CHAPTER 14

Population Interactions

Population Interactions

Why does a particular species live in one place and not another? All life on Earth is interconnected. Populations of organisms constantly interact. Individuals within populations interact among themselves and with other populations. They also interact with the nonliving environment. What interactions do you see in the opening art? The actions of these organisms affect their environment. And the environment influences these organisms. These interactions help determine the distribution of organisms on Earth.

The study of the living and nonliving parts of the environment and how they affect organisms is called **ecology**. Ecology is the branch of science that focuses on natural systems. In fact, the natural systems you will study are called *eco*systems. You studied physical and chemical systems in unit 1, *Interactions Are Interesting*, and living systems in unit 2, *Inside Life*. In unit 3, you studied systems on a global scale. You learned how matter, such as water and carbon, moves between different reservoirs. This matter is important for both the nonliving, or physical, environment and the biological environment on Earth.

In chapter 14, *Population Interactions*, you will focus on populations and ecosystems on a regional scale. You will analyze changes in growth for different populations and learn what influences population growth. Then you will look at examples of how populations interact in ecosystems. You will find that there is both the cycling of matter and the transfer of much energy in ecosystems.

Goals for the Chapter

By the end of chapter 14, you will be able to answer the following questions:

- What makes population size change?
- Is there a limit to population size? If so, what limits population size?
- What is the relationship between populations and ecosystems?
- What components make up an ecosystem?
- What kinds of interactions do organisms have in ecosystems?
- How are ecosystems related to geochemical cycles?
- How are the interactions among organisms and the environment related to the diversity of life on Earth?

The following activities will help you learn how populations interact with one another and with the environment.

ENGAGE	What Do You Know about Populations?
EXPLORE	Changing Populations
EXPLAIN	Systems in Balance
ELABORATE	Finding Your Niche
EVALUATE	Interpret the Interactions

This chapter organizer is your guide for learning about populations and ecosystems. Use it to review what you have learned and to see what new things you will be learning.

Population Interactions

Linking Question

How can I build on what I know about populations to determine what factors affect population size?

ENGAGE

What Do You Know about Populations?

Key Ideas:

- Population size can change.
- Different kinds of interactions occur in ecosystems.

EXPLORE

Changing Populations

Key Idea:

The size of a population is affected by environmental factors and interactions with other organisms.

Linking Question

How are populations and ecosystems related?

EVALUATE

Interpret the Interactions

Key Ideas:
- Population growth is affected by many factors.
- The interactions between the biotic and abiotic parts of an ecosystem result in the transfer of energy and the cycling of matter.
- Interactions can lead to natural selection.

Linking Question

How can I use what I have learned to demonstrate my understanding of populations and ecosystems?

CHAPTER 14 Major Concepts

- Populations grow and decline.
- There are limits to population growth.
- Ecosystems are made up of the biotic and abiotic environments.
- Organisms both cooperate and compete in an ecosystem.
- Interactions among populations can lead to natural selection and contribute to the diversity of organisms on Earth.

ELABORATE

Finding Your Niche

Key Idea:
Interactions among organisms are part of the process of natural selection and can lead to diverse species on Earth.

EXPLAIN

Systems in Balance

Key Ideas:
- Population growth is limited by limiting factors that can be abiotic or biotic.
- Interactions occur between organisms and between organisms and the abiotic environment.
- Ecosystems are important for the flow of energy and the cycling of matter.

Linking Question

How are competitive interactions related to natural selection?

ENGAGE

What Do You Know about Populations?

▲ **Figure 14.1 Student population.** Does your school population change? What might limit the size of the population at your school?

Every day populations of organisms surround you. For example, all the students in your school system make up a population (figure 14.1). Many things influence the size of the student population and how the students in the school system interact. Your school population shares some characteristics with biological populations.Do you ever think about the interactions between organisms in other systems? In *What Do You Know about Populations?*, you will share your current ideas about populations and natural systems.

Materials

none

Process and Procedure

1. Record in your science notebook whether you think each of the following statements is true or false. Provide a 1 or 2 sentence explanation for each of your answers.
   a. Populations can grow indefinitely. (T or F)
   b. You have a population of fruit flies in a large building. If you gave the population all the food and water it needs, the population would continue to increase in size. (T or F)
   c. All of the species in an environment have the same maximum population size. (T or F)
   d. A species of fish can cooperate with one organism and can compete with another. (T or F)
   e. Light, water, and nutrients are abiotic parts of an ecosystem. (T or F)
   f. Temperature can influence the size of a population. (T or F)
   g. A forest contains as many woodpeckers that eat insects as there are insects. (T or F)
   h. When one organism eats another, all the energy stored as food is passed to the consumer. (T or F)
2. Add a specific example to support each of your explanations in Step 1.
3. Compare your examples and explanations from Steps 1 and 2 to those of a classmate.
4. Record in your science notebook why each explanation is or is not valid for each statement.

You will revisit your explanations in the evaluate activity, *Interpret the Interactions*.

Reflect and Connect

Record your ideas to the following questions in your science notebook.

1. List 2 factors that you think might increase a population of plants. Then list 2 factors that might decrease the same population. For each factor, explain why it would cause an increase or a decrease.
2. Recall what you learned about cycles in chapter 11, *Carbon on the Move*. Use what you learned in unit 3 to describe how you think organisms contribute to the cycling of carbon. For example, how would a pine tree contribute to the cycling of carbon?

Changing Populations

EXPLORE

A group of individuals of the same species that lives in a particular area and interbreeds is called a **population**. Each population has certain characteristics, such as size, density, and distribution. In *Changing Populations*, you will investigate how the size of populations changes across time. In Part I, you will discover how different environments result in yeast populations of different sizes. In Part II, you will review almost 50 years of data to learn how populations of wolves, moose, and balsam fir interact on an island.

Part I: Yeast Population Explosion

Changes in the population size of organisms are difficult to investigate in the classroom. The changes occur over long periods of time. For example, scientists monitor changes in animal populations across years. Even changes in the size of insect and plant populations take weeks to occur. Can you think of any populations that change size in a shorter time frame? Scientists use different techniques to estimate population size, depending on the organism they are investigating (see figure 14.2).

Microorganisms are small, reproduce rapidly, and have short life spans, so they are good to study in the classroom. Bacteria and yeast are examples of microorganisms. If you have had food poisoning, you have experienced a bacterium population rapidly growing and causing illness.

In this investigation, you will use common baker's yeast (*Saccharomyces cerevisiae*) to observe a population of yeast cells. The cells are growing in a test tube in a liquid called a broth medium. This population is a closed population. A closed population lets you estimate the rate of population growth more easily than an open system. In nature, open populations increase or decrease in size as organisms enter or leave them. Matter can cycle through the open population.

▲ **Figure 14.2 Determining population size.** Scientists estimate population size in different ways, depending on the organism they are studying. (a) In the laboratory, scientists can use microscopes to estimate the population size of microorganisms such as bacteria or yeast. (b) In nature, scientists use techniques such as aerial surveys to sample populations of larger organisms. During aerial surveys, scientists count animals such as birds, elk, or whales from a plane or helicopter. Why might it be valuable to know the population size of different organisms?

Materials

For each team of 3 students

- 3 pairs of safety goggles
- 2 16×150-mm test tubes with screw caps, each with 10 mL yeast suspension
- 2 18×150-mm test tubes
- 1 dropping pipet
- microscope slides
- coverslips
- 1 compound microscope
- 1 test-tube rack
- methylene blue (optional)
- 1-mL graduated pipet (optional)
- water (optional)
- paper towel
- 1 glass-marking pencil
- 1 transparent metric ruler
- 4 sheets of graph paper
- 1 tally counter

Cautions

Wear safety goggles when working with any liquid. Culture test tubes should be inverted gently to avoid foaming, which would result in inaccurate counts. Caps on culture tubes should be loosened slightly before storage to prevent gas buildup. Avoid contact with methylene blue because it will dye your skin and clothes. Methylene blue is harmful if ingested. Wash your hands thoroughly before leaving the classroom.

Process and Procedure

1. Read the following 2 paragraphs about yeast. Use this question to focus your reading: "What do yeast need to survive?"

   Yeast are fungi that grow as single cells. They can reproduce asexually by budding, or they can reproduce sexually. They reproduce rapidly in moist environments that have a supply of nutrients such as sugars and amino acids.

   Like all organisms, yeast undergo cellular respiration. Cellular respiration produces the energy needed for growth and reproduction. Recall that you investigated cellular respiration in decaying vegetation in chapter 11. Yeast undergo cellular respiration with oxygen present (aerobic respiration) and without oxygen (anaerobic respiration). Anaerobic respiration is also called fermentation. When yeast respire anaerobically, they break down sugars into carbon dioxide and ethanol. These two reaction products alter the environment and affect the yeast's growth and reproduction.

2. Participate in a class discussion about different conditions you could create for a yeast population. Use Questions 2a–c to guide your discussion.
   a. What conditions do you think affect a yeast population?
   b. What conditions might increase reproduction?
   c. What conditions might decrease reproduction?
3. As a team, develop 2 or 3 hypotheses that might explain how different conditions will affect the size of a yeast population. Record these in your science notebook.

A hypothesis is a statement that suggests an explanation of an observation or an answer to a scientific problem.

4. Discuss with your team how you could design an investigation to study yeast population growth under different conditions. Be prepared to share your ideas with the class.

Focus on how to create different environments. In Step 7, you will read a protocol describing how to measure yeast population growth. Remember that a control may help you understand variables, which in this case are the different environments.

5. Participate in a class discussion to decide how to design investigations to study yeast population growth in different environments. Consider how each team could test different conditions.
6. Decide on 1 design for your team and record it in your science notebook. Have your teacher approve your design.

Protocol

7. Read *Measuring Population Growth in Yeast Protocol*. Then decide how to create a data table for your investigation. Use an entire sheet of paper for the data table.

Make sure you include space in your table to record the yeast population for different environmental conditions.

8. Collect the materials you need and begin your investigation.

This investigation will continue for 7 class periods. Make population counts each day, then continue with other activities as your teacher directs.

9. Once you have finished collecting data, graph the change in the yeast population size. Include a caption and highlight comments on the graph.

Stop & THINK

PART I

Participate in a class discussion of the following questions. Record your answers in your science notebook.

1. Is there a general trend in how the population size changed? Is the trend the same for all teams? Describe the trend in your own words.
2. Review the hypotheses you developed in Step 3. Are any of them supported by the data the class gathered? Are any of them not supported by these data? Explain.

   A hypothesis is supported when it is consistent with the data collected. For example, consider this hypothesis: "A yeast population will grow faster in an environment where 5 grams (g) of sugar is added than in an environment where no sugar is added." Next, study your graphed data. Does the yeast with the sugar have a steeper slope than the yeast without sugar? If so, the data are consistent with the hypothesis, and thus support it.

3. What factors contributed to population growth? What factors contributed to a decline in population growth? What evidence do you have?

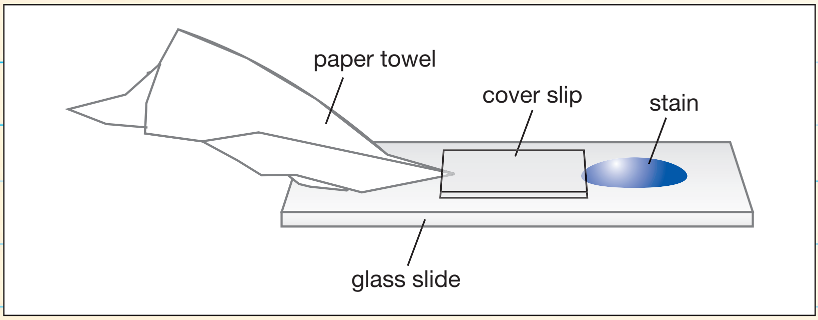
Protocol

Measuring Population Growth in Yeast Protocol

To determine how fast the yeast population grows, make population counts during the course of the investigation.

