atmosphere, and on the surface of Earth in the form of lakes, streams, rivers, glaciers, ice caps, and oceans. Use Figure 2.17 to trace processes that cycle water through the biosphere.

Connection Earth Science Water is constantly evaporating into the atmosphere from bodies of water, soil, and organisms. Water in the atmosphere is called water vapor. Water vapor rises and begins to cool in the atmosphere. Clouds form when the cooling water vapor condenses into droplets around dust particles in the atmosphere. Water falls from clouds as precipitation in the form of rain, sleet, or hail, transferring water to the Earth’s surface. As you can see in Figure 2.17, groundwater and runoff from land surfaces flow into streams, rivers, lakes, and oceans, only to evaporate into the atmosphere to continue the water cycle. Approximately 90 percent of water vapor evaporates from oceans, lakes, and rivers; about 10 percent evaporates from the surface of plants through a process called transpiration. You will learn more about transpiration in Chapter 22.

All living organisms rely on freshwater. Freshwater constitutes only about 3 percent of all water on Earth. Water available for living organisms is about 31 percent of all freshwater. About 69 percent of all freshwater is found in ice caps and glaciers, which then is unavailable for use by living organisms. Even ocean-dwelling organisms rely on freshwater flowing to oceans to prevent high saline content and maintain ocean volume.

Reading Check Identify three processes in the water cycle.

Figure 2.17 The largest reservoirs of water on Earth?

Captain Question Fig. 2.17 The largest reserves of water are the oceans.

Reading Check Three processes in the water cycle are evaporation, condensation, and precipitation.
The carbon and oxygen cycles As you will learn in Chapter 6, all living things are composed of molecules that contain carbon. Atoms of carbon form the framework for important molecules such as proteins, carbohydrates, and fats. Oxygen is another element that is important to many life processes. Carbon and oxygen often make up molecules essential for life, including carbon dioxide and simple sugar.

Look at the cycles illustrated in Figure 2.18. During a process called photosynthesis, discussed in Chapter 8, green plants and algae convert carbon dioxide and water into carbohydrates and release oxygen back into the air. These carbohydrates are used as a source of energy for all organisms in the food web. Carbon dioxide is recycled when autotrophs and heterotrophs release it back into the air during cellular respiration. Carbon and oxygen recycle relatively quickly through living organisms.

Carbon enters a long-term cycle when organic matter is buried underground and converted to peat, coal, oil, or gas deposits. The carbon might remain as fossil fuel for millions of years. Carbon is released from fossil fuels when they are burned, which adds carbon dioxide to the atmosphere.

In addition to the removal of carbon from the short-term cycle by fossil fuels, carbon and oxygen can enter a long-term cycle in the form of calcium carbonate, as shown in Figure 2.19. Calcium carbonate is found in the shells of plankton and animals such as coral, clams, and oysters. These organisms, such as algae, fall to the bottom of the ocean floor, creating vast deposits of limestone rock. Carbon and oxygen remain trapped in these deposits until weathering and erosion release these elements to become part of the short-term cycle.

Caption Question  Fig. 2.18 Carbon moves from the abiotic parts of the ecosystem when producers convert carbon dioxide into food.

Going Further Have students draw a Venn diagram on the back of their Foldables to compare the nitrogen cycle and the phosphorus cycle. Diagrams will vary, but might include overlapping zones such as “absorbed into organisms” and “returned to the environment when organism decomposes.”

Skill Practice

SAY TO STUDENTS: Look closely at Figure 2.18 and read the caption.
ASK STUDENTS: Where in the carbon-oxygen cycle do you see carbon and oxygen intertwined? Carbon and oxygen are found together in CO₂, carbonate rock, fossil fuels, and in living material. Stress the fact that life on Earth, as it is presently understood, could not have evolved without the presence of carbon and oxygen.

Critical Thinking

ASK STUDENTS: Based on your understanding of the carbon cycle, predict what might happen if large areas of tropical rainforest continue to be cleared. Carbon dioxide would continue to build up in the atmosphere without the plants that use the CO₂ for photosynthesis.
**Interactive Figure** Students can interact with the nitrogen cycle art at biologygmh.com.

---

**Mini Lab 2.2**

See FAST FILE Unit 1 Resources, MiniLab worksheet.

