SECTION 3

The Diversity of Living Things

Objectives

- Name the six kingdoms of organisms and identify two characteristics of each.
- Explain the importance of bacteria and fungi in the environment.
- Describe the importance of protists in the ocean environment.
- Describe how angiosperms and animals depend on each other.
- Explain why insects are such successful animals.

Key Terms

bacteria
fungus
protist
gymnosperm
angiosperm
invertebrate
vertebrate

Life on Earth is incredibly diverse. Take a walk in a park, and you will see trees, birds, insects, and maybe fish in a stream. All of these organisms are living, but they are all very different from one another. How do scientists organize this variety into categories they can understand?

Most scientists classify organisms into six *kingdoms*, as described in **Table 2,** based on different characteristics. Members of the six kingdoms get their food in different ways and are made up of different types of *cells*, the smallest unit of biological organization. The cells of animals, plants, fungi, and protists contain a *nucleus* (NOO klee uhs), which consists of a membrane that surrounds a cell's genetic material. A characteristic shared by bacteria, fungi, and plants is the *cell wall*, a structure that surrounds a cell and provides it with rigid support.

Bacteria

Bacteria are microscopic, single-celled organisms that usually have cell walls and reproduce by dividing in half. Bacteria also lack nuclei, unlike all other organisms. Scientists have found two main kinds of bacteria, archaebacteria (AHR kee bak TIR ee uh) and eubacteria (YOO bak TIR ee uh). Most bacteria, including the kinds that cause disease and those found in garden soil, are eubacteria. Bacteria live in every habitat on Earth, from hot springs to the bodies of animals.

Table 2 ▼

The Kingdoms of Life

Kingdom	Characteristics	Examples
Archaebacteria	single celled; lack cell nuclei; reproduce by dividing in half; found in harsh environments	methanogens (live in swamps and produce methane gas) and extreme thermophiles (live in hot springs)
Eubacteria	single celled; lack cell nuclei; reproduce by dividing in half; incredibly common	proteobacteria (common in soils and in animal intestines) and cyanobacteria (also called *blue-green algae*)
Fungi	absorb their food through their body surface; have cell walls; most live on land	yeasts, mushrooms, molds, mildews, and rusts
Protists	most single celled but some have many cells; most live in water	diatoms, dinoflagellates (red tide), amoeba, trypanosomes, paramecia, and *Euglena*
Plants	many cells; make their own food by photosynthesis; have cell walls	ferns, mosses, trees, herbs, and grasses
Animals	many cells; no cell walls; ingest their food; live on land and in water	corals, sponges, worms, insects, fish, reptiles, birds, and mammals

Bacteria and the Environment Bacteria play many important roles in the environment. Some kinds of bacteria break down the remains and wastes of other organisms and return nutrients to the soil. Others recycle mineral nutrients, such as nitrogen and phosphorous. For example, certain kinds of bacteria play a very important role by converting nitrogen in the air into a form that plants can use. Nitrogen is important because it is a main component of proteins and genetic material.

Bacteria also allow many organisms, including humans, to extract certain nutrients from their food. The bacteria in **Figure 12** are *Escherichia coli*, or *E. coli*, a bacterium found in the intestines of humans and other animals. Here, *E. coli* helps digest food and release vitamins that humans need.

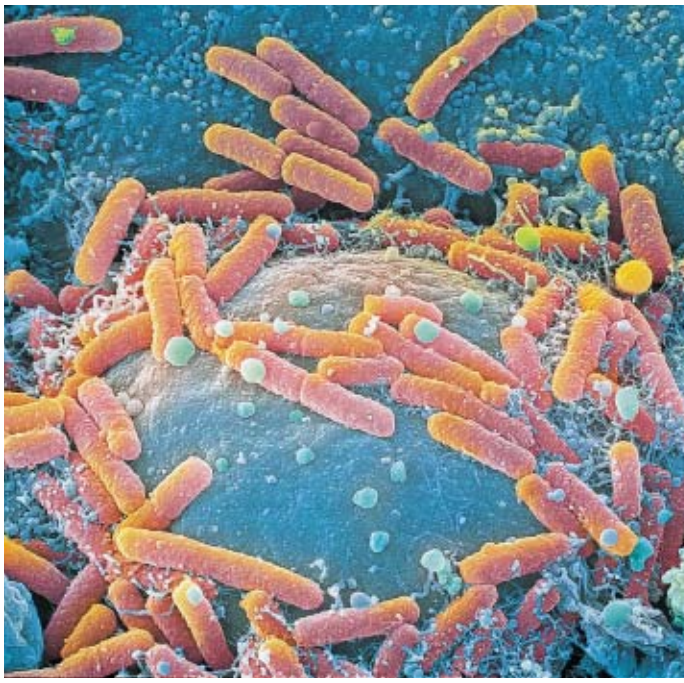


Figure 12 ▶ The long, orange objects in the image above are *E. coli* bacteria as they appear under a microscope.