1. Yeast cells settle to the bottom of test tubes. Before counting the yeast population, gently invert the test tube several times to distribute the yeast.
2. Use a dropping pipet to transfer a drop from the test tube to a slide. Carefully place a clean coverslip over the drop. Try not to trap any air bubbles.
3. Examine the slide with the high-power lens of a microscope, such as the 400× lens. Adjust the focus and the amount of light until you can easily see yeast cells.

If the light is too bright, yeast cells are difficult to see. Adding a stain such as methylene blue to the slide will make it easier to see yeast cells. Add the stain to the drop of water when first preparing the slide, or later, after viewing the cells. Add stain to a prepared slide by carefully holding a small piece of paper towel on one side of a coverslip while you drop stain on the other side (see illustration).



Adding stain to a slide. Carefully hold a small piece of paper towel on one side while you drop stain on the other side.

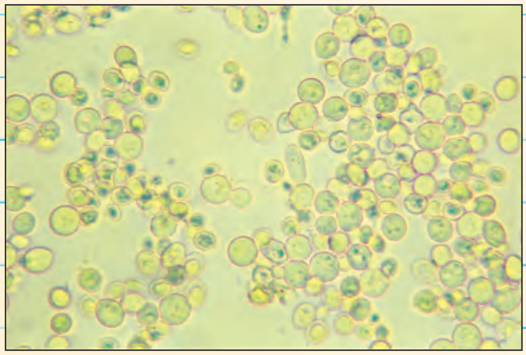
Cautions

Avoid contact with methylene blue because it will dye your skin and clothes. Methylene blue is harmful if ingested.

4. Count all the yeast cells in your field of view. Your field of view is the circular area you see when you look through the microscope. If your count is more than 300 or too many to count, make a dilution by following Steps 4a–c.

Make certain you are counting yeast cells and not other material. Buds also count as individual yeast cells. The yeast cells often stick together. Don't count clumps of 3 or more cells as one cell. Refer to the following figure to see the appearance of yeast cells.

   a. Use the 1-milliliter (mL) graduated pipet to transfer 0.9 mL water to a clean test tube. Then add 0.1 mL culture to the test tube. Label this test tube "D1" for first dilution.
   b. Invert test tube D1 several times to mix, and then use the dropping pipet to transfer 1 drop to the grid of the slide. Add a coverslip as in Step 2.
   c. Count the yeast cells.



▲ **Yeast cells you might see in your light microscope.** Note the buds that are still attached to the yeast cells. These buds will become new individuals.

If there are still too many yeast cells to count, make another dilution by transferring 0.1 mL of D1 to a clean test tube with 0.9 mL water. Label this test tube "D2" for second dilution.

   d. Record the count, the dilution you made, if any, and the magnification of the lens you are using in your science notebook.

5. Record the count as the number of yeast cells per milliliter in the data table. Assume that the drop you placed on the slide is 0.1 mL.

What additional calculations must you make if you made the first dilution? The second dilution?

6. Make multiple counts. Do this by moving the slide to different positions without changing the magnification of the microscope. Record each count in your data table.
7. Calculate the average number of yeast cells per field of view. Do this by dividing the number of yeast cells by the number of fields of view counted. Record the average count as yeast cells per milliliter.
8. Continue to make counts of the number of yeast cells in culture each day for 7 days (except for weekends). Repeat the counting procedure from Steps 4–7.
9. Wash your hands thoroughly before leaving the classroom.

Part II: Interacting Populations

There is another way to investigate populations from your classroom. You can look at data that scientists have already gathered about populations in nature. How does population growth in a natural environment compare with yeast growing in a lab? The conditions you grew the yeast in varied, just as conditions in nature vary. But populations in nature interact with one another. A yeast population in nature would interact with other populations, such as bacteria.

In Part II, you and a partner will analyze scientists' data from Isle Royale National Park. You will learn how the interactions of three populations affect their size. Isle Royale is the largest island in Lake Superior (see figure 14.3). Its isolation gives scientists a unique opportunity to study the interactions of mammal populations. It is a closed system because mammals cannot regularly enter or leave the island. Scientists have learned valuable information about population interactions from this system.

▲ **Figure 14.3 Map of Lake Superior and surrounding region.** Isle Royale is located off the northern coast of Lake Superior. The island is about 72 kilometers (km) long and 14 km wide at its widest point. It was designated as a national park in 1931.

Materials

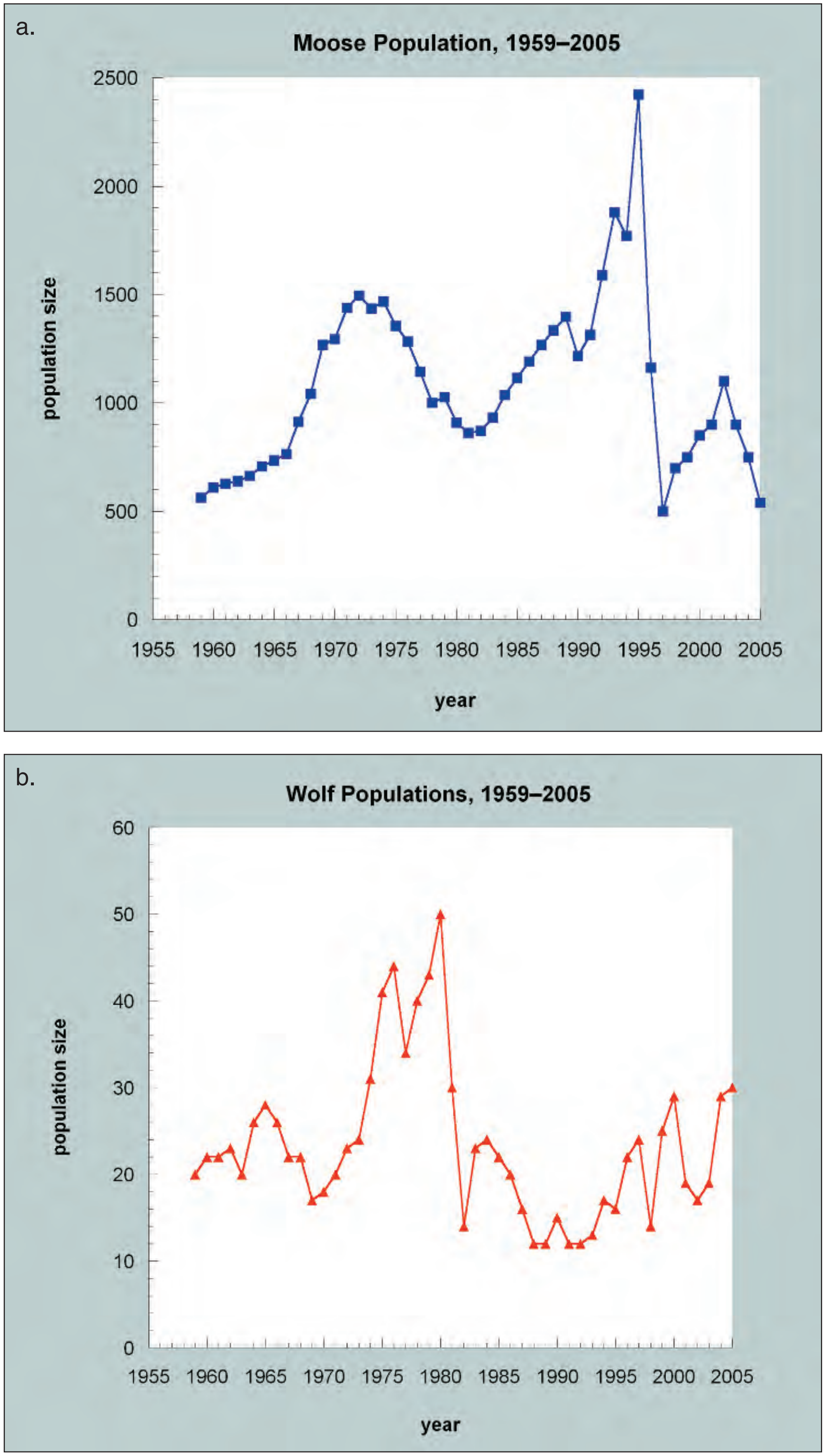
none

Process and Procedure

1. Study the graphs in figure 14.4.
   a. Sketch the essential features of the graphs in your science notebook.
   b. Write highlight comments and a caption for each figure.

Focus on any changes you observe.

   c. Look at the change in the moose population between 1995 and 1998. Then look at the wolf population between 1995 and 1998. What do you notice? Describe the changes in the moose and wolf populations. How do you think the moose and wolf populations might be related?



▶ **Figure 14.4 Moose and wolf populations on Isle Royale.** Biologists estimated the (a) moose and (b) wolf populations on Isle Royale from 1959 to 2005. What changes do you notice in the moose and wolf populations?

d. Read to a partner your highlight comments, captions, and description of how the moose and wolf populations are related. Modify what you have written if necessary.

2. Read *Moose and Wolves on Isle Royale* to learn what scientists know about these populations.

   a. As you read, draw a food web in your science notebook that shows the relationship between the organisms described. Include a caption with your drawing.

   b. Read your caption aloud to a partner. Then adjust your caption based on feedback from your partner.

READING

Moose and Wolves on Isle Royale

The research on Isle Royale constitutes one of the world's longest, continuous studies of either wolves or moose. Moose arrived on the island around 1900. They either swam or crossed an ice bridge, which rarely forms, from the mainland (see figure 14.5). Wolves crossed an ice bridge around 1950. The monitoring of the moose and wolf populations began in 1959 and has continued since. Isle Royale is essentially a single prey–single predator system. The simplicity of this system is not typical but makes it well suited for research. Scientists hope that studying this simple system will help them better understand more complex systems.

▲ **Figure 14.5 Isle Royale in the winter.** Isle Royale is separated from the mainland by more than 24 km of water. Very few species have colonized the island. What might bring more organisms to the island?

Moose and Wolves on Isle Royale, continued

Moose (*Alces alces*) are the only large herbivores on Isle Royale (figure 14.6). Moose feed on aquatic vegetation in the summer and woody vegetation in the winter. They prefer to feed on balsam fir (*Abies balsamea*) seedlings over other tree species. In 2005, the moose population consisted predominantly of old moose, those that were more than 10 years old. These moose survived a large die-off in their population in 1996, which was caused by a severe winter and delayed spring. Mild winters can also be difficult for moose because of the increased number of winter ticks. A high number of ticks in moose can lead to anemia and reduced feeding. Older moose and moose weakened by winter ticks are more vulnerable to wolf attacks.

▲ **Figure 14.6** **Moose in the winter.** Moose have difficulty moving and finding food in deep snow.