**RUBRIC** A rubric for evaluating MiniLabs is found on your TeacherWorks™ CD-ROM.

**Est. Time** 30 min

**Safety Precaution** Approve lab safety forms before work begins.

**Teaching Strategies**
- Water samples and a nitrate test kit can be purchased from biological supply companies.
- This could also be done as a demonstration to save time and materials.
- Encourage students to think about how household practices, such as fertilizing the lawn, contribute to nitrate pollution.

**Analysis**

1. The samples probably contained different amounts of nitrate because different water sources are going to contain different levels of contamination.
2. Sample answer: agricultural activities and lawn maintenance
3. Sample answer: An increase in algae could cause an algal bloom, which can cause human health problems.

**Test for Nitrates**

How much nitrate is found in various water sources? One ion containing nitrogen found in water can be easily tested—nitrate. Nitrate is a common form of inorganic nitrogen that is used easily by plants.

**Procedure**

1. Read and complete the lab safety form.
2. Prepare a data table to record your observations.
3. Obtain the water samples from different sources that are provided by your teacher.
4. Using a nitrate test kit, test the amount of nitrate in each water sample.
5. Dispose of your samples as directed by your teacher.

**Analysis**

1. **Determine** Did the samples contain differing amounts of nitrate? Explain.
2. **Identify** What types of human activities might increase the amount of nitrate in the water?
3. **Infer** What problems could a high nitrate level cause considering that nitrates also increase the growth rate of algae in waterways?

---

**Demonstration**

**Mineral Cycles** Display an empty fertilizer carton or bag. Show students the label that lists the amount of each mineral. Instruct students how to read the contents of the fertilizer. Point out the amount of nitrogen, phosphorus, and potassium in the fertilizer. Tell students that applying large quantities of fertilizer to an area adds excess biochemicals to the food web. Est. time: 5 min

---

**Figure 2.20** Nitrogen is used and reused as it is cycled continuously through the biosphere.

To see an animation of the nitrogen cycle, visit biologygmh.com.

---

The nitrogen cycle Nitrogen is an element found in proteins. The largest concentration of nitrogen is found in the atmosphere. Plants and animals cannot use nitrogen directly from the atmosphere. Nitrogen gas is captured from the air by species of bacteria that live in water, the soil, or grow on the roots of some plants. The process of capture and conversion of nitrogen into a form that is usable by plants is called nitrogen fixation. Some nitrogen also is fixed during electrical storms when the energy from lightning bolts changes nitrogen gas to nitrates. Nitrogen also is added to soil when chemical fertilizers are applied to lawns, crops, or other areas.

Nitrogen enters the food web when plants absorb nitrogen compounds from the soil and convert them into proteins, as illustrated in Figure 2.20. Consumers get nitrogen by eating plants or animals that contain nitrogen. They reuse the nitrogen and make their own proteins. Because the supply of nitrogen in a food web is dependent on the amount of nitrogen that is fixed, nitrogen often is a factor that limits the growth of producers.

Nitrogen is returned to the soil in several ways, also shown in Figure 2.20. When an animal urinates, nitrogen returns to the water or soil and is reused by plants. When organisms die, decomposers transform the nitrogen in proteins and other compounds into ammonia. Organisms in the soil convert ammonia into nitrogen compounds that can be used by plants. Finally, in a process called denitrification, some soil bacteria convert fixed nitrogen compounds back into nitrogen gas, which returns it to the atmosphere.
The phosphorus cycle Phosphorus is an element that is essential for the growth and development of organisms. Figure 2.21 illustrates the two cycles of phosphorus—a short-term and long-term cycle. In the short-term cycle, phosphorus as phosphates in solution, is cycled from the soil to producers and then from the producers to consumers. When organisms die or produce waste products, decomposers return the phosphorus to the soil where it can be used again. Phosphorus moves from the short-term cycle to the long-term cycle through precipitation and sedimentation to form rocks. In the long-term cycle, weathering or erosion of rocks that contain phosphorus slowly adds phosphorus to the cycle. Phosphorus, in the form of phosphates, may be present only in small amounts in soil and water. Therefore, phosphorus often is a factor that limits the growth of producers.

**Section 2.3 Assessment**

**Section Summary**
- Biogeochemical cycles include the exchange of important elements between the abiotic and biotic parts of an ecosystem.
- The carbon and oxygen cycles are closely intertwined.
- Nitrogen gas is limited in its ability to enter biotic portions of the environment.
- Phosphorus and carbon have short-term and long-term cycles.