Fungi

A **fungus** (plural, *fungi*) is an organism whose cells have nuclei, cell walls, and no chlorophyll (the pigment that makes plants green). Cell walls act like miniature skeletons that allow fungi, such as the mushrooms in **Figure 13**, to stand upright. A mushroom is the reproductive structure of a fungus. The rest of the fungus is an underground network of fibers. These fibers absorb food from decaying organisms in the soil.

Indeed, all fungi absorb their food from their surroundings. Fungi get their food by releasing chemicals that help break down organic matter, and then absorbing the nutrients. The bodies of most fungi are a huge network of threads that grow through the soil, dead wood, or other material on which the fungi are feeding. Like bacteria, fungi play an important role in the environment by breaking down the bodies and body parts of dead organisms.

Like bacteria, some fungi cause diseases, such as athlete's foot. Other fungi add flavor to food. The fungus in blue cheese, shown in **Figure 13**, gives the cheese its strong flavor. And fungi called *yeasts* produce the gas that makes bread rise.

Figure 13 ▶ A mushroom (left) is the reproductive structure of a fungus that lives in the soil. The cheese (above) gets its taste and its blue color from a fungus.

Figure 14 ▶ Kelp (left) are huge protists with many cells that live attached to the ocean floor. The microscopic diatoms (right) are protists that live in the plankton.

Protists

Most people have some idea what bacteria and fungi are, but few could define a protist. **Protists** are a diverse group of organisms that belong to the kingdom Protista. Some, such as amoebas, are animallike. Others, such as the kelp in **Figure 14,** are plantlike. Still others are more like fungi. Most protists are one-celled microscopic organisms. This group includes amoebas and *diatoms* (DIE uh TAHMS). Diatoms, shown in **Figure 14,** float on the ocean surface. The most infamous protist is *Plasmodium,* the one-celled organism that causes the disease malaria.

From an environmental standpoint, the most important protists are probably algae. Algae are plantlike protists that can make their own food using the sun's energy. Green pond "scum" and seaweed are examples of algae. They range in size from the giant kelp to the one-celled *phytoplankton,* which are the initial source of food in most ocean and freshwater ecosystems.

Plants

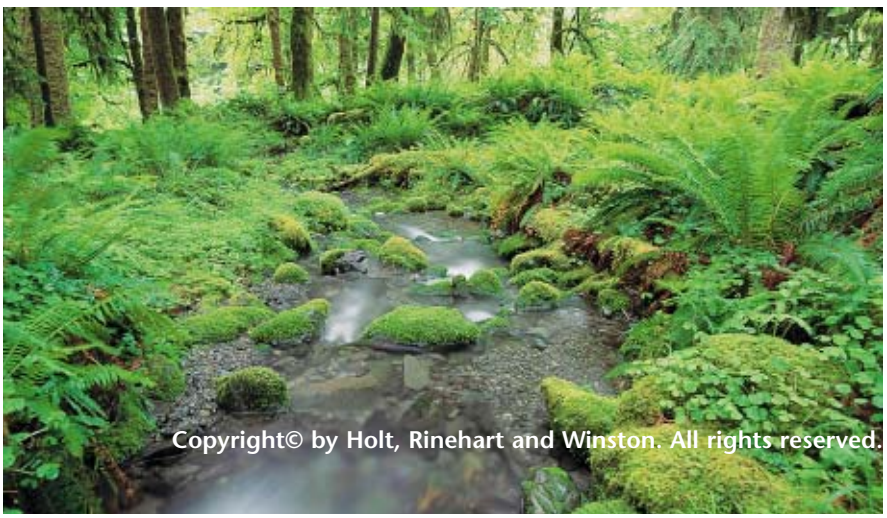
Plants are many-celled organisms that make their own food using the sun's energy and have cell walls. Most plants live on land, where the resources a plant needs are separated between the air and the soil. Sunlight, oxygen, and carbon dioxide are in the air, and minerals and water are in the soil. Plants have roots that tap resources underground and leaves that intercept light and gases in the air. Leaves and roots are connected by *vascular tissue,* a system of tubes that carries water and food. Vascular tissue has thick cell walls, so a wheat plant or a tree is like a building supported by its plumbing.