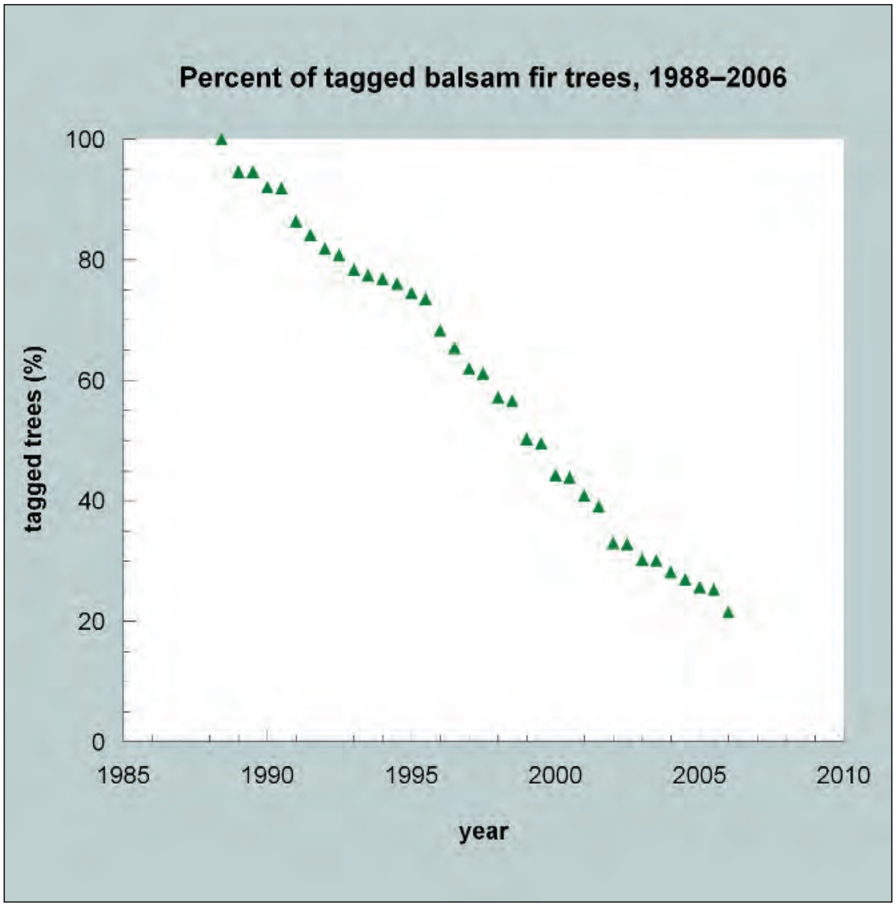
▲ **Figure 14.7** **Wolf pack.** Wolves work together in packs to catch their prey. How do you think deep snow affects the likelihood of a wolf pack attacking a moose?

Hunting of moose and wolves on the island is prohibited. Gray wolves (*Canis lupus*) are the only predators of the moose on the island (figure 14.7). Moose make up 90 percent of the wolves' diet. The other 10 percent of the diet consists of beavers (*Castor canadensis*) and snowshoe hares (*Lepus americanus*). Beavers eat balsam fir, and hares eat grass. The wolf population responds to fluctuations in its prey population (moose), but it is also influenced by other factors. In the early 1980s, many wolves died from canine parvovirus accidentally introduced by humans or their pet dogs. A decline in genetic diversity might also have the potential to affect the wolf population. Some species inbreeding makes populations more vulnerable to fitness loss. (Inbreeding is breeding between closely related individuals. Fitness is the ability of an organism to survive and reproduce in its environment.) For example, inbreeding might increase the likelihood that individuals in the wolf population will have a genetic disorder. Scientists have gathered evidence of vertebrae abnormalities in the Isle Royale wolf population. But so far, there is no evidence that the survival rate of wolves with the abnormality has changed.

3. Now that you know a little more about moose and wolves on Isle Royale, complete the tasks in Steps 3a–b.
   a. List at least 2 factors that you think might cause the moose population to *increase*. Then list at least 2 factors that might cause the moose population to *decrease*. Explain why for each factor.
   b. Repeat Step 3a for the wolf population.
4. Study the graph in figure 14.8. Then answer Questions 4a–b about the balsam fir population.

Look for and try to explain any changes you see. This is one of many effective ways to study graphs and charts.

   a. Describe the trend for tagged balsam fir trees.



▲ **Figure 14.8 Percentage of tagged balsam fir trees.** Scientists tagged a portion of the balsam fir trees on Isle Royale in 1988. All of the trees were mature, meaning they were able to produce seeds. Since 1988, the number of tagged trees has declined. What has happened to the number of mature fir trees since 1988? What might have caused this change?

b. The data in figure 14.8 show the percentage of tagged mature fir trees that remain each year since 1988. Mature trees produce seeds. These trees are necessary for saplings (young trees) to become established and contribute new growth in the forest. How do you think the change in the abundance of mature balsam fir trees will affect the overall abundance of balsam fir trees?

Think about a factor that should increase the population.

5. Read the following paragraph about the forest vegetation on Isle Royale. Use the following questions to focus your reading:
   - "How does the age and number of trees on the east end of the island compare with the trees on the west end of the island?"
   - "What factors contribute to the differences?"

   Forests on the east end of the island have more young balsam fir trees than forests on the west end of the island. After a wildfire burned many trees on the east end, the number of new balsam fir trees there has been gradually increasing. On the west end of the island, the growth of new balsam firs is very low. As moose feed on balsam fir saplings, they prevent the saplings from growing (see figure 14.9). Most of the trees on the west end are old and produce fewer seeds. Many of the older trees are expected to die in the next 10 years.

6. Complete Steps 6a–d to show what you have learned about the abundance of balsam fir trees and how the abundance might change in the future.

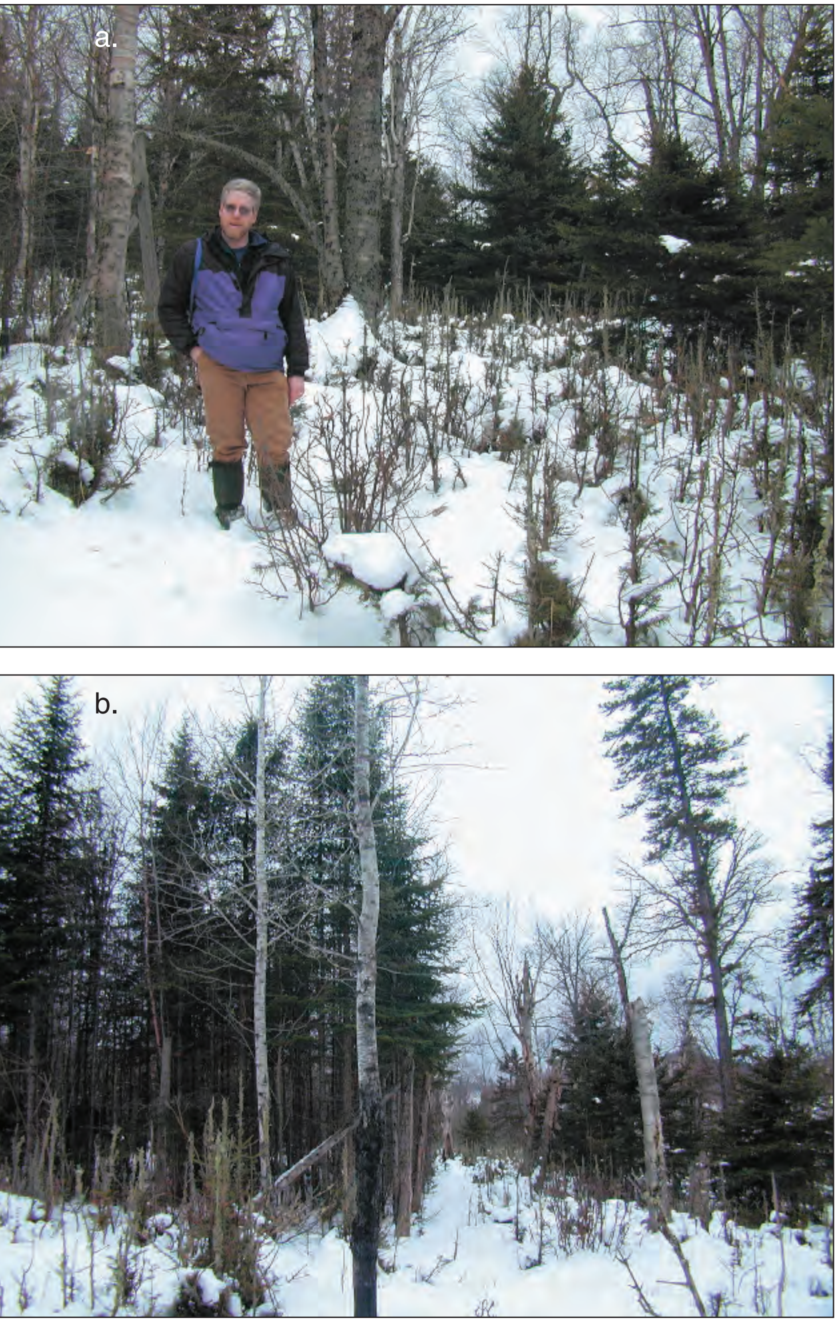


Figure 14.9 The effect of moose on balsam fir. (a) Balsam fir growth is hindered where moose feed intensely. Moose can feed in this forest, where there is an open canopy and very few mature balsam fir. (b) An exclosure is an area fenced off to keep organisms out. This 50-year-old exclosure shows that where moose are excluded, balsam fir are abundant and healthy. This forest is protected from moose and contains mature balsam firs and a dense canopy.

a. Represent in a sketch what you read about the current abundance of firs. Consider making a map of the island that uses simple drawings to represent the abundance of balsam firs. (A map of Isle Royale is shown in figure 14.10.) Include highlight comments and a caption with your sketch.
b. Create another labeled sketch that represents the abundance of firs on Isle Royale in 10 years.
c. Use an effective strategy to get feedback on your sketch.
d. Record the results of your feedback in your science notebook.

SCILINKS NSTA
Go to: www.scilinks.org
Topic: moose population
Code: 2Inquiry719a
Topic: wolf population
Code: 2Inquiry719b

Reflect and Connect

Work alone to answer the following questions in your science notebook.

1. Study figure 14.10. Explain why moose are distributed unevenly across Isle Royale during the winter of 2002.

Review the paragraph from Step 5 to help you answer the question.

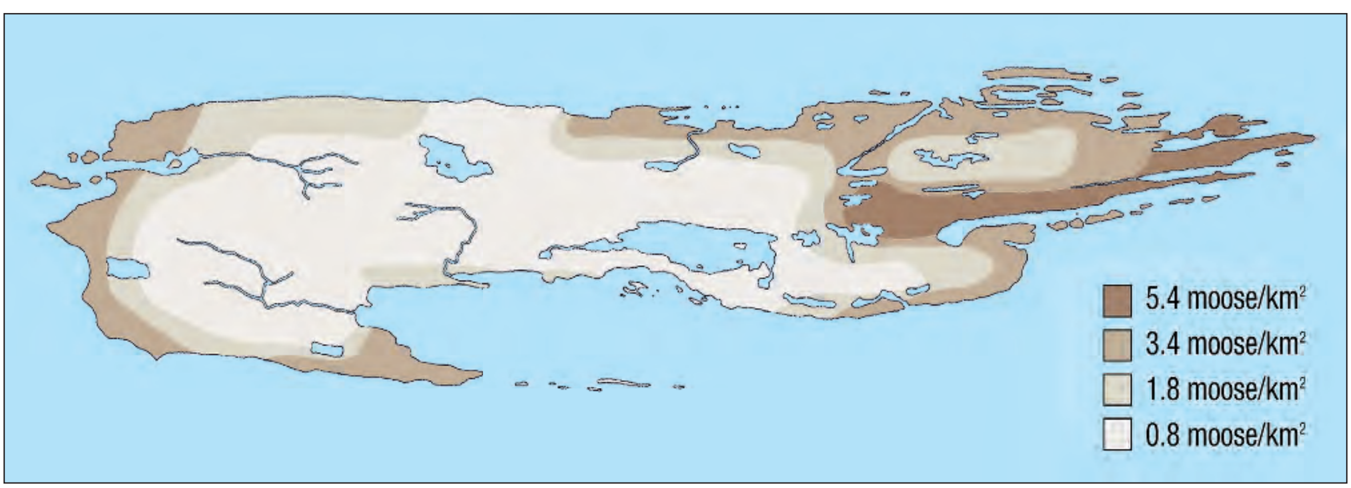
2. Copy figure 14.8 into your science notebook and extend the *x*-axis to 2055.
   a. Predict how the balsam fir population will change over the next 50 years.

Extending the line will help you make your prediction.

   b. Add highlight comments to the graph to explain why you think those changes will occur.
3. Copy figure 14.4 into your science notebook. Extend the *x*-axis to 2055.
   a. Predict how the moose and wolf populations will change over the next 50 years.

Extending the line for both populations will help you make your predictions.

▼ **Figure 14.10 Moose distribution on Isle Royale during winter 2002.** Moose are more common on one end of the island. What might cause this distribution?



b. Add highlight comments to the graph to explain why you think those changes will occur.