**Understand Main Ideas**
1. **MAKE A LIST** List four important biogeochemical processes that cycle nutrients.
2. **COMPARE AND CONTRAST** two of the cycles of matter.
3. **EXPLAIN** the importance of nutrients to an organism of your choice.
4. **DESCRIBE** how phosphorus moves through the biotic and abiotic parts of an ecosystem.

**Think Scientifically**

5. **Design an Experiment**

Suppose a particular fertilizer contains nitrogen, phosphorus, and potassium. The numbers on the fertilizer's label represent the amounts of each element in the fertilizer. Design an experiment to test how much fertilizer should be added to a lawn for the best results.

**Formative Assessment**

**Evaluation** Have students draw the steps of the carbon, nitrogen, and phosphorus cycles. Have them label each step of each cycle. See Figures 2.18, 2.20, and 2.21 in this section for reference.

**Remediation** Have students work in pairs to draw each step of each cycle on an index card. When they are finished, have students shuffle the cards together and put the steps for each cycle in sequence.

**Self-Check Quiz** biologygmh.com
Purpose
Students will describe ways in which damming a river impacts the ecosystem. Students will evaluate the pros and cons of damming a river in terms of the biological, economic, and recreational impacts on the area. C.4, F.3, F.5, F.6

Anticipatory Guide
ASK STUDENTS: Why do people build dams? Sample answers: for flood control, or hydroelectric power. What are some positive side effects of building a dam? the creation of lakes and recreation areas around the lakes, flood control, and hydroelectric power. In this feature, students will learn how damming a river impacts the ecosystem as well as the economic gains that can result from a dam.

Background
The Glen Canyon Dam project has not been without controversy. Some say that it was the building of the Glen Canyon Dam that kicked off the original environmental movement back in the early 1960s because of how it would affect the Colorado River.

To Dam or Not to Dam
The Glen Canyon area is a popular location for white-water rafting, fishing, hiking, and kayaking. The Glen Canyon area also is the location of a controversial dam, the Glen Canyon Dam. It was built between 1956 and 1963 in Arizona on the Colorado River. The dam holds and releases water from Lake Powell.

Economic benefits The Glen Canyon Dam provides electricity to many rural communities. It also provides water to California, New Mexico, Arizona, and Nevada. Lake Powell, which is one of the most visited tourist destinations of the southwest, provides jobs for many of the local residents. Millions of tourists visit Lake Powell each year for activities such as hiking, boating, fishing, and swimming.

Impact on temperature Before the dam was built, the water temperature of the Colorado River ranged from near freezing in the winter to a warm 29°C in the summer. Since the dam was built, the temperature of the water released downstream remains steady at 7–10°C. This temperature is fine for the nonnative trout that are bred for recreational activities; however, the native species do not fare as well.

The Glen Canyon Dam has negatively impacted the ecosystem of the Colorado River area, but it has benefited the area economically. How do the costs weigh against the benefits? Biologists face real-world issues like these every day.

Impact on flora and fauna The construction of the dam has brought economic benefits to the area, but it also has negatively impacted the Colorado River ecosystem. The habitat of native fish has changed as a result of the dam. Three species of fish—the round-tail chub, the bonytail chub, and the Colorado squawfish—have become extinct.

The Lake Powell shoreline now is dominated by a non-native, semidesert scrub known as saltcedar or tamarisk. The saltcedar outcompetes native vegetation such as the sandbar willow, Gooding’s willow, and fremont cottonwood. Saltcedar collects salt in its tissues over time. This salt eventually is released into the soil, making it unsuitable for many native plants.

Collaborate This is an example of a real-world situation that has both positive and negative effects. If a dam is necessary, careful planning—including ecological modeling and impact studies—can minimize its damage to the ecosystem. Have students research both sides of the issue and come to class prepared to debate either side. After students debate the issue, have the class vote on which side was the most persuasive. Discuss the results as a class.
FIELD INVESTIGATION: EXPLORE HABITAT SIZE AND SPECIES DIVERSITY

Background: Ecologists know that a major key to maintaining not only individual species but also a robust diversity of species is preserving the proper habitat for those species.

Question: What effect does increasing the size of a habitat have on the species diversity within that habitat?

Materials
Choose materials that would be appropriate for the experiment you plan.

Safety Precautions
WARNING: Follow all safety rules regarding travel to and from the study site. Be alert on site and avoid contact, if possible, with stinging or biting animals and poisonous plants.