Lower Plants The first land plants had no vascular tissue, and they also had swimming sperm. As a result, these early plants could not grow very large and had to live in damp places. Their descendants alive today are small plants such as mosses. Ferns and club mosses were the first vascular plants. Some of the first ferns were as large as small trees, and some of these tree ferns live in the tropics and in New Zealand today. Some examples of lower plants are shown in **Figure 15.**

Connection to Physics

Cell Size Every cell must exchange substances with its environment across its surface. The larger the cell, the smaller its surface is compared with its volume. So the larger the cell, the more slowly substances move from outside the cell to its interior. This relationship limits most cells to microscopic sizes.

Figure 15 ▶ Lower plants, such as these mosses and ferns, live in damp places.



Gymnosperms Pine trees and other evergreens are common examples of gymnosperms (JIM noh SPUHRMZ). **Gymnosperms** are woody plants whose seeds are not enclosed in fruits. Gymnosperms such as pine trees are also called *conifers* because they bear cones, as shown in **Figure 16.**

Gymnosperms have several adaptations that allow them to live in drier conditions than lower plants can. Gymnosperms produce *pollen,* which protects and moves sperm between plants. These plants also produce *seeds,* which protect developing plants from drying out. And a conifer's needle-like leaves lose little water. Much of our lumber and paper comes from gymnosperms.

Angiosperms Most land plants today are **angiosperms** (AN jee oh SPUHRMZ), flowering plants that produce seeds in fruit. All of the plants in **Figure 17** are angiosperms. The flower is the reproductive structure of the plant. Some angiosperms, such as grasses, have small flowers that produce pollen that is carried by the wind. Other angiosperms have large flowers that attract insects or birds to carry their pollen to other plants. Many flowering plants depend on animals to disperse their seeds and carry their pollen. For example, a bird that eats a fruit will drop the seeds elsewhere, where they may grow into new plants.

Most land animals are dependent on flowering plants. Most of the food we eat, such as wheat, rice, beans, oranges, and lettuce, comes from flowering plants. Building materials and fibers, such as oak and cotton, also come from flowering plants.

Figure 16 ▶ This gymnosperm has male and female reproductive structures called *cones.*

QuickLAB

Pollen and Flower Diversity

Procedure

1. Use a **cotton swab** to collect pollen from a common **flowering plant.**
2. Tap the cotton swab on a **microscope slide** and cover the slide with a **cover slip.**
3. Examine the slide under a **microscope**, and draw the pollen grains in your ***EcoLog.***
4. Repeat this exercise with a **grass plant in bloom.**

Analysis

1. Based on the structure of the flower and the pollen grains, explain which plant is pollinated by insects and which is pollinated by wind.

Figure 17 ▶ This meadow contains a wide array of angiosperms, including grasses, trees, and wildflowers.

MATHPRACTICE

Insect Survival Most invertebrates produce large numbers of offspring. Most of these offspring die before reaching adulthood. Suppose an insect lays 80 eggs on a plant. If 70 percent of the eggs hatch and 80 percent of those that hatch die before reaching adulthood, how many insects will reach adulthood?

Animals

Animals cannot make their own food like plants can. They have to take in food from their environment. In addition, animal cells have no cell walls, so animals' bodies are soft and flexible. Some animals have evolved hard skeletons against which their muscles can pull to move the body. As a result, animals are much more mobile than plants and all animals move around in their environments during at least one stage in their lives.

Invertebrates Animals that lack backbones are **invertebrates** (in VUHR tuh brits). Many invertebrates live attached to hard surfaces in the ocean and filter their food out of the water. These organisms move around only when they are larvae. At this early stage of life, they are part of the ocean's plankton. Filter feeders include corals, various worms, and mollusks such as clams and oysters. **Figure 18** shows a variety of invertebrates. Other invertebrates, including squid in the ocean and insects on land, move around actively in search of food.

More insects exist on Earth than any other type of animal. They are successful for several reasons. Insects have a waterproof external skeleton, they move quickly, and they reproduce quickly. Also, most insects can fly. Their small size allows them to live on little food and to hide from enemies in small spaces, such as a seed or in the hair of a mammal.

Many insects and plants have evolved together and depend on each other to survive. Insects carry pollen from male parts of flowers to fertilize a plant's egg, which develops into a fruit. Without insect pollinators, we would not have tomatoes, cucumbers, apples, and many other crops. Insects are also valuable because they eat other insects that we consider to be pests. But, humans and insects are often enemies. Bloodsucking insects transmit human diseases, such as malaria, sleeping sickness, and West Nile virus. Insects probably do more damage indirectly, however, by eating our crops.

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Figure 18 ▶ Examples of invertebrates include a banana slug (left), a leaf-footed bug (middle), and a cuttlefish (right).