4. In Part I, you investigated different environmental conditions for a population of yeast. What environmental conditions do you think might affect the populations on Isle Royale? List at least 2 conditions.

5. Suppose you could add an organism that feeds on yeast to the yeast culture. Explain how you think the yeast population would be affected. Give your answer as a graph that shows the resulting yeast population and the population of another organism across time. Include a caption with your graph.

EXPLAIN

Systems in Balance

Natural processes are important to the maintenance of systems. Chemical reactions are one type of natural process. You learned in unit 1 that many chemical reactions are reversible under the right conditions. A chemical system is at equilibrium when the rate of the forward reaction equals the rate of the reverse reaction. These reactions are an important part of processes in living systems. In unit 3, you learned that fluxes into and out of a system maintain the system. In the global carbon cycle, many of the carbon fluxes depend on processes that involve chemical reactions. (Remember, a carbon flux is the movement of carbon between reservoirs.)

In *Systems in Balance*, you will learn how natural processes maintain ecosystems from year to year (figure 14.11). Changes in populations are part of these natural processes. For example, fluxes into and out of a population eventually cause a population to reach equilibrium. Interactions between populations, just like interactions between molecules, influence a system. In this case, the system is an ecosystem. In Part I, you will learn what influences populations. Then in Part II, you will learn what shapes ecosystems, including how the interactions of populations shape ecosystems.

▼ **Figure 14.11 Oak-grassland ecosystem.** Oak-grassland ecosystems consist of a mixture of oak forest, meadows, and grasslands. What natural process might help maintain this ecosystem?

Part I: Population Dynamics

Materials

For each student

1 calculator

graph paper

graphs of the yeast population from the activity *Changing Populations*

Process and Procedure

You have investigated several populations. Did these populations stay the same or change across time? What makes a population change? Given enough space and **resources**, a population can potentially continue to grow indefinitely. In Part I, you will work alone or with a partner to learn what characterizes populations and what limits population growth.

1. Imagine a single bacterium cell in a large container of nutrient medium. If the cell and its descendants divide every 30 minutes (min), how many cells would you expect to find in the container in 24 hours (hr)? Model the population growth of bacteria through calculations and graphing. Steps 1a–e will help you.
   a. Copy the table in figure 14.12 into your science notebook. Add enough rows so that you can calculate for 24 hr in Step 1d. You will calculate the increase in the number of bacterium cells in 3 hr. Perform the calculations and complete the column titled "number of bacterium cells."
   b. Identify the mathematical relationship in the right-hand column. First, read down the middle columns. How much does the number of bacterium cells increase by? Now read down the right-hand column. Calculate what n is by using the amount of increase.

For example, if $2 = 2^n$, then n must be 1 for the second row.

Time (hours)	Number of cell divisions	Number of bacterium cells	Mathematical representation
0.0	0	1	$= 2^n$
0.5	1	2	$= 2^n$
1.0	2	4	$= 2^n$
1.5	3	8	$= 2^n$
2.0	4		$= 2^n$
2.5	5		$= 2^n$
3.0	6		$= 2^n$

◀ **Figure 14.12 Modeling bacterium population growth.** How does the number of bacterium cells change every 30 min?

c. Notice how the population doubles every 30 min. What does the 2 in the right-hand column represent? What does *n* represent?

d. Now calculate the bacterium population after 24 hr. Show your work. Consider rounding the number and giving your answer in scientific notation.

For example, the scientific notation for 5,869,481 is 5.9×10^6.

e. Draw a graph of this bacterium population for a 12-hr period. Include highlight comments on your graph. Your graph represents 1 type of population growth curve.

2. Read the following 2 paragraphs to learn about exponential growth. Then write an answer in your science notebook for the question in the second paragraph.

The graph of the bacterium population is an example of **exponential growth**. Exponential growth happens when an increase occurs at a constant *rate* per unit of *time*. At first, the population grows slowly, then it increases progressively faster and faster. The number of individuals added to the population gets larger and larger across time. This occurs because the constant rate of growth applies to a larger and larger population. Eventually, the population reaches a very large size. Exponential growth occurs in other situations as well. For example, compound interest makes the money in your savings account grow quickly. The amount your money grows depends on your interest rate.

Think about this. Would you rather start with $1 in your savings account and have it double every month for 1 year, or get $100 each month for a year? Calculate the total for your savings account for both situations after 1 year. Then explain why you would choose $1 that doubles every month or $100 a month. Show your calculations.

3. Complete the tasks in Steps 3a–c to learn how exponential growth affects populations.

a. Read the information in the following paragraph. You will use it to create a graph showing the relationship between population growth and population density.

Why hasn't exponential growth resulted in enormous numbers of organisms that completely overwhelm Earth's resources? In reality, populations rarely grow exponentially. As a population grows, its **population density** increases as well. Population density is the number of individuals per unit of land area or water volume.

b. Look at the data in figure 14.13. Decide how you will label the axes of your graph. Then graph the data to see how the growth of a paramecium population changes as the population density increases. Include highlight comments on your graph.

c. How is the paramecium graph similar to the bacterium graph? How is it different?

4. Add a horizontal line to your graph indicating the *carrying capacity* of the paramecium population. Read the following 2 paragraphs to learn what carrying capacity is.

The pattern of a population's size growing slowly, then rapidly, and finally leveling off is called **logistic growth**. You are familiar with logistic growth in other situations. For example, wages increase steadily when you begin working. Then they level off as you approach retirement.

Let's look at what happens in natural systems. As a population's density increases in an environment, the amount of space and resources decreases. Competition within the population increases as nutrients and other resources are used up. Toxic bodily wastes may build up in the environment. Predators and parasites may become common. All these factors reduce reproduction and increase the number of deaths in the population. This slows population growth. A population that develops in a new environment may begin to grow exponentially. But it soon slows and eventually approaches a maximum size. This maximum is called the **carrying capacity**. Carrying capacity is the largest population of a species that the environment can support in a given period of time. Carrying capacities are not fixed.

5. Read *Population Growth* to learn what causes populations to change size.

a. Use this question to focus your reading: "How is population size related to births, deaths, immigration, and emigration?"

b. Fill in the T-table in figure 14.14 as you read.

Time (days)	Number of organisms
1	25
2	120
3	310
4	375
5	375
6	375

Source: G. F. Gause. (1934). *The struggle for existence.* Baltimore: Williams and Wilkins.

▲ **Figure 14.13** **Paramecium population data.** Paramecia are single-celled organisms. How will a graph of these data compare with the graph of the bacterium population in Step 1?

Term	How it is related to the focus question
birthrate	
mortality rate	
immigration	
emigration	
limiting factor	

▲ **Figure 14.14** **Relationship to population size.** Describe how each term on the left is related to the focus question. Add any terms to the T-table that you think are important.

READING

Population Growth

Imagine a park with 125 oak trees. Thirty years later, the park has only 115 oak trees. What does the decrease of 10 oak trees represent? Because trees cannot wander away, they must have died or been cut down. In this situation, the decrease represents the death rate, or **mortality rate**, of the oak tree population. The number of deaths in the oak tree population per unit of time is the mortality rate. Mortality is not the only change that can affect a population, however. While some of the trees may have died, some young oak trees may have started to grow from seed. Death decreases a population; reproduction increases it. The rate at which reproduction increases the population is called the **birthrate**.

Immigration and emigration are two other ways that change population size in organisms that can move. Imagine you studied the pigeon population in your city. You discovered that in 1 year a certain number of pigeons flew into the city and a certain number flew out. **Immigration** occurs when one or more individuals move into an area where others of their type can be found. Immigration increases the population. **Emigration** occurs when individuals leave the area. Emigration decreases the population. A simple way to remember the difference is that during *immigration* organisms move *into* an area. During *emigration*, organisms *exit* an area.

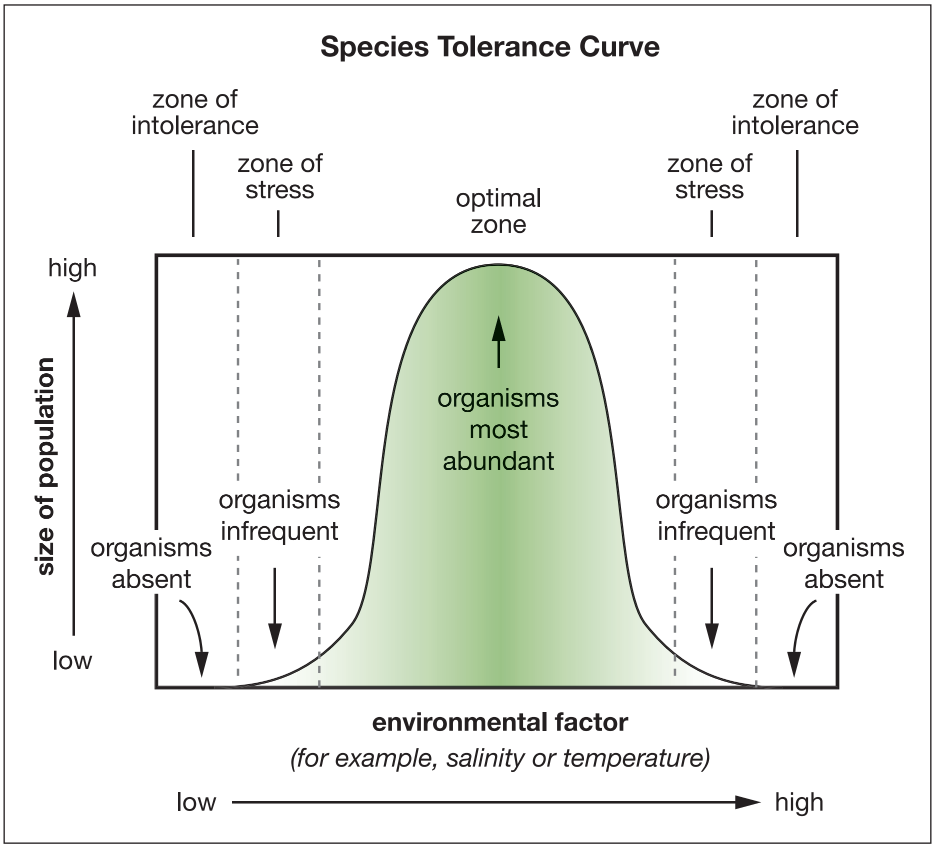


Figure 14.15 Species tolerance curve. There are maximum and minimum levels of environmental factors that affect where an organism can survive. These levels might be determined by abiotic factors such as salinity or temperature. Can you think of other environmental factors that will affect where an organism lives?

In any population that can move, birthrate and immigration increase the population. And mortality and emigration decrease the population. Thus, a population's size is the result of the relationships among these rates.

What are some things that might decrease population growth? That is, what could reduce the birthrate or increase the mortality rate? Are there factors that could increase emigration? How does the environment influence population growth?

The **environment** is everything that surrounds and affects an organism. The environment has two parts. The living part is called the **biotic** environment. The biotic environment for a wolf on Isle Royale includes all the plants, animals, and microorganisms that live or once lived on the island. The nonliving part is called the **abiotic** environment. The abiotic environment includes such things as sunlight, water, nutrients, and physical structure.

The environment affects individuals. The environment may slow the individual's growth, kill it, or stimulate its growth and reproduction. Any biotic or abiotic factor that can *limit* the growth of a population is a **limiting factor**. For example, predators like coyotes are biotic limiting factors for a population of rabbits. Temperature is an example of an abiotic limiting factor. Many plants and animals only survive in a specific range of temperatures. Figure 14.15 shows a species tolerance curve. This graph illustrates how environmental factors affect the abundance of organisms.

SCiLINKS NSTA
Topic: population growth
Go to: www.scilinks.org
Code: 2Inquiry725

6. Complete the following 2 tasks to show your understanding of population growth.
   a. Finish the following equation to show how population size is related to births, deaths, immigration, and emigration.

      population size = ________________

   b. Calculate the size of a population of least bitterns (see figure 14.16) over a period of 4 years using data in figure 14.17.