Plan and Perform the Experiment
1. Read and complete the lab safety form.
2. Form a hypothesis that you can test to answer the above question.
3. Record your procedure and list the materials you will use to test your hypothesis.
4. Make sure your experiment allows for the collection of quantitative data, which is data that can be expressed in units of measure.
5. Design and construct appropriate data tables.
6. Make sure your teacher approves your plan before you proceed.
7. Carry out the procedure at an appropriate field site.

Analyze and Conclude
1. Graph Data Prepare a graph of your data and the combined class data if it is available.
2. Analyze Do any patterns emerge as you analyze your group and/or class data and graphs? Explain.
3. Conclude Based on your data, was your initial hypothesis correct?
4. Error Analysis Compare your observations and conclusions with your classmates. Did your observations and conclusions match? If not, what could explain the differences? How could you verify your results?
5. Did the populations and diversity change proportionally as the habitat was expanded? As the habitat expanded, did it become more or less suitable for supporting life?
6. Think Critically Would you expect the same results if you were to perform this experiment in other types of habitats? Explain.
7. Think Critically Would you expect the same results 10 years from now? 20 years from now? Explain your answer.

Apply Your Skill
Presentation Diagram and explain at least one food chain that might exist in the habitat you explored in this lab. To learn more about habitat size and species diversity, visit BioLabs at biologygmh.com.

Analyze and Conclude
1. Have each lab team graph their data and then use the data from all lab teams to prepare a class data table and graph.
2. Often, as the habitat grows larger, the number of different species increases.
3. Accept any reasonable conclusion that is based on data collected.
4. Answers will vary. Encourage students to share ideas about improving the lab. Lab teams in close proximity to each other may note greatly varied data. Life on Earth is not a homogenous layer. It is found in clumps. Thus, even the clumps of life found in the small neighboring study quadrants of this lab may be vastly different.
5. Answers will depend on the data collected. Generally, as the habitat expands so does the population and diversity, a direct proportion. A habitat will generally become more suitable for life as it expands.
6. Observations and results gathered from one type of habitat in one locale may not hold true for other types of habitats and situations in other locations.

7–8. Answers will vary. For example, if the area undergoes a lot of development, the results may vary substantially.
Study Guide

FOLDABLESTM The law of conservation of matter states that under normal circumstances, matter can be neither created nor destroyed. Through natural cycles, such as the water cycle, the carbon cycle, and the phosphorus cycle, matter moves through an ecosystem in the form of nutrients. Physical and chemical changes take place during these natural cycles. For example, the carbon in carbon dioxide undergoes a series of reactions and forms new substances throughout the cycle, but matter is neither created nor destroyed.

Vocabulary

Section 2.1 Organisms and Their Relationships

- abiotic factor (p. 35)
- biological community (p. 36)
- biome (p. 36)
- bioreactor (p. 34)
- biotic factor (p. 35)
- commensalism (p. 40)
- ecology (p. 32)
- ecosystem (p. 36)
- habitat (p. 38)
- mutualism (p. 39)
- niche (p. 38)
- parasitism (p. 40)
- population (p. 36)
- predation (p. 38)
- symbiosis (p. 39)

Key Concepts

MAIN Concept Biotic and abiotic factors interact in complex ways in communities and ecosystems.

- Ecology is the branch of biology in which interrelationships between organisms and their environments are studied.
- Levels of organization in ecological studies include individual, population, biological community, ecosystem, biome, and biosphere.
- Abiotic and biotic factors shape an ecosystem and determine the communities that will be successful in it.
- Symbiosis is the close relationship that exists when two or more species live together.

Section 2.2 Flow of Energy in an Ecosystem

- autotroph (p. 41)
- biomass (p. 44)
- carnivore (p. 41)
- detritivore (p. 42)
- food chain (p. 43)
- food web (p. 43)
- herbivore (p. 41)
- heterotroph (p. 41)
- omnivore (p. 42)
- trophic level (p. 42)

MAIN Concept Autotrophs capture energy, making it available for all members of a food web.

- Autotrophs capture energy from the Sun or use energy from certain chemical substances to make food.
- Heterotrophs include herbivores, carnivores, omnivores, and detritivores.
- A trophic level is a step in a food chain or food web.
- Food chains, food webs, and ecological pyramids are models used to show how energy moves through ecosystems.