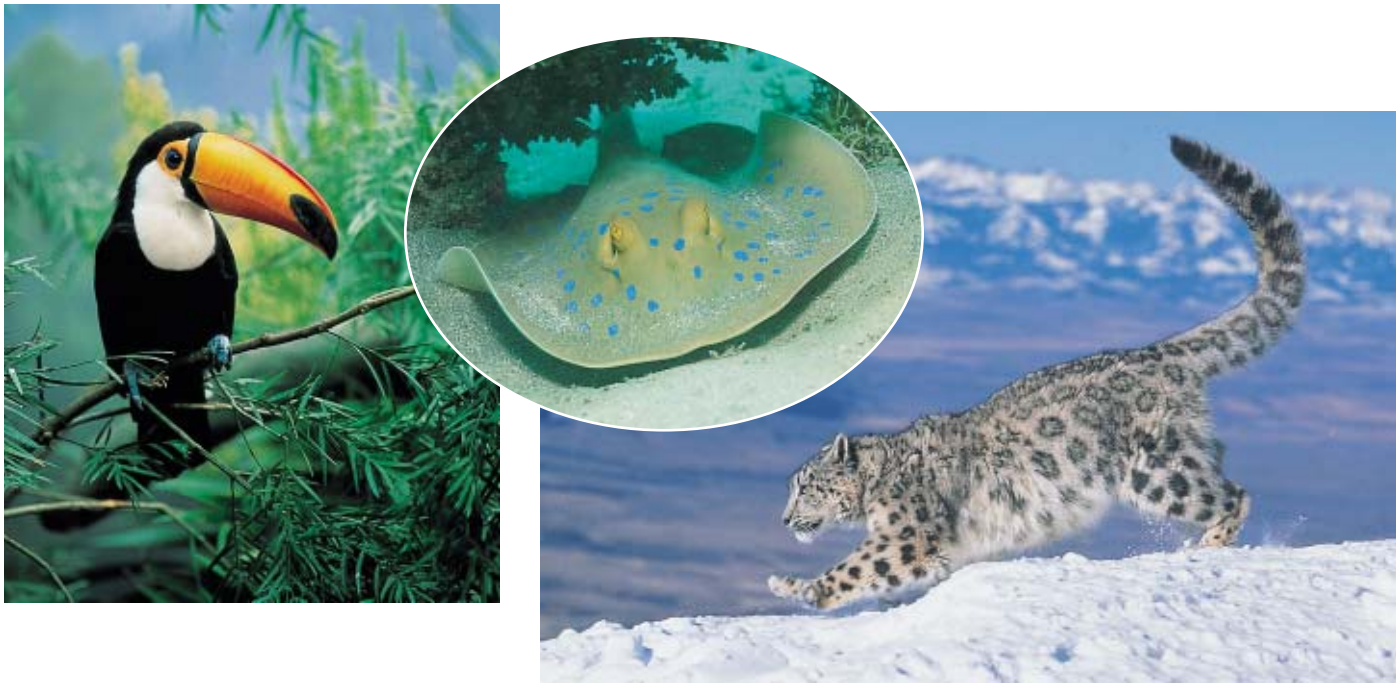


Figure 19 ▶ Examples of vertebrates include the toco toucan (left), the blue-spotted stingray (middle), and the snow leopard (right).

Vertebrates Animals that have backbones are called vertebrates. Members of three vertebrate groups are shown in **Figure 19.** The first vertebrates were fish, but today most vertebrates live on land. Amphibians, which include toads, frogs, and salamanders, are partially aquatic. Nearly all amphibians must return to water to lay their eggs.

The first land vertebrates were the reptiles, which today include turtles, lizards, snakes, and crocodiles. These animals were successful because they have an almost waterproof egg, which allows the egg to hatch on land, away from predators in the water.

Birds are warm-blooded vertebrates with feathers. Bird eggs have hard shells. Adult birds keep their eggs and young warm until they develop insulating layers of fat and feathers. *Mammals* are warm-blooded vertebrates that have fur and feed their young milk. The ability to maintain a high body temperature allows birds and mammals to live in cold areas, where other animals cannot survive.

Ecofact

Conserving Water Arthropods and vertebrates are the only two groups of animals that have adaptations that prevent dehydration so effectively that some of them can move about freely on land on a dry, sunny day. No other animals have this adaptation.

SECTION 3 Review

1. **Describe** how animals and angiosperms depend on each other. Write a short paragraph to explain your answer. WRITING SKILLS
2. **Describe** the importance of protists in the ocean.
3. **Name** the six kingdoms of life, and give two characteristics of each.
4. **Explain** the importance of bacteria and fungi in the environment.