▲ **Figure 14.16 Least bittern and chicks (*Ixobrychus exilis*).** Least bitterns are secretive marsh birds that live in wetlands with tall vegetation.

Time	Starting population	Birthrate (chicks/year)	Mortality rate (birds/year)	Immigration (birds/year)	Emigration (birds/year)
Begin	30	4	6	10	2
year 1	?	3	3	2	5
year 2	?	3	3	2	5
year 3	?	3	4	3	6
year 4	?				

◀ **Figure 14.17 Information about a least bittern population.** How does the population change from one year to the next?

Stop & THINK

PART I

Work alone or with a partner to answer the following questions in your science notebook.

1. What are the 4 factors that determine population size?
2. How is a limiting reagent in a chemical reaction similar to a limiting factor for a population? How is it different? Use a Venn diagram to show the similarities and differences.
3. You have learned about exponential and logistic growth. Apply this new knowledge to the yeast investigation from the explore activity, *Changing Populations*, and answer Questions 3a–c. Refer to your graph of the yeast population and the graphs from other teams.
   - **a.** What growth pattern (exponential or logistic) did the yeast population have? Explain your answer.
   - **b.** What was the carrying capacity of your team's yeast population? Provide evidence for your answer. If your yeast population did not reach carrying capacity, then estimate what the carrying capacity might have been if you had continued to monitor the yeast population. Provide an explanation for your estimate.
   - **c.** Was the carrying capacity for your team's yeast population different from the carrying capacity for other teams? Explain why or why not, and discuss possible limiting factors in your response.
4. Answer Questions 4a–d about the moose and wolf populations on Isle Royale. Review the text and graphs from the explore activity as necessary.
   - **a.** Which of these factors affect the moose and wolf populations: birthrate, mortality rate, immigration, and emigration?
   - **b.** Predict the carrying capacity for moose and wolves on Isle Royale.
   - **c.** List 4 limiting factors for the population of moose. At least 1 of the factors must be abiotic.
   - **d.** How do you think the change in the balsam fir population will affect the carrying capacity for moose on Isle Royale? Explain your answer.

Part II: Ecosystems

Materials

none

Process and Procedure

The world around you consists of more than populations of living organisms. How do the conditions in an environment influence populations? In Part II, you will work with a partner to learn about the systems that affect and are affected by living organisms. You also will relate what you learn about these systems to the cycling of matter and the flow of energy.

1. Think about what kind of relationships you have with the people you encounter. You also have relationships with organisms other than people. In fact, organisms are constantly interacting with other organisms. Work with your partner to consider these relationships.
   a. Read *Relationships among Populations* to learn about some of these interactions.
   b. Look ahead to Steps 2 and 3 to guide your reading. Take turns talking about your ideas. Revise your responses if you get new information after talking with your partner. Remember, this is the think-share-advise-revise (TSAR) strategy.

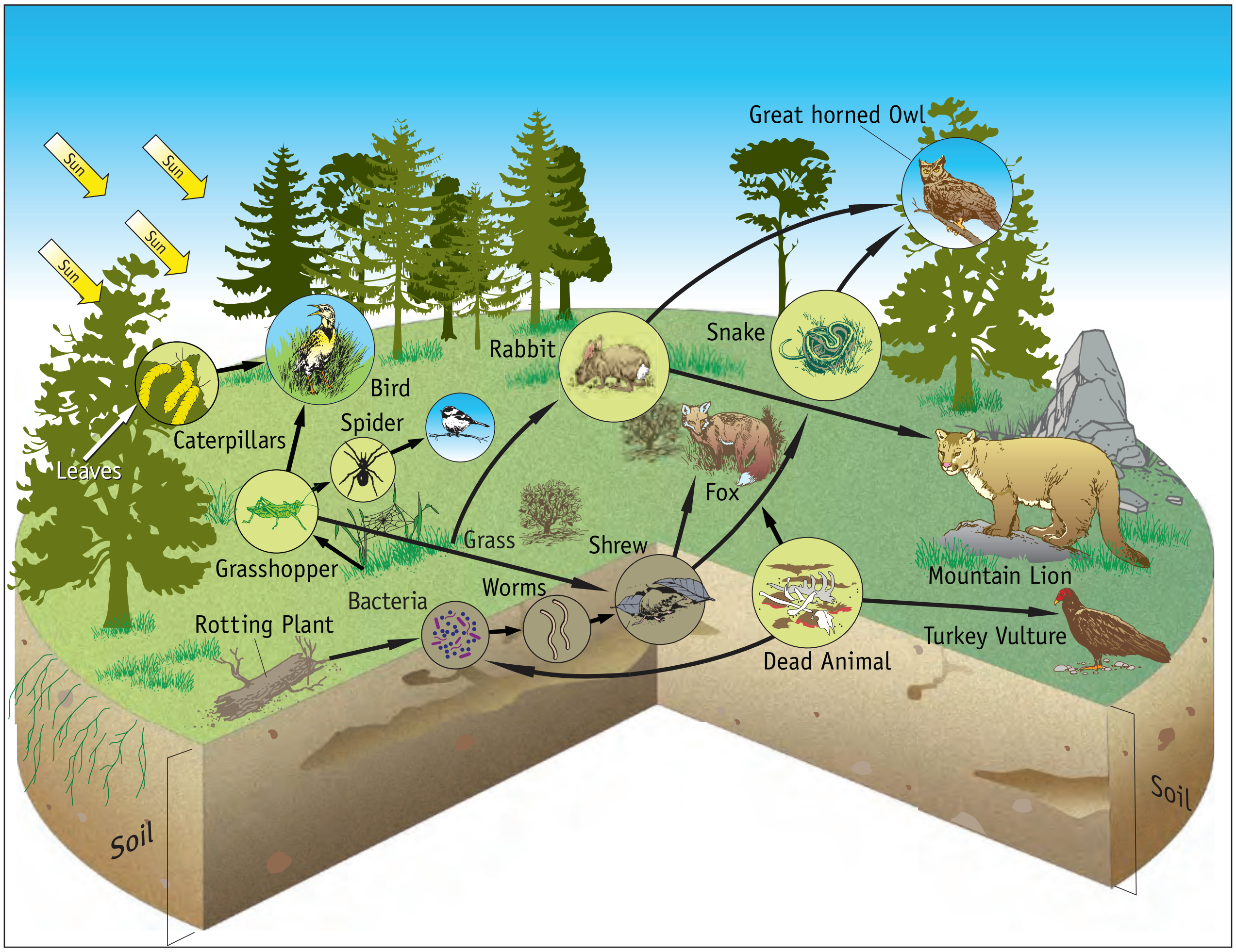
READING

Relationships among Populations

All populations of organisms, including human populations, interact with one another. The interactions form a complex web of relationships. These interactions can be beneficial or harmful. But all involve the cycling of matter and the flow of energy.

All the populations of different species in a designated area make up a **community**. Each environment has a community of different organisms. Many types of relationships help form a community's web of life. Each relationship involves at least two different organisms. The most obvious relationship between organisms is who eats whom. This is called a feeding relationship. Most organisms get their food from many sources.

We can use a food web to illustrate the feeding relationships in a community of organisms. Figure 14.18 shows one example of a food web. Notice how many of the relationships are between predators and prey. Also notice the decomposers that break down the dead bodies of plants and animals. There are other common relationships between organisms besides predator-prey relationships. These include competition and mutualism (see figure 14.19).



▲ **Figure 14.18 Food web.** Food webs show the feeding relationships among different species within a community. Arrows in the diagram show the direction of energy flow. The arrow points from the organisms getting consumed to the consumer. For example, worms get eaten by shrews, which in turn get eaten by foxes. Recall that producers are organisms that make their own food and consumers obtain their food by eating or breaking down other organisms. Can you think of other arrows that you would include for the organisms shown in this community?

Relationship	Effect of the relationship	Description
Mutualism	+ / +	A relationship among organisms in which both organisms benefit. For example, lichens often consist of an alga and a fungus that live in close association. The alga produces food through photosynthesis and the fungus provides moisture and nutrients. Another example is the relationships between some plant species and insects. Insects eat pollen or nectar provided by the plant and the insect helps the plants reproduce through pollination.
Predator-prey	+ / −	One organism (predator) eats another (prey). This relationship is lethal to the prey but is not an intimate association.
Parasitism	+ / −	One organism (parasite) lives on or in another organism (the host), using it as a food source. The relationship between the two species is more intimate, but not usually as lethal as predator-prey.
Herbivory	+ / −	The consumption of living plant material by a consumer (grazers). The relationship is usually not as lethal as predator-prey and is not intimate.
Competition	− / −	Organisms may compete for such things as food, space, sunlight, nutrients, or water. The competition is often for a resource that limits the growth of a population. In competition, both organisms are harmed.

▲ **Figure 14.19 Relationships in ecosystems classified by effects of the relationship.** In figure 14.18, organisms were classified by feeding relationships. It is sometimes useful to classify species in a community by the effect they have on each other. The survival or reproduction of a species may benefit from the presence of another species (+) or be harmed by it (−). In the table, + / + indicates that both species benefit from a relationship, + / − indicates that one species is harmed and the other benefits, and − / − indicates that both species are harmed.

SCILINKS NSTA
Topic: food webs
Go to: www.scilinks.org
Code: 2Inquiry729

2. After completing the reading, identify the following relationships as predator-prey, parasitism, herbivory, competition, or mutualism. Justify your response and record it in your science notebook. You will use your responses in a class discussion.
   a. A hummingbird getting nectar from a flower and getting pollen on its back
   b. Prairie dogs and bison feeding on grass
   c. Wolves and moose on Isle Royale
   d. Leeches on a fish
   e. A bird removing seeds from a pinecone

3. Answer Questions 3a–b about how relationships can affect population size. Provide a brief explanation for each answer.
   a. How does a predator-prey relationship affect the population size of the 2 organisms involved?
   b. How do you think competition between 2 organisms affects their population sizes?
4. Read *Structure of an Ecosystem* to learn what characteristics ecosystems have and how energy and matter move into and out of ecosystems. Look ahead to Step 5 to guide your reading.

READING

Structure of an Ecosystem

A community (the biotic environment) and the abiotic environment make up an ecological system, or **ecosystem**. You learned that the biotic and abiotic environments influence populations. Scientists look at the abiotic and biotic environments to understand how natural systems work. Suppose a trout population in one river ecosystem is wiped out. Yet a trout population in a different river ecosystem flourishes. You may wonder why. So you would compare the abiotic environments in the two ecosystems. From that, you would learn that the first ecosystem had water temperatures above the trout's tolerance limit. As a result, the temperatures wiped out the trout in that ecosystem. Read FYI—*Climatic and Topographic Effects* to learn how climate and topography affect the biotic and abiotic environments in ecosystems.

Ecosystems are open systems. Things constantly enter and leave them. Energy is one of the largest inputs into ecosystems. The Sun is the ultimate source of energy for most ecosystems. Other sources include wind, rain, water flow, or fuel (for ecosystems with humans). Energy outputs can be in the form of heat and organic matter (food and waste products). Other fluxes for ecosystems include water, air, nutrients, and organisms. If you find learning about ecosystems interesting, you might enjoy a career in ecology. You can learn more about careers in ecology in the sidebar *Working for the Environment*.

All organisms require energy. Thus, the amount of energy and material entering and leaving an ecosystem determines the size and diversity of the biotic community. The flow of energy and the cycling of matter from one organism to another tie organisms together. The flow of energy begins with producers. Producers convert light energy from the Sun into food (chemical energy). The conversion occurs through photosynthesis, which involves a series of chemical reactions.

How does energy flow through an ecosystem? The answer is in the ecosystem's trophic structure. The trophic structure is made up of the feeding relationships among the producers and consumers. Each step in a food web is a trophic level. The relationships between trophic levels determine the flow of energy and the cycling of matter in the ecosystem.