Section 2.3 Cycling of Matter

- biogeochemical cycle (p. 45)
- denitrification (p. 48)
- nitrogen fixation (p. 48)
- nutrient (p. 45)

MAIN Concept Essential nutrients are cycled through biogeochemical processes.

- Biogeochemical cycles include the exchange of important elements between the abiotic and biotic parts of an ecosystem.
- The carbon and oxygen cycles are closely intertwined.
- Nitrogen gas is limited in its ability to enter biotic portions of the environment.
- Phosphorus and carbon have short-term and long-term cycles.

Vocabulary PuzzleMaker

For additional practice with vocabulary, have students access the Vocabulary PuzzleMaker online at biologygmh.com.
Section 2.1

Vocabulary Review
Replace each underlined word with the correct vocabulary term from the Study Guide page.
1. A **niche** is the place in which an organism lives.
2. The presence of interbreeding individuals in one place at a given time is called a biological community.
3. A group of biological communities that interact with the physical environment is the **biosphere**.

Understand Key Concepts
4. Which of these levels of organization includes all the other levels?
   A. community  C. individual
   B. ecosystem  D. population

5. Which would be an abiotic factor for a tree in the forest?
   A. a caterpillar eating its leaves
   B. wind blowing through its branches
   C. a bird nesting in its branches
   D. fungus growing on its roots

Use the photo below to answer questions 6 and 7.

6. The insect in the photo above is gathering pollen and nectar for food, but at the same time is aiding in the plant’s reproduction. What does this relationship demonstrate?
   A. predation  C. mutualism
   B. commensalism  D. parasitism

7. What term best describes the bee’s role of gathering pollen?
   A. niche  C. parasite
   B. predator  D. habitat

Use the illustration below to answer question 8.

8. Which type of heterotroph best describes this snake?
   A. herbivore  C. omnivore
   B. carnivore  D. detritivore

Constructed Response
9. Short Answer Explain the difference between a habitat and niche.
10. Open Ended Describe two abiotic factors that affect your environment.
11. CAREERS IN BIOLOGY Summarize why most ecologists do not study the biosphere level of organization.

Think Critically
12. Identify an example of a predator-prey relationship, a competitive relationship, and a symbiotic relationship in an ecosystem near where you live.
13. Explain why it is advantageous for organisms such as fungi and algae to form mutualistic relationships.

Section 2.2

Vocabulary Review
Explain how the terms in each set below are related.
14. heterotroph, omnivore, carnivore
15. food chain, food web, trophic level
16. decomposer, heterotroph, carnivore
17. autotroph, food chain, heterotroph

Use the photo below to answer question 18.

9. A habitat is an area where an organism lives. A niche is a role an organism plays in the habitat.
10. Student responses will vary widely, but may include abiotic factors such as temperature and rainfall.
11. There are extreme difficulties in studying the entire biosphere. It is easier and more economical to study populations, communities, or ecosystems on a local level.

Think Critically
12. Student answers will vary depending upon the examples they choose. Sample response: A predator-prey relationship exists between starlings that eat worms. The starlings may compete among themselves for the worms. Lice may be parasitic on the skin of the starlings.
13. Each organism benefits from the other, because each organism provides something the other cannot get on its own.
**Understand Key Concepts**

18. B  
19. A  
20. A  
21. D  
22. D  

**Constructed Response**

23. Answers will vary. For example: grass → grasshopper → starling, or something similar. Students should not just say insect or bird, but should name a specific kind.  
24. Food webs are more complex than food chains; they are better models for showing energy flow in communities or ecosystems because they can show more detail.  
25. 990 calories  

**Think Critically**

26. Posters will vary depending upon the area of the country where you live. Accept all reasonable food web interactions.

---

**Section 2.3**

**Vocabulary Review**

27. nutrient  
28. nitrogen fixation  
29. biogeochemical cycle  

**Understand Key Concepts**

30. D  
31. B  

**Constructed Response**

23. Open Ended Illustrate a three-step food chain that might occur in your community. Use specific organisms.  
24. Short Answer Describe why food webs usually are better models for explaining energy flow than food chains.  
25. Short Answer Determine approximately how much total energy is lost from a three-step food chain if 1000 calories enter at the autotroph level.  
26. Apply Information Create a poster of a food web that might exist in an ecosystem that differs from your community. Include as many organisms as possible in the food web.  