CRITICAL THINKING

5. **Analyzing Relationships** Explain how the large number and wide distribution of angiosperm species is related to the success of insects.
6. **Understanding Concepts** Write a short paragraph that compares the reproductive structures of gymnosperms and angiosperms. WRITING SKILLS

CHAPTER 4

Highlights

1 Ecosystems: Everything Is Connected

Key Terms

ecosystem, 93
biotic factor, 94
abiotic factor, 94
organism, 95
species, 95
population, 95
community, 96
habitat, 96

Main Ideas

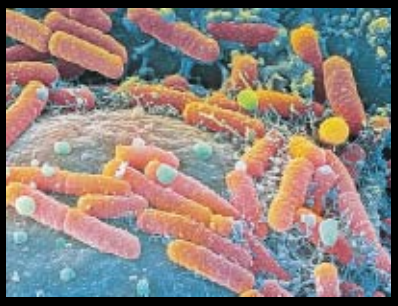
- Ecosystems are composed of many interconnected parts that often interact in complex ways.
- An ecosystem is the community of all the different organisms living in an area and their physical environment.
- An ecosystem contains biotic (living) and abiotic (nonliving) components.
- Organisms live as populations of one species in communities with other species. Each species has its own habitat, or type of place that it lives.

2 Evolution

natural selection, 97
evolution, 97
adaptation, 99
artificial selection, 100
resistance, 101

- The naturalist Charles Darwin used the term natural selection to describe the unequal survival and reproduction that results from the presence or absence of particular traits.
- Darwin proposed that natural selection is responsible for evolution—a change in the genetic characteristics of a population from one generation to the next.
- By selecting which domesticated animals and plants breed, humans cause evolution by artificial selection.
- We have unintentionally selected for pests that are resistant to pesticides and for bacteria that are resistant to antibiotics.

3 The Diversity of Living Things



bacteria, 102
fungus, 103
protist, 104
gymnosperm, 105
angiosperm, 105
invertebrate, 106
vertebrate, 107

- Organisms can be divided into six kingdoms, which are distinguished by the types of cells they possess and how they obtain their food.
- Bacteria and fungi play the important environmental roles of breaking down dead organisms and recycling nutrients.
- Gymnosperms are evergreen plants, many of which bear cones, while angiosperms produce flowers and bear seeds in fruit.
- Insects, invertebrates that are the most successful animals on Earth, affect humans in both positive and negative ways.
- Vertebrates, or animals with backbones, include fish, amphibians, reptiles, birds, and mammals.

CHAPTER 4 Review

Using Key Terms

Use each of the following terms in a separate sentence.

1. *adaptation*
2. *invertebrate*
3. *abiotic factor*
4. *habitat*
5. *species*

For each pair of terms, explain how the meanings of the terms differ.

6. *community* and *population*
7. *evolution* and *natural selection*
8. *gymnosperm* and *angiosperm*
9. *bacteria* and *protists*

STUDY TIP

Make an Outline After reading each section, summarize the main ideas into a short outline, leaving space between each entry. Then write the key terms under the subsection in which they are introduced, followed by a short definition for each.

Understanding Key Ideas

10. Which of the following pairs of organisms belong to the same population?
    a. a dog and a cat
    b. a marigold and a geranium
    c. a human mother and her child
    d. a spider and a cockroach
11. Which of these phrases does *not* describe part of the process of evolution by natural selection?
    a. the environment contains limited resources
    b. organisms produce more offspring than will survive to reproduce
    c. communities include populations of several species
    d. organisms in a population differ in their traits
12. Which of the following components of an ecosystem are *not* abiotic factors?
    a. wind
    b. small rocks
    c. sunlight
    d. tree branches
13. Some snakes produce a powerful poison that paralyzes their prey. This poison is an example of
    a. coevolution.
    b. an adaptation.
    c. a reptile.
    d. a biotic factor.
14. Angiosperms called roses come in a variety of shapes and colors as a result of
    a. natural selection.
    b. coevolution.
    c. different ecosystems.
    d. artificial selection.
15. Single-celled organisms that live in swamps and produce methane gas are
    a. protists.
    b. archaebacteria.
    c. fungi.
    d. eubacteria.
16. Which of the following statements about protists is *not* true?
    a. Most of them live in water.
    b. Some of them cause diseases in humans.
    c. They contain genetic material.
    d. Their cells have no nucleus.
17. Which of the following statements about plants is *not* true?
    a. They make their food from carbon dioxide and water through photosynthesis.
    b. Land plants have cell walls that help hold their stems upright.
    c. They have adaptations that help prevent water loss.
    d. Plants absorb food through their roots.