Producers make up the trophic level that supports an ecosystem. Consumers are another trophic level. Consumers can depend directly or indirectly on producers for energy and matter.

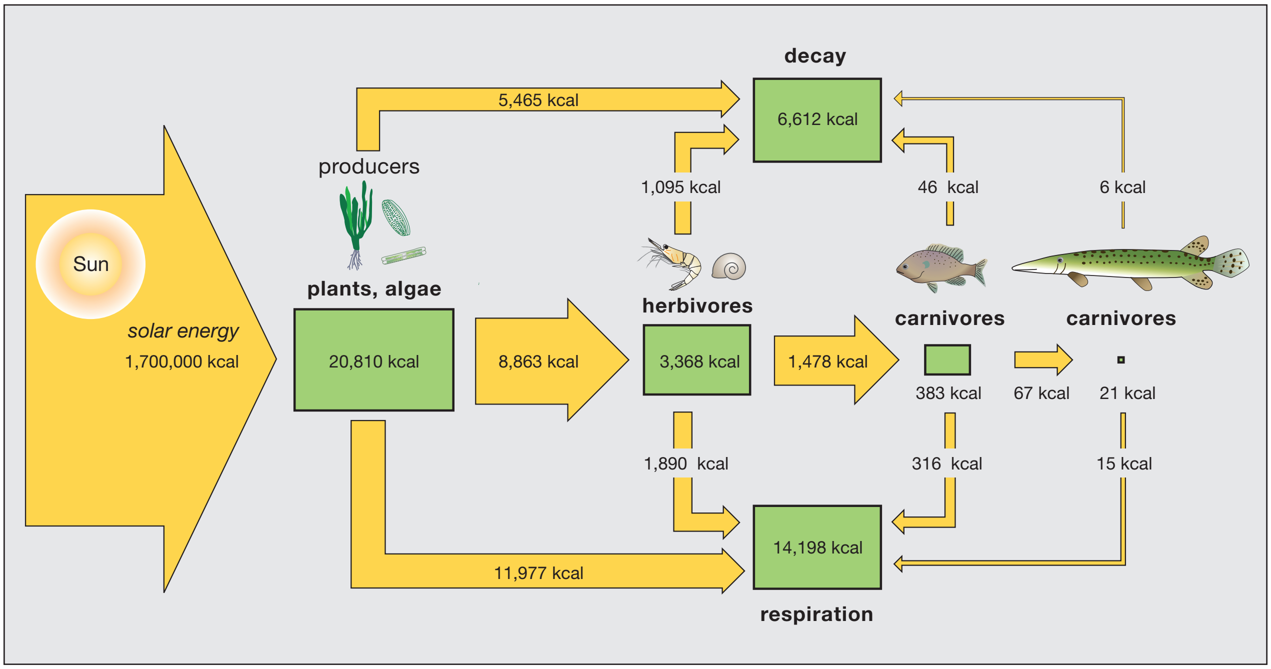
Herbivores (organisms that consume plants or algae) are the primary consumers. Deer, grasshoppers, and garden snails are primary consumers. Carnivores that eat herbivores are secondary consumers. Carnivores that eat other carnivores are tertiary (third-level) consumers. Finally, decomposers consume organic material and dead organisms from all trophic levels. Can you identify the trophic levels of the organisms in figure 14.18?

You can use trophic levels to illustrate the amount of energy entering and leaving an ecosystem. Study figure 14.20 to see how energy is distributed from one trophic level to another. Notice that primary producers are the foundation. Each trophic level above them receives less energy. In many ecosystems, each trophic level receives about one-tenth the energy of the level below it. Where does the energy go? Most of the energy is lost to the environment as heat and also to activities needed to keep an organism alive.

You know that the available energy declines at higher trophic levels. So does **biomass**. Biomass is the total amount of living organic matter for a given area of the environment. Living organic matter includes all the living organisms in an area such as plants and animals. Recall that all organisms are composed of organic molecules.

The rate at which new biomass forms, or the **productivity**, is highest among producers. Consumers at higher tropic levels generate less biomass and so are less productive. Therefore, an ecosystem can sustain far fewer top-level carnivores than low-level consumers and producers. For example, the total mass of the coyotes in a grassland is much less than the total mass of rabbits and other prey. The total mass of the coyotes also is less than all the mass of the grass.

In the next chapter, you will learn how the productivity of different ecosystems and agricultural systems has implications for humans.



▲ **Figure 14.20** **Energy flow diagram for Silver Springs, Florida.** How does the amount of energy (in kilocalories, or kcal) differ from one trophic level to the next? Can you calculate what percentage of energy is transferred from producers to herbivores (primary consumers)?

5. After completing the reading, answer Questions 5a–d about ecosystems.
   a. Would you expect most ecosystems to contain more primary consumers or more secondary consumers? Explain your answer.
   b. Imagine a grassland ecosystem with mice, other herbivores, and predators, such as weasels, which eat mice. Use a sketch or diagram to represent the relative biomass of different trophic levels in this ecosystem. For example, trophic levels often are shown as horizontal, stacked bars inside a pyramid. The lowest trophic level is on the bottom.
   c. Figure 14.21 shows how energy might be distributed in the different trophic levels for the grassland ecosystem described in Step 5b. Create a diagram like the one in figure 14.20 to show the flow of energy for the grassland. Your diagram should include the following:
      - Inputs and outputs of energy
      - Three trophic levels that are labeled
      - The total energy lost through cellular respiration and the energy stored in the remains of organisms

Calculate the total energy lost based on the information in figure 14.21.

      - Sizes of boxes and arrows that are scaled to represent the relative amount of energy

For example, the box for producers should be larger than the box for consumers.

   d. Why is only *part* of the chemical energy produced by plants available for use by herbivores?
6. The interactions of organisms in ecosystems ensure that all organisms have a supply of energy from food. The abiotic environment continues to supply the matter that organisms need to survive. Read *Cycling of Matter in Ecosystems* to learn how. Take notes as you read.

SCiLINKS NSTA
Topic: ecosystem
Go to: www.scilinks.org
Code: 2Inquiry732

Figure 14.21 Energy for a grassland. Calculate the total energy lost through cellular respiration and the energy stored in the remains of organisms. Where does the energy input for plants come from?

Part of the ecosystem	Energy input (kcal)	Energy produced (kcal)	Energy loss from cellular respiration (kcal)	Unused energy from the remains of organisms that later decay (kcal)
Plants (primarily grass)	4,710,000	52,800	9,600	26,950
Mice and other herbivores	16,250	14,300	3,700	10,200
Weasels and other predators	400	6	5	1

READING

Cycling of Matter in Ecosystems

How are conditions in ecosystems maintained for hundreds or thousands of years? A constant recycling of materials between the biotic and abiotic environments is required. Recall that the amount of chemical elements on Earth is fixed. Essentially, the same atoms and molecules are used over and over. Many of the processes that allow atoms and molecules to be used again occur in ecosystems. In chapter 3, *Collisions—Atomic Style*, you learned about the law of conservation of matter. This law states that matter is conserved in ordinary chemical and physical changes. In other words, matter is transformed, but it doesn't disappear. It cycles endlessly.

You learned about the cycling of water and carbon in unit 3. You know that water cycles between global reservoirs. But it also cycles through ecosystems. Plants absorb water from the soil. Land animals, other consumers, and decomposers absorb water from food or drink it directly. Aquatic organisms are constantly bathed in water. Water returns to the atmosphere through cellular respiration, transpiration (water loss by plants), and evaporation, mostly from the oceans.

Carbon is important for ecosystems. It must cycle through ecosystems to provide the raw materials living organisms need. Living organisms are made up of organic molecules that are based on a skeleton of carbon atoms. Recall from chapter 11 and Level 1 of this program that plants take in carbon dioxide during photosynthesis. Then a series of chemical reactions makes organic molecules. Some of the carbon remains in the bodies of producers and consumers. The carbon leaves them when their bodies decay on a forest or ocean floor. The remaining carbon returns to the air as carbon dioxide through cellular respiration in producers, consumers, and decomposers.

Reflect and Connect

Complete the following tasks individually in your science notebook.

1. Explain how an abiotic factor can affect biotic factors in an ecosystem.
2. Why is energy said to *flow through* an ecosystem in one direction, whereas matter such as carbon *cycles* through an ecosystem? Think about what the source of energy and matter is for ecosystems.
3. Explain why ecosystems typically have so few top-level consumers such as tigers, eagles, and sharks. Think about what you learned about the amount of energy that flows through the different trophic levels in ecosystems.

FYI

Climatic and Topographic Effects

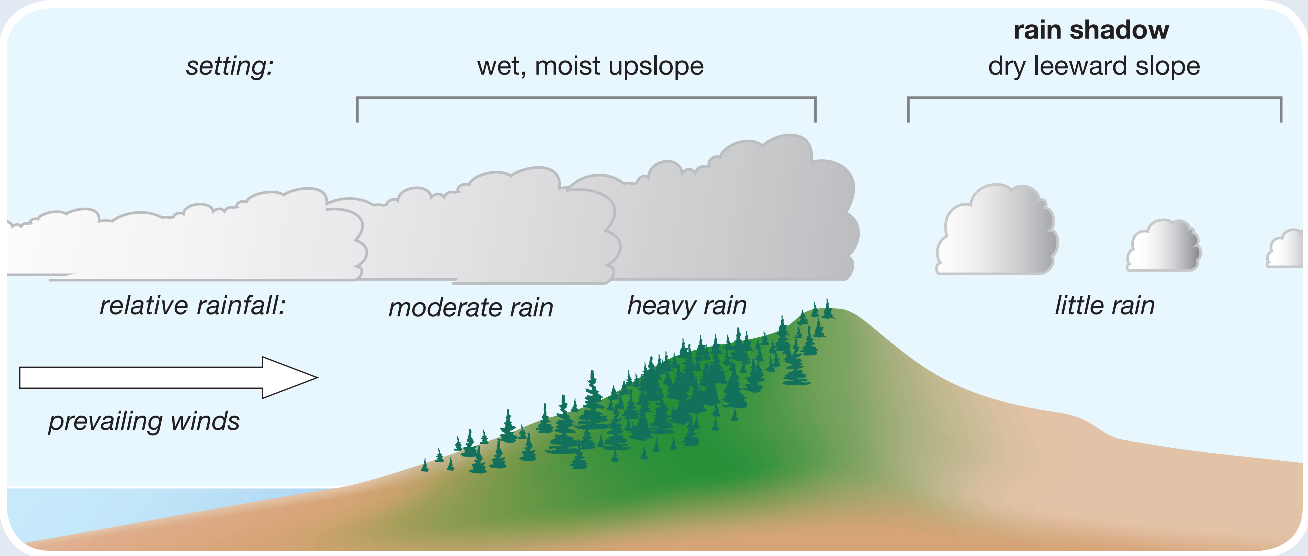
Climate

Climate is an important abiotic factor that shapes ecosystems. Climate is the weather conditions in an area over long periods of time. Climate depends on factors such as temperature, precipitation, humidity, and wind. For example, the climate of a tropical rain forest ecosystem is hot and humid year-round. This ecosystem also receives a lot of precipitation. In contrast, a desert ecosystem can have hot or cool temperatures depending on the time of year. This ecosystem gets very little precipitation.

Topography

Topography, the elevation and shape of Earth's surface, contributes to climate. For example, mountains cause rain shadows. Rain shadows are dry areas on the leeward (downwind) slopes of mountain ranges (see the illustration). Topography also affects temperature. Have you ever driven up a mountain? You probably noticed that the air gets colder as you go up in elevation. Similarly, temperatures are cooler at higher latitudes. Solar radiation is less at the poles than at the equator because of the angle of incoming radiation.