---

**Section 2.3**

**Vocabulary Review**

Each of the following sentences is false. Make each sentence true by replacing the italicized word with a vocabulary term from the Study Guide page.  
27. Because nitrogen is required for growth, it is considered an essential nitrate.  
28. Converting nitrogen from a gas to a useable form by bacteria is denitrification.  
29. The movement of chemicals on a global scale from abiotic through biotic parts of the environment is a lithospheric process.  

**Understand Key Concepts**

30. What is the name of the process in which bacteria and lightning convert nitrogen into compounds that are useful to plants?  
   A. ammonification  
   B. denitrification  
   C. nitrate cycling  
   D. nitrogen fixation  

Use the following diagram to answer question 31.

---

**Understand Key Concepts**

31. Where is the largest concentration of nitrogen found?  
   A. animals  
   B. atmosphere  
   C. bacteria  
   D. plants
32. What are the two major life processes that involve carbon and oxygen?
   A. coal formation and photosynthesis  
   B. photosynthesis and respiration  
   C. fuel combustion and open burning  
   D. death and decay  

33. Which process locks phosphorus in a long-term cycle?
   A. organic materials buried at the bottom of oceans  
   B. phosphates released into the soil  
   C. animals and plants eliminating wastes  
   D. rain eroding mountains  

**Constructed Response**

34. **Short Answer** Clarify what is meant by the following statement: Grass is just as important as the din of a carnivore such as a fox.

35. **Short Answer** The law of conservation of matter states that matter cannot be created or destroyed. How does this law relate to the cycling of carbon in an ecosystem?

36. **Short Answer** Explain the role of decomposers in the nitrogen cycle.

**Think Critically**

*Use the illustration below to answer question 37 and 38.*

37. **Interpret Scientific Illustrations** Predict the effect of additional mountain building in the Rocky Mountains on the levels of phosphorus in the surrounding valleys.

38. **Explain** how decomposers supply phosphorus to soil, groundwater, oceans, lakes, ponds, and rivers.

**Additional Assessment**

39. **Writing in Biology** Write a poem that includes vocabulary terms and concepts from the chapter.

**Document-Based Questions**

The following information pertains to an ancient sand dune in Florida that is now landlocked—Lake Wales Ridge. Read the passage and answer the following questions.


The federally listed animals that live on the ridge are the blue-tailed mole skink, the Florida scrub jay, and the sand skink (which seems to “swim” through loose sand of the scrub). Other animals on the ridge are the eastern indigo snake (which can grow to more than eight feet long, making it the longest nonvenomous snake species in North America), the Florida black bear, the Florida gopher frog, the Florida mouse, the Florida pine snake, the Florida sandhill crane, the Florida scrub lizard, the gopher tortoise, Sherman’s fox squirrel, and the short-tailed snake.

The gopher tortoise is particularly important because its burrows, sometimes as long as thirty feet, serve as homes for several of the rare species as well as many other more common organisms. The burrows also provide temporary havens when fires sweep through the area, or when temperatures reach high or low extremes.

40. Construct a simple food web using at least five of the organisms listed.

41. Explain how the burrows are used during fires and why they are effective.

**Cumulative Review**

42. Distinguish between science and pseudoscience. (Chapter 1)

43. Describe conditions under which a controlled experiment occurs. (Chapter 1)

**Answers:**

32. B  
33. A  

**Constructed Response**

34. It is true that the fox depends on mice for food. However, the mice depend on producers for food. Without the grass, there could be no mice and, therefore, no foxes.

35. Carbon can be converted into different chemical compounds and used first by one organism and then by another before entering the atmosphere for recycling, but the carbon atoms are never created nor destroyed.

36. The decomposers break down tissues and wastes and release nitrogen-containing compounds that are converted to other nitrogen-containing compounds or nitrogen gas.

**Think Critically**

37. Available phosphorus levels would increase. These increases could allow greater plant growth and higher animal productivity.

38. Decomposers break down organisms, which allows the phosphorus in the organisms to go back into the ecosystem.

**Additional Assessment**

40. Students should produce a food web with the maximum number of possible connections.

41. Organisms hide in the burrows to escape fires. They are effective because they are underground shelters that are out of the way of the fire.

**Document-Based Questions**


42. Science is a body of knowledge based on the study of nature and its physical setting. Pseudoscience is an area of study that tries to imitate science.

43. A controlled experiment is an investigation in which only one factor, called the independent variable, is changed at the time. Data is gathered about the changes in the dependent variable. Other experimental conditions are held constant, and a control group might be used for comparison.
1. Which would be considered an ecosystem?
   A. bacteria living in a deep ocean vent
   B. biotic factors in a forest
   C. living and nonliving things in a pond
   D. populations of zebras and lions

   Use the illustration below to answer questions 2 and 3.