CHAPTER 4 Review

Short Answer

18. List the five components that an ecosystem must contain to survive indefinitely.

19. What is the difference between biotic and abiotic factors in an ecosystem?

20. What is the difference between adaptation and evolution?

21. Describe the three steps by which a population of insects becomes resistant to a pesticide.

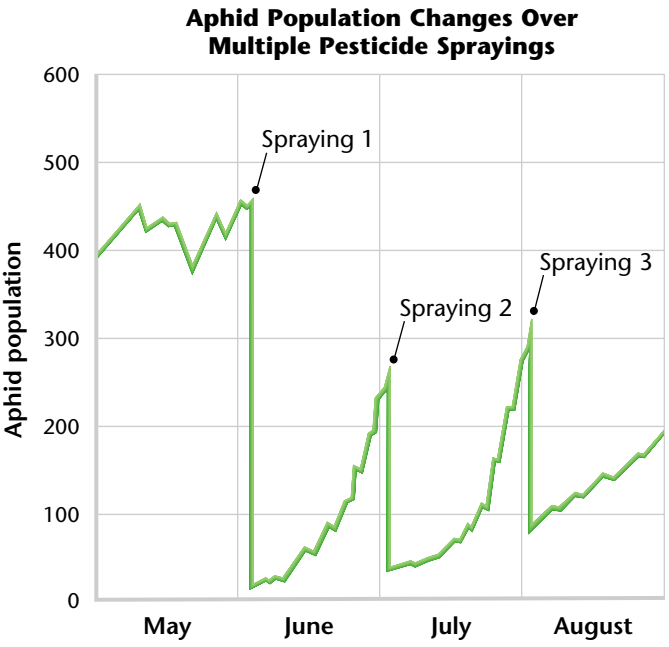
22. List the six kingdoms of organisms and the characteristics of each kingdom.

Interpreting Graphics

Below is a graph that shows the number of aphids on a rose bush during one summer. The roses were sprayed with a pesticide three times, as shown. Use the graph below to answer questions 23 and 24.

23. What evidence is there that the pesticide killed aphids?

24. Aphids have a generation time of about 10 days. Is there any evidence that the aphids evolved resistance to the pesticide during the summer? Explain your answer.



Concept Mapping

25. Use the following terms to create a concept map: *ecosystem*, *abiotic factor*, *biotic factor*, *population*, *species*, *community*, and *habitat*.

Critical Thinking

26. Analyzing Ideas Can a person evolve? Read the description of evolution in this chapter and explain why or why not. READING SKILLS

27. Making Inferences A scientist applies a strong fungicide, a chemical that kills fungi, to an area of forest soil every week during October and November. How might this area look different from the surrounding ground at the end of the experiment?

28. Drawing Conclusions In what building in your community do you think bacteria are evolving resistance to antibiotics most rapidly? Explain your answer.

29. Evaluating Assumptions Many people assume that the human population is no longer evolving. Do you think these people are right? Explain your answer.

Cross-Disciplinary Connection

30. Geography Find out how the isolation of populations on islands has affected their evolution. Research a well-known example, such as the animals and plants of Madagascar, the Galápagos Islands, and the Hawaiian Islands. Write a short report on your findings. WRITING SKILLS

Portfolio Project

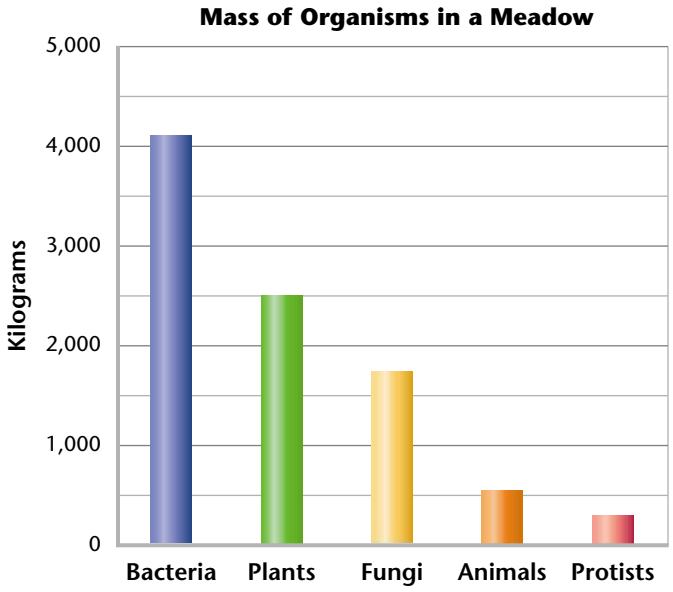
31. Study an Ecosystem Observe an ecosystem near you, such as a pond or a field. Identify biotic and abiotic factors and as many populations of organisms as you can. Do not try to identify the organisms precisely. Just list them, for example, as spiders, ants, grass, not as a specific type. Make a poster showing the different populations. Put the organisms into columns to show which of the kingdoms they belong to.

MATH SKILLS

Use the graph below to answer questions 32–33.

32. Analyzing Data The graph below shows the mass of different types of organisms found in a meadow. How much greater is the mass of the plants than that of the animals?