Topography affects the location of water reservoirs. Remember that water is an important abiotic factor in ecosystems. Contours of the land, such as ridges and valleys, determine where water accumulates in ponds or lakes and runs in rivers. Different species of plants grow depending on the availability of water. For example, you will never find lily pads growing in a desert. Changes in elevation also determine how fast water flows in rivers. Have you ever noticed that water seems to run faster in mountain streams? There is more dissolved oxygen in fast-flowing rivers than in slower rivers. Water temperatures are also colder in mountain streams, allowing more oxygen to dissolve. As a result, trout only survive in cold, fast-flowing rivers because they need higher levels of oxygen to survive. Oxygen is an important abiotic factor for many organisms.



Rain shadow effect. Rain shadows are areas of low rainfall on the leeward (downwind) slope of a mountain range. They form as warm, moist air rises to higher elevations where temperatures are cooler. Cool air holds less moisture than warm air, causing precipitation to fall on the windward side. The air has lost most of its moisture by the time it reaches the leeward slope.

Earth is a patchwork of distinctive ecosystems called **biomes**. Biomes are large habitats created by major types of climates. They feature a characteristic type of vegetation. For example, warm, arid climates are associated with desert vegetation. Semiarid climates usually are covered with grassland. Moist climates support forests. Each type of plant life, in turn, supports a characteristic variety of animal life. The resulting community of plants and animals forms the biome.

Scientists benefit from studying the physical surroundings that organisms live in. They can better understand the ways that matter and energy are stored or move between parts of an ecosystem. They also learn how an ecosystem works by studying its organization and function.

SIDEBAR

Working for the Environment

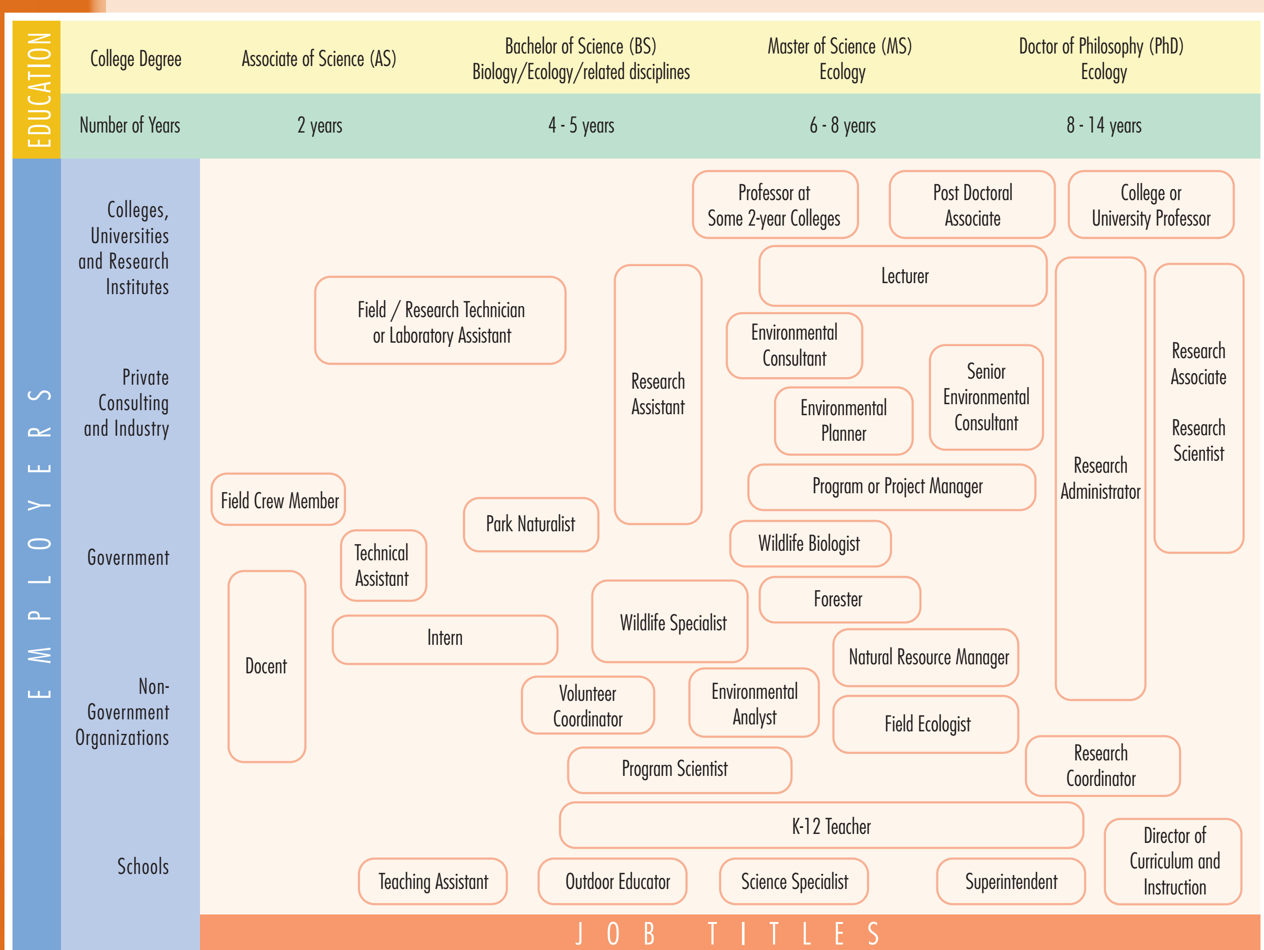
Careers in ecology are diverse and often fun and rewarding. The type and location of the work depend on the job. Ecology jobs can take place indoors in the lab or outdoors in a unique ecosystem. The work can be solitary or with a team of people. Recall that ecology is the study of how living things interact with one another and their environment. People who work in the ecology field are curious about the natural world, enjoy investigating problems, and often want to contribute to society. Their work adds to our understanding and preservation of the natural world.

People with ecology careers need a background in science and certain skills. Ecology involves biotic and abiotic systems. Thus, ecologists need to understand all fields of science. These sciences help them study the links between living things and their environment. Mathematics is also important for making measurements and predictions about the natural world. Sometimes researchers use mathematical models to study processes in ecosystems. Computer skills are important for using tools to analyze data. Communicating ideas in written and oral form is another needed skill. Finally, some ecological issues involve more than the natural world. They may require an understanding of economics or engineering.

Careers in ecology exist for different interests and levels of education. If you like being outdoors, you can find a job that involves fieldwork. Fieldwork can be sampling plants or taking soil samples in a local ecosystem. It can take place far away in a rain forest or on an ice field. Fieldwork involves research. However, research can also take place in the laboratory. With a two-year associate's degree, you can be a field technician, lab assistant, or teaching assistant. With more training, you could become a wildlife biologist or an ecologist. Maybe you are more interested in managing or restoring populations and ecosystems. Then you could become a manager for a state park or a wildlife refuge. If you enjoy teaching as well as ecology, you could work at a high school, museum, or college or university. Some people bring their teaching interest outdoors by working as an educator at a nature center or as a naturalist at a park. To help solve environmental problems or influence policy makers, you could become an environmental consultant, environmental planner, or even an environmental lawyer.

Careers in ecology. Do any of these careers interest you?

Ecological and environmental jobs will always be available because we depend on ecosystems. Disturbances to ecosystems are likely to increase because humans will continue to interact with ecosystems. Thus, more people with ecological backgrounds will be needed to better understand how ecosystems work. They will also need to educate the public and develop management plans to sustain and restore ecosystems. Job opportunities are expected to grow in private companies, nongovernment organizations, and precollege schools. The number of jobs with universities and the federal government is expected to stay the same.



Finding Your Niche

ELABORATE

How do you think species' interactions influence the traits of species? Could interactions be important for evolution? Competition for limited resources is a common interaction among species in ecosystems. For example, foxes and coyotes compete for some of the same food resources, such as rabbits. Because they compete, foxes are less abundant in areas where coyotes also live. Foxes and coyotes are species in the same trophic level that coexist because they do not use the same resources entirely. Scientists have evidence that the great diversity of organisms on Earth is a result of interactions.

In *Finding Your Niche*, you will think about how six species of shorebird use the same habitat in a way that minimizes competition. Shorebirds are a group of birds that are adapted to live near water. You will work alone and with your classmates to discover how interactions may have led to diverse species of shorebirds.

Materials

For each student

colored pencils 1 *Shorebird Habitat* handout

Process and Procedure

1. Read about the shorebirds shown in figure 14.22. Are these shorebirds competing for the same resources? Why or why not?
2. Shorebirds live in a variety of habitats. A **habitat** is the specific environment where an organism lives. Shorebirds live in habitats such as seashores, coastal wetlands, inland wetlands, and grasslands. Wetlands are just as they sound—areas that are saturated with water for at least part of the year. Obtain the *Shorebird Habitat* handout from your teacher to see how a wetland habitat for shorebirds might look in South Dakota.
3. Use the *Shorebird Habitat* handout and Steps 3a–d to create a guide that shows where each shorebird in figure 14.22 feeds.
   - **a.** Use a different-colored pencil to shade in areas for each shorebird.
   - **b.** The shaded areas should indicate if shorebirds find food in different depths of soil or different parts of the water. Some of the shaded areas may overlap.
   - **c.** Create a key for your guide.
   - **d.** Use the TSAR strategy to compare your guide with the guides of 2 other classmates. Revise your guide if you learn something new after talking with a classmate. Continue using this strategy throughout the activity.

Semipalmated plovers (*Charadrius semipalmatus*) are small shorebirds. They are about 18 centimeters (cm) long, with short legs and a very short bill. They feed by picking invertebrates off the soil's surface or off plants.

Greater yellowlegs (*Tringa melanoleuca*) are medium-sized shorebirds. They are about 30 cm long, with long legs and a long, thin bill. They feed by wading in water and picking invertebrates off the water's surface or plants.

Dowitchers (*Limnodromus sp.*) are medium-sized birds. They are about 30 cm long, with medium-length legs and a long, straight bill. They feed by probing their bills into soil to find invertebrates. They search for food on wet mud and in shallow water.

Wilson's phalaropes (*Phalaropus tricolor*) are small shorebirds. They are about 22 cm long, with short legs and a medium-length bill. They feed by wading in shallow water or swimming in deeper water and picking invertebrates off the water's surface. In deep water, they use their legs to churn up the water and bring invertebrates closer to the surface.

Baird's sandpipers (*Calidris bairdii*) are small shorebirds. They are about 15 cm long, with medium-length legs and a short bill. They feed by probing their bills into soil to find invertebrates. They search for food on wet mud and in shallow water.

Pectoral sandpipers (*Calidris melanotos*) are medium-sized shorebirds. They are about 20 cm long, with medium-length legs and a medium-length bill. They feed by probing their bills into soil to find invertebrates or by picking invertebrates off wet mud or water. They search for food on wet mud and in shallow water.

▲ **Figure 14.22** **Shorebirds found in shallow wetlands.** How do you think natural selection might have led to so many species of shorebirds?

4. Are the shorebirds using different parts of the same habitat? Based on your guide, describe how these 6 shorebird species interact in a wetland habitat.
5. Read *An Ecological Niche* to learn how scientists describe the different roles of species in habitats. Answer Questions 5a–c in your science notebook as you read. Then use the TSAR strategy to refine your answers.
   a. Are shorebirds generalists or specialists? Explain your answer.
   b. How are shorebirds minimizing competition in the same habitat? Include in your answer how the traits of the species differ.
   c. Suppose 2 populations of the same species are competing for the same resource. Both populations have variations in their traits that make them use resources slightly differently, as shown in figure 14.24. Describe how natural selection could result in a new species.

Remember that natural selection occurs when members of a population with the most successful adaptations to their environment are more likely to survive and reproduce than members of the same population with less successful adaptations.