2. Which part of the diagram above relates to carbon leaving a long-term cycle?
   A. Dissolved CO₂
   B. Fuel combustion
   C. Photosynthesis and respiration
   D. Volcanic activity

3. Which part of the diagram above relates to carbon moving from an abiotic to a biotic part of the ecosystem?
   A. Dissolved CO₂
   B. Fuel combustion
   C. Photosynthesis and respiration
   D. Volcanic activity

4. Which is a scientific explanation of a natural phenomenon supported by many observations and experiments?
   A. factor
   B. hypothesis
   C. result
   D. theory

5. The mole is the SI unit for which quantity?
   A. number of particles in a substance
   B. compounds that make up a substance
   C. number of elements in a substance
   D. total mass of a substance

6. Suppose two leaf-eating species of animals live in a habitat where there is a severe drought, and many plants die as a result of the drought. Which term describes the kind of relationship the two species probably will have?
   A. commensalism
   B. competition
   C. mutualism
   D. predation

Use the illustration below to answer questions 7–9.

7. Which part of the food web above contains the greatest biomass?
   A. foxes
   B. green plants
   C. mice
   D. rabbits

8. Which part of the food web above contains the least biomass?
   A. foxes
   B. green plants
   C. mice
   D. rabbits

9. What happens to the energy that the fox uses for maintaining its body temperature?
   A. It is taken up by decomposers that consume the fox.
   B. It moves into the surrounding environment.
   C. It stays in the fox through the metabolism of food.
   D. It travels to the next trophic level when the fox is eaten.
10. What are two biotic factors and two abiotic factors that affect a worm found in a situation similar to what is shown in the diagram?

11. Explain the portions of the following biogeochemical cycles that are related to the diagram above.
   A. Nitrogen cycle
   B. Oxygen cycle
   C. Carbon cycle

12. Distinguish between the everyday use of the term theory and its true scientific meaning.

13. Evaluate how scientific knowledge changes and how the amount of scientific knowledge grows. Suggest a reason why it probably will continue to grow.

14. Describe how a forest ecosystem might be different without the presence of decomposers and detritivores.

15. Suppose that some unknown organisms are discovered in the deep underground of Earth. Give two examples of questions that biologists might try to answer by researching these organisms.

**Short Answer**

Use the illustration below to answer questions 10 and 11.

**Extended Response**

Use this drawing to answer questions 16 and 17.

16. Someone tells you that bats and birds are closely related because they both have wings. Evaluate how this diagram could be used to critique the idea that bats and birds are not closely related.

17. Suppose you form a hypothesis that bats and birds are not closely related and you want to confirm this by comparing the way bats and birds fly. Design an experiment to test this hypothesis.

**Essay Question**

Various substances or elements on Earth move through long-term and short-term biogeochemical cycles as they become part of different aspects of the biosphere. The amount of a substance that is involved in a long-term cycle has an effect on the availability of that substance for use by humans and other organisms on Earth.

Using the information in the paragraph above, answer the following question in essay format.

18. Choose a substance or element that you know is involved in both long-term and short-term biogeochemical cycles. In a well-organized essay, describe how it moves through both types of cycles, and how these cycles affect its availability to humans and other organisms.

**Extended Response**

16. The drawing clearly shows that the structure of a bat wing and a bird wing are different and therefore not closely related. A bat’s wing is structurally more similar to a human arm. The multiple bones in the outer part of a bat’s wing are similar to the multiple bones in the fingers of the human hand. In a bird’s wing, the outer bones are few in number.

17. Answers can vary. For example, one experiment is to make movies of bats and birds in flight. Then, compare characteristics, such as the range of wing movement and frequency of wing motion, by doing graphic analysis of the movie frames.

**Essay Question**

18. Answers can vary, depending on which substance students choose to write. For example, water is a possible topic. Water cycles through a short-term cycle when it evaporates from bodies of water, forms clouds, and falls back to Earth in the form of precipitation. It can also enter a long-term cycle if it is frozen in glaciers or percolates into inaccessible areas underground. Water that is part of a long-term cycle is not available to humans for drinking, bathing, fishing, and so on. The only freshwater that is useful to humans is involved in short-term cycles through the biosphere.