Population Biology

What You'll Learn

- You will explain how populations grow.
- You will identify factors that inhibit the growth of populations.
- You will summarize issues in human population growth.

Why It's Important

How a population of organisms grows is critical to the survival of its species. A population that grows rapidly may run out of food or space. A population that grows too slowly may become extinct.

Understanding ▶ the Photo

King penguins are highly social animals that live and breed in large colonies called rookeries in some of the most isolated islands in the subantarctic. Even though few people will ever encounter these animals, maintaining their populations is important for keeping the ecosystems in that portion of the world healthy.

💻 Biology Online

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- study the entire chapter online
- access Web Links for more information and activities on population biology
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Population Dynamics

SECTION PREVIEW

Objectives

Compare and contrast exponential and linear population growth.

Relate the reproductive patterns of different populations of organisms to models of population growth.

Predict effects of environmental factors on population growth.

Review Vocabulary
population: a group of organisms of the same species that live in a specific area (p. 38)

New Vocabulary
exponential growth
carrying capacity
life-history pattern
density-dependent factor
density-independent factor

FOLDABLES
Study Organizer

**Populations** Make the following Foldable to help you identify the main factors that affect populations.

STEP 1 **Fold** a sheet of paper in half lengthwise.

STEP 2 **Fold** in half, then fold in half again to make three folds.

**STEP 3** **Unfold and cut** only the top layer along the three folds to make four tabs.

STEP 4 **Label** the tabs.

Population Increase

Carrying Capacity

The Environment

Other Organisms
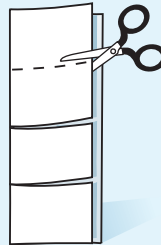
Compare and Contrast As you read Chapter 4, compare the effects these factors have on population size. List some of the effects under the appropriate tab.

Figure 4.1
Ecologists can study bacterial population growth in the laboratory.
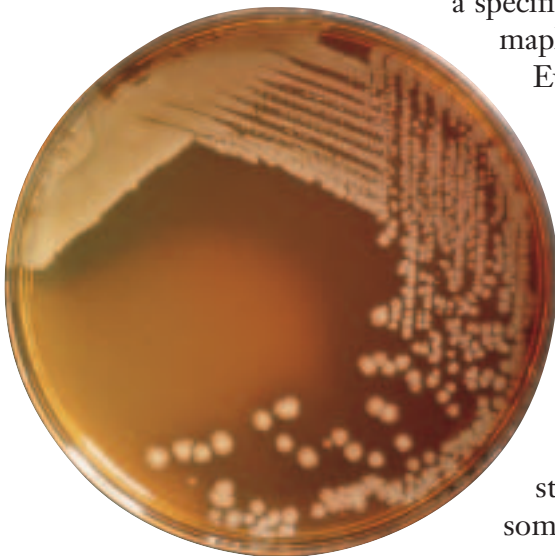
Principles of Population Growth

A population is a group of organisms, all of the same species, that live in a specific area. There are populations of spruce trees, populations of maple trees, of bluebirds, dandelions, fruit flies, and house cats. Every organism you can think of is a member of a population. A healthy population will grow and die at a relatively steady rate unless it runs out of water, food, or space, or is attacked in some way by disease or predators.

Scientists study changes in populations in a variety of ways. One method involves introducing organisms into a controlled environment with abundant resources; then watching how the organisms react. That is what is happening in *Figure 4.1*. Bacterial cells are placed in a dish of sterile, nutrient-rich solution and population growth is observed over a period of time. Through studies such as these, scientists have been able to identify some trends in the growth of bacterial cells.

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MiniLab 4.1

Make and Use Tables

Fruit Fly Population Growth Fruit flies *(Drosophila melanogaster)* are used in biological research because they reproduce quickly and are easy to keep and count. In this activity you will observe the growth of a fruit fly population as it exploits a food supply.

Procedure

1. Place half of a banana in an uncovered jar and allow it to sit outside in a warm shaded area, or put it in a warm area in your classroom.
2. Leave the jar for one day or until you have at least three fruit flies in it. Put a cloth on top of the jar and fasten with the rubber band.
3. Each day for at least three weeks, record how many adult fruit flies are alive in the jar. Put data into table form. Graph your data. **CAUTION:** *Make wise choices. Do not eat the fruit. Return the flies and fruit to your teacher for disposal.*

Fruit flies feeding on a banana

Analysis

1. **Observe and Infer** How many fruit flies did you start with? On what day were there the most fruit flies? How many were there?
2. **Analyze Trends from Data** Why do you think the number of fruit flies decreased?
3. **Predict Trends from Data** What might help the population to begin growing again after a decrease?

Information on bacterial cell growth might be helpful in fighting disease. Studies of populations of larger organisms, such as an elk population in a national park, require methods such as the use of radio monitors. Use the *MiniLab* on this page to learn one method of measuring growth in a fruit fly population.

How fast do populations grow?

The growth of populations is unlike the growth of pay you get from a job. Suppose your job pays $5 per hour. You know if you work for two hours, you will be paid $10; if you work for four hours, you will be paid $20; if you work for eight hours, you will be paid $40; and so on. If you were to plot money earned against your time in hours, the graph would show a steady, straight-line (linear) increase.

Populations of organisms, however, do not experience linear growth. Rather, the graph of a growing population starts out slowly, then begins to resemble a J-shaped curve, as illustrated in a population of houseflies in *Figure 4.2*. The initial increase in the number of organisms is slow because the number of reproducing individuals is small. Soon, however, the rate of population growth increases because the total number of individuals that are able to reproduce has increased.