33. Analyzing Data What is the ratio of the mass of the bacteria to the mass of the fungi?



WRITING SKILLS

34. Communicating Main Ideas Why is evolution considered to be such an important idea in biology?

35. Outlining Topics Outline the essential steps in the evolution of pesticide resistance in insects.

READING FOLLOW-UP

Now that you have read the chapter, take a moment to review your answers to the **Reading Warm-Up** questions in your ***EcoLog.*** If necessary, revise your answers.

STANDARDIZED TEST PREP

Read the passage below, and then answer the questions that follow.

Some Central American acacia trees, called *ant acacias,* have a mutually beneficial relationship with ants that live on them. The trees have several structures that benefit the ants. The trees have hollow thorns in which the ants live, glands that produce sugary nectar, and swollen leaf tips, which the ants remove and feed to their larvae.

The ants reduce the damage that other organisms do to the tree. They remove dust, fungus spores, and spider webs. They destroy seedlings of other plants that sprout under the tree, so that the tree can obtain water and nutrients without competition from other plants. The ants sting animals that try to eat the tree.

Proof that the ants are valuable to the acacia tree comes from studies in which the ants are removed. Fungi invade the tree, it is eaten by herbivores, and it grows more slowly. When ants are removed from the tree, it usually dies in a few months.

1. According to the passage, which of the following statements is not true?
- **a.** Ants and ant acacias have evolved a relationship beneficial to both of them.
- **b.** The ants prevent fungi from growing on the acacia.
- **c.** The tree would benefit from not having ants.
- **d.** The ants benefit from living on the tree.

2. What is the advantage to an acacia of not having other plants grow nearby?
- **a.** Ants cannot crawl onto the acacia from the other plants.
- **b.** The acacia keeps more ants for itself.
- **c.** This reduces competition for water and nutrients.
- **d.** This reduces competition for fungi.

CHAPTER 4

Inquiry Lab: DESIGN YOUR OWN

Objectives

- **USING SCIENTIFIC METHODS** **Observe** the behavior of brine shrimp.
- **USING SCIENTIFIC METHODS** **Identify** a variable, and design an experiment to test the effect of the variable on habitat selection by brine shrimp.

Materials

aluminum foil
brine shrimp culture
corks sized to fit tubing
Detain™ or methyl cellulose
fluorescent lamp or grow light
funnel
graduated cylinder or beaker
hot-water bag
ice bag
metric ruler
Petri dish
pipet
plastic tubing, 40cm × 1cm, clear, flexible
screen, pieces
screw clamps
tape
test-tube rack
test tubes with stoppers

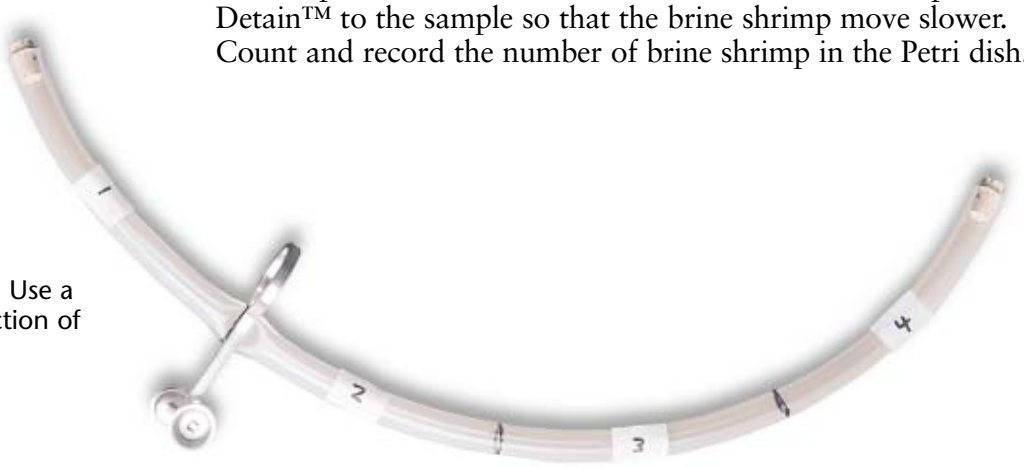
How Do Brine Shrimp Select a Habitat?

Different organisms are adapted for life in different habitats. For example, brine shrimp are small crustaceans that live in saltwater lakes. Organisms select habitats that provide the conditions, such as a specific temperature range and amount of light, to which they are best adapted. In this investigation, you will explore habitat selection by brine shrimp and determine which environmental conditions they prefer.