READING

An Ecological Niche

The role that each species plays in the community is its **ecological niche**. A habitat is an organism's address, and a niche is its profession. A niche includes where an organism lives, what it eats, how it obtains its food, and how it interacts with other species. Some species are specialists and occupy a narrow niche. For example, black-footed ferrets (*Mustela nigripes*, see figure 14.23a)

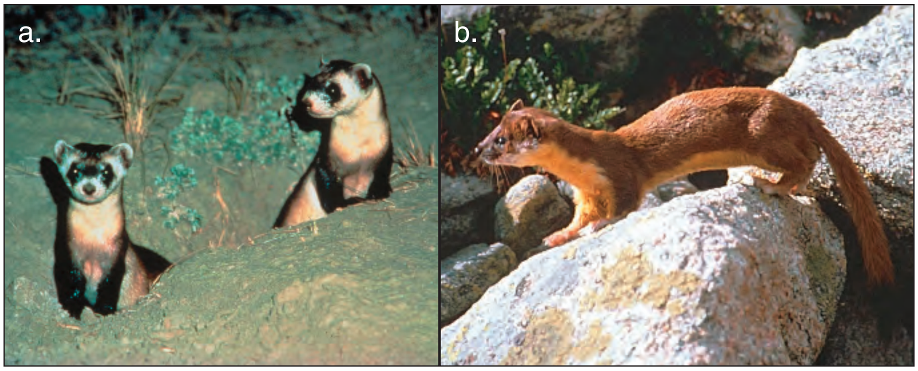


Figure 14.23 Specialist (black-footed ferret) and generalist (long-tailed weasel). (a) Black-footed ferrets have a narrow niche that is limited to habitats containing prairie dogs. (b) Long-tailed weasels have a broad niche that includes different habitats and foods.

An Ecological Niche, continued

rely exclusively on prairie dog towns for food and shelter. Long-tailed weasels (*Mustela frenata*, see figure 14.23b) are related to black-footed ferrets. But they are generalists, eat a wide variety of foods, and occur in a wide variety of habitats.

No two species occupy the same, exact niche in a community for very long. Eventually, one species gains a larger share of the resources. The other migrates to a new area, becomes extinct, or adapts to reduce competition. Recall that adaptations are traits that help an organism survive and reproduce in a particular environment. Adaptations can be physical or behavioral traits. Adaptations allow species to use resources differently and occupy different niches. To understand how humans can affect the balance of species in an ecosystem read the sidebar *Invasive Populations*.

You can show graphically how differences in niches can reduce competition. You did this when you shaded different areas of a wetland used by shorebirds. You can also show differences in niches with a graph like the one in figure 14.24. The x-axis shows the use of resources such as food or habitat. The y-axis shows the abundance of organisms. Competition occurs where the niches of two species overlap (figure 14.24a). Across time, individuals occupying the part of the niche where competition occurs are less successful. Fewer of these individuals survive and reproduce. Eventually, the two species might have fewer variations in their traits and they become more specialized. This means their niches become narrower (figure 14.24b). Specialization allows different species to use resources differently and coexist in the same habitat.

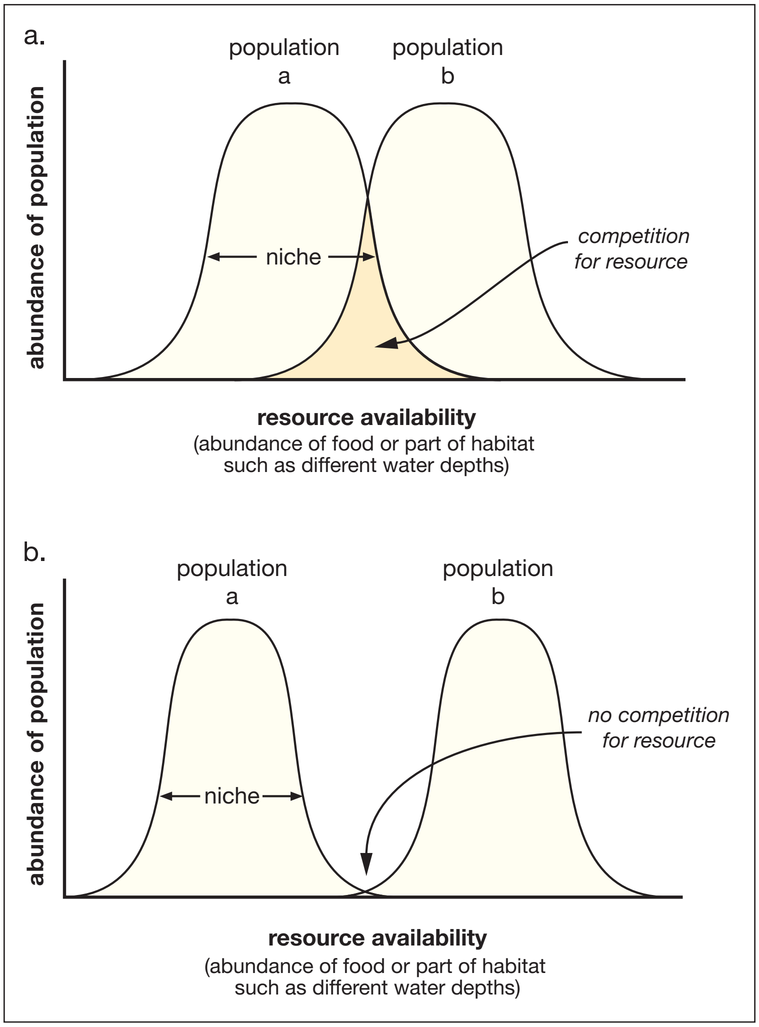


Figure 14.24 Niches of two species. (a) The niches of two species using the same habitat may overlap because some individuals from each population use the same resources. The shaded area shows the part of the two populations competing for resources. (b) Competition is reduced when niches do not overlap.

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Invasive Populations

SIDEBAR

You have been learning about how plant and animal populations interact in ecosystems. Humans also interact with these populations. In fact, human populations can unintentionally disrupt the balance of species in an ecosystem. Humans can affect the balance by introducing a new species or changing the conditions in an ecosystem in a way that favors some species over others.

Humans transport plants and animals to new locations for food or enjoyment, and sometimes by accident. Arriving with the plants and animals are the bacteria, fungi, and diseases associated with those species. In most cases, when organisms are moved away from their native habitat, they die out once humans no longer use them. Sometimes, however, the limiting factors that were present in a species' natural habitat are not present at a new location. Or a species might invade a new niche that didn't exist in its natural habitat. If non-native species thrive, they can potentially cause harm. These introduced species are called invasive species. Some well-known examples of invasive species are purple loosestrife, zebra mussels, fire ants, and whirling disease.

Purple loosestrife (*Lythrum salicaria*) is a plant brought to the wetlands in northeastern North America from Europe in the 1800s. Immigrants may have brought the seeds because of their value as an herb and ornamental plant. Although purple loosestrife is attractive, it outcompetes and replaces native wetland plants (see the photographs). It produces abundant nectar, but it is a poorer source of nutrition for wildlife than native plants.

Zebra mussels (*Dreissena polymorpha*) are small, fingernail-sized mussels native to the Caspian and Black Seas between Europe and Asia. They are now found in the United Kingdom, western Europe, Canada, and the United States. In 1988, they arrived in the Great Lakes in the ballast water of a transoceanic ship. Ballast water is water held in a ship's ballast tanks and cargo holds to provide stability. This water is taken from a coastal port area and transported to the next port, where it may be discharged. Zebra mussels breed prolifically and live and feed in many aquatic habitats. They filter large amounts of food from the water. This action reduces

Before and after purple loosestrife establishment. (a) The photograph shows a wildlife refuge in New York in 1968. (b) Ten years later, the native vegetation has been replaced by purple loosestrife.

Invasive Populations, continued

the food supply for other organisms and causes some animal populations to decline.

Black and red fire ants (*Solenopsis sp.*) were accidentally brought to the United States from South America in the early 1900s. As of 2006, they have spread to 14 states. Fire ants sting their victims repeatedly. The sting injects venom that causes a burning sensation. Fire ants sometimes attack and kill newborn domestic animals as well as pets and wildlife. They can also damage some crops.

Whirling disease was brought to North America from Europe in the 1950s. Whirling disease is caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of trout and salmon. It does not infect humans. Fish infected with the parasite swim erratically (whirl) and have difficulty feeding and avoiding predators. Water sources with severe infections result in high mortality rates of young fish. This disease is one of the biggest threats to native trout populations.

Some problem populations are viruses that need a host organism such as a bird or human to reproduce and spread. For example, West Nile virus and the avian flu are viruses that mainly infect birds but can spread to humans. West Nile was found in North America in 1999. It is common in Africa, Europe, the Middle East, and west and central Asia. The virus might have arrived in the United States through illegally imported birds, a person who was infected with the virus, or mosquitoes trapped on a plane or boat. Mosquitoes spread West Nile between birds and to humans. When a mosquito feeds on the blood of an infected individual, it can transmit the virus to an uninfected individual during its next feeding. Most cases of West Nile virus in humans occur in people who are immune compromised—their immune systems are not strong.

The avian flu is an infection caused by avian flu viruses. There are many subtypes of avian flu viruses. These viruses occur naturally in birds worldwide. Wild birds usually do not get sick from the viruses, but the viruses are very contagious and spread quickly. The avian flu virus can cause domesticated birds such as chickens, ducks, and turkeys to become very sick and die. Avian flu viruses occur mainly in birds, but occasionally they infect humans. Most human infections result from direct contact with infected domesticated birds. These infections usually do not pass from person to person. However, because flu viruses are constantly changing, they might adapt over time to infect and spread among humans.

New species from other countries are introduced in the United States every year. They may be introduced intentionally or accidentally, but their introduction can potentially create problems for native populations and human health.

6. Create a graph like figure 14.24. Show the niches of 2 shorebirds that you choose. Your graph should have the following:
    - An x-axis labeled “habitat type”

Choose the appropriate habitat type depending on which shorebirds you graph.

- A *y*-axis labeled "abundance"
- Each curve labeled with the names of the shorebirds
- A caption and highlight comments

Reflect and Connect

Work alone to answer the following questions in your science notebook.

1. Describe how a niche is different from a habitat. Use an example in your answer.
2. Describe in a short paragraph how interactions between populations of shorebirds in the past might have led to diverse species of shorebirds.

Interpret the Interactions

EVALUATE

One of the important parts of doing science is reviewing data that other scientists have collected. In *Interpret the Interactions*, you will use what you have learned about populations and ecosystems to *interpret* the results from different real scientific studies. For example, you will look at data from a study of populations in a kelp forest ecosystem (see figure 14.25). As you analyze and interpret the results of these studies, you will be acting like real scientists.

▲ **Figure 14.25 Sea otter.** This sea otter is eating a sea urchin. Sea urchins are marine invertebrates that feed on kelp, a type of alga. Sea otters and sea urchins live in kelp forest ecosystems in coastal waters.

In Part I, you will work alone and with your classmates to revisit the true-false statements from the engage activity, *What Do You Know about Populations?* You will decide whether your responses have changed now that you have completed the activities in this chapter. Then in Part II, you will take a test that asks you to analyze data from current and past research and answer a series of questions about how the populations change and what interactions are taking place in the ecosystems.

Part I: What Have You Learned about Populations?

Materials

For each student

1 *Interpret the Interactions Scoring Rubric* handout

answers from the engage activity

Process and Procedure

1. Get a copy of the *Interpret the Interactions Scoring Rubric* handout from your teacher. Review it with your class.
2. Review your true or false answers to the statements from the engage activity.
3. Use the TSAR strategy to decide whether to change any of your answers based on what you and your classmates have learned in the chapter. Consult with at least 2 other students. Record any evidence you have for keeping or changing each answer.

Even though your answers may not have changed, your reasoning may have. You should have more knowledge now and be able to write better explanations than you did in the engage activity.

Part II: Analyzing Research

Materials

For each student

1 *Analyzing Research* handout

Process and Procedure

1. Get the *Analyzing Research* handout from your teacher and see what you have learned. Steps 1a–c will help you.
   a. Review the graphs carefully before answering each question. Focus on any changes you see.
   b. Write and mark on the graphs as necessary to show what you understand about the data.
   c. You must complete the test in the time allotted by your teacher.