Procedure

Establish a Control Group

1. To make a test chamber and to establish a control group, divide a piece of plastic tubing into four sections by making a mark at 10 cm, 20 cm, and 30 cm from one end. Label the sections "1", "2", "3", and "4".
2. Place a cork in one end of the tubing. Then transfer 50 mL of brine shrimp culture to the tubing. Place a cork in the other end of the tubing. Set the tube aside, and let the brine shrimp move about the tube for 30 min.
3. After 30 min, divide the tubing into four sections by placing a screw clamp at each mark on the tubing. While someone in your group holds the corks firmly in place, tighten the middle clamp at 20 cm and then tighten the other two clamps.
4. Remove the cork from the end of section 1 and pour the contents of section 1 into a test tube labeled "1." Repeat this step for the other sections by loosening the screw clamps and pouring the contents of each section into their corresponding test tubes.
5. To get an accurate count for the number of brine shrimp in each test tube, place a stopper on test tube 1, and invert the tube gently to distribute the shrimp. Use a pipet to transfer a 1 mL sample of the culture to a Petri dish. Add a few drops of Detain™ to the sample so that the brine shrimp move slower. Count and record the number of brine shrimp in the Petri dish.



▶ **Making a Test Chamber** Use a screw clamp to divide one section of tubing from another.

6. Empty the Petri dish, and take two more 1 mL samples of brine shrimp from test tube 1. Calculate the average of the three samples recorded for test tube 1.
7. Repeat steps 5 and 6 for each of the remaining test tubes to count the number of brine shrimp in each section of tubing.

Ask a Question

8. Write a question you would like to explore about brine shrimp habitat selection. For example, you can explore how temperature or light affects brine shrimp. To explore the question, design an experiment that uses the materials listed for this lab.
9. Write a procedure and a list of safety precautions for your group's experiment. Have your teacher approve your procedure and precautions before you begin the experiment.
10. Set up and conduct your group's experiment.

Analysis

1. **Constructing Graphs** Make a bar graph of your data. Plot the environmental variable on the *x*-axis and the number of brine shrimp on the *y*-axis.
2. **Evaluating Results** How did the brine shrimp react to changes in the environment?
3. **Evaluating Methods** Why did you have to have a control in your experiment?
4. **Evaluating Methods** Why did you record the average of three samples to count the number of brine shrimp in each test tube in step 6?

Conclusions

5. **Drawing Conclusions** What can you conclude from your results about the types of habitat that brine shrimp prefer?

Extension

1. **Formulating Hypotheses** Now that you have observed brine shrimp, write a hypothesis about how brine shrimp select a habitat that could be explored with another experiment, other than the one you performed in this lab. Formulate a prediction based on your hypothesis.
2. **Evaluating Hypotheses** Conduct an experiment to test your prediction. Write a short explanation of your results. Did your results support your prediction? Explain your answer.

▶ **Brine Shrimp** These crustaceans have specific habitat preferences.

Making a difference

BUTTERFLY ECOLOGIST

Imagine millions of butterflies swirling through the air like autumn leaves, clinging in tightly packed masses to tree trunks and branches, and covering low-lying forest vegetation like a luxurious, moving carpet. According to Alfonso Alonso-Mejía, this is quite a sight to see.

Every winter Alfonso climbs up to the few remote sites in central Mexico where about 150 million monarch butterflies spend the winter. He is researching the monarchs because he wants to help preserve their habitat and the butterflies themselves. His work helped him earn a Ph.D. in ecology from the University of Florida.

Monarchs are famous for their long-distance migration. The butterflies that eventually find their way to Mexico come from as far away as the northeastern United States and southern Canada. Some of them travel an amazing 3,200 km before reaching central Mexico.

Wintering Habitat at Risk

Unfortunately, the habitat that the monarchs travel long distances to reach is increasingly threatened by logging and other human activities. Only 9 to 11 of the monarchs' wintering sites remain (monarchs colonize more sites in some years than in others). Five of those sites are set aside as sanctuaries for the butterflies, but even these sanctuaries are endangered by people who cut down fir trees for firewood or for commercial purposes.

Alfonso's work is helping Mexican conservationists better understand and protect monarch butterflies. Especially important is Alfonso's discovery that monarchs depend on bushlike vegetation, called *understory vegetation,* that grows beneath the fir trees.

Keeping Warm

Alfonso's research showed that when the temperature falls below freezing, as it often does in the mountains where the monarchs winter, understory vegetation can mean the difference between life and death for some monarchs. These conditions are life threatening to monarchs because low temperatures (–1°C to 4°C, or 30°F to 40°F) limit their movement. In fact, the butterflies are not even able to fly at such low temperatures. At extremely cold temperatures (–7°C to –1°C, or 20°F to 30°F), monarchs resting on the forest floor are in danger of freezing to death. But if the forest has understory vegetation, the monarchs can slowly climb the vegetation until they are at least