Figure 4.2
Because they grow exponentially, populations of houseflies have the potential for unchecked growth. Notice that the shape of the curve is like the letter *J*.

Population Growth of Houseflies
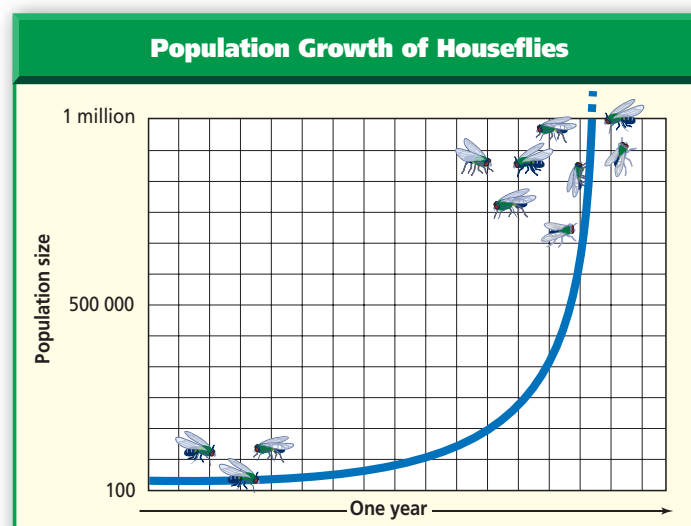
Is growth unlimited?

A J-shaped growth curve illustrates exponential population growth. **Exponential growth** means that as a population gets larger, it also grows at a faster rate. Exponential growth results in unchecked growth.

What can limit growth?

Can a population of organisms grow indefinitely? Through observation and population experiments, scientists have found that population growth does have limits. Eventually, limiting factors, such as availability of food, disease, predators, or lack of space, will cause population growth to slow. Under these pressures, the population may stabilize in an S-shaped growth curve, which you can see in *Figure 4.3*.

Carrying capacity

The number of organisms of one species that an environment can support indefinitely is its **carrying capacity.** When a population is developing in an environment with resources, there are more births than deaths and the population increases until the carrying capacity is reached or passed. When a population overshoots the carrying capacity, then limiting factors may come into effect. Deaths begin to exceed births and the population falls below carrying capacity. Thus, the number of organisms in a population is sometimes more than the environment can support and sometimes less than the environment can support. *Figure 4.4* on the next page shows a population growth line that moves above and below the carrying capacity. Many different types of organisms can show such growth patterns in nature.
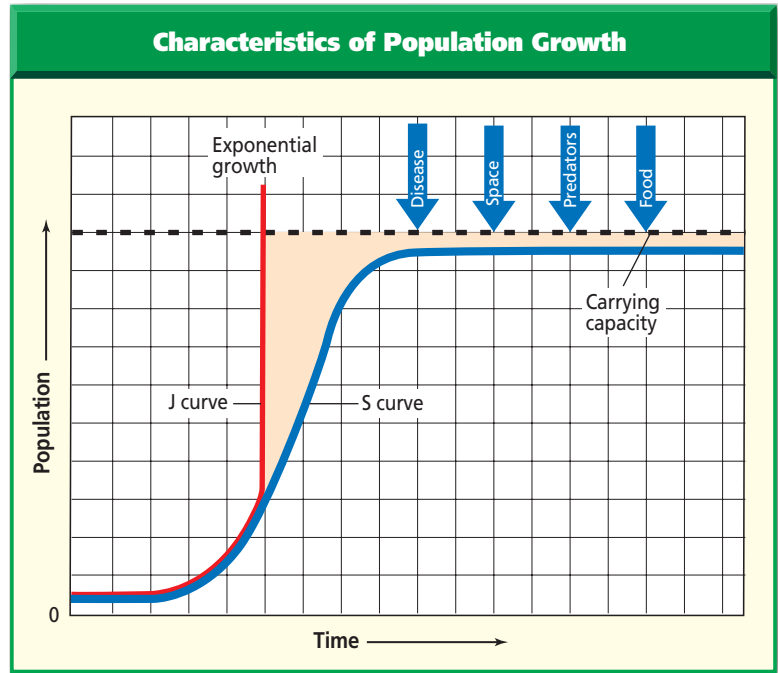

Characteristics of Population Growth

Exponential growth

Disease · Space · Predators · Food

Carrying capacity

J curve — S curve

Population

0

Time

Figure 4.3
The graph above compares exponential growth and growth that is influenced by limiting factors such as disease, space, predators, or food. Over time, one or more of these limiting factors can keep a population at or below the carrying capacity of the environment.

Reproduction Patterns

In nature, animal and plant populations change in size. For example, mosquitoes are more numerous at certain times of the year than others. Why don't populations reach carrying capacity and remain stable? To answer this question, population biologists study the factor that determines population growth—an organism's reproductive pattern, also called its **life-history pattern.**

A variety of population growth patterns are possible in nature. Two extremes of these patterns are demonstrated by the population growth rates of mosquitoes and elephants. Mosquitoes exhibit a rapid life-history pattern. Elephants, like many other large organisms, exhibit characteristics of the slow life-history pattern. Mosquitoes reproduce very rapidly and produce many offspring in a short period of time, whereas elephants have a slow rate of reproduction and produce relatively few young over their lifetime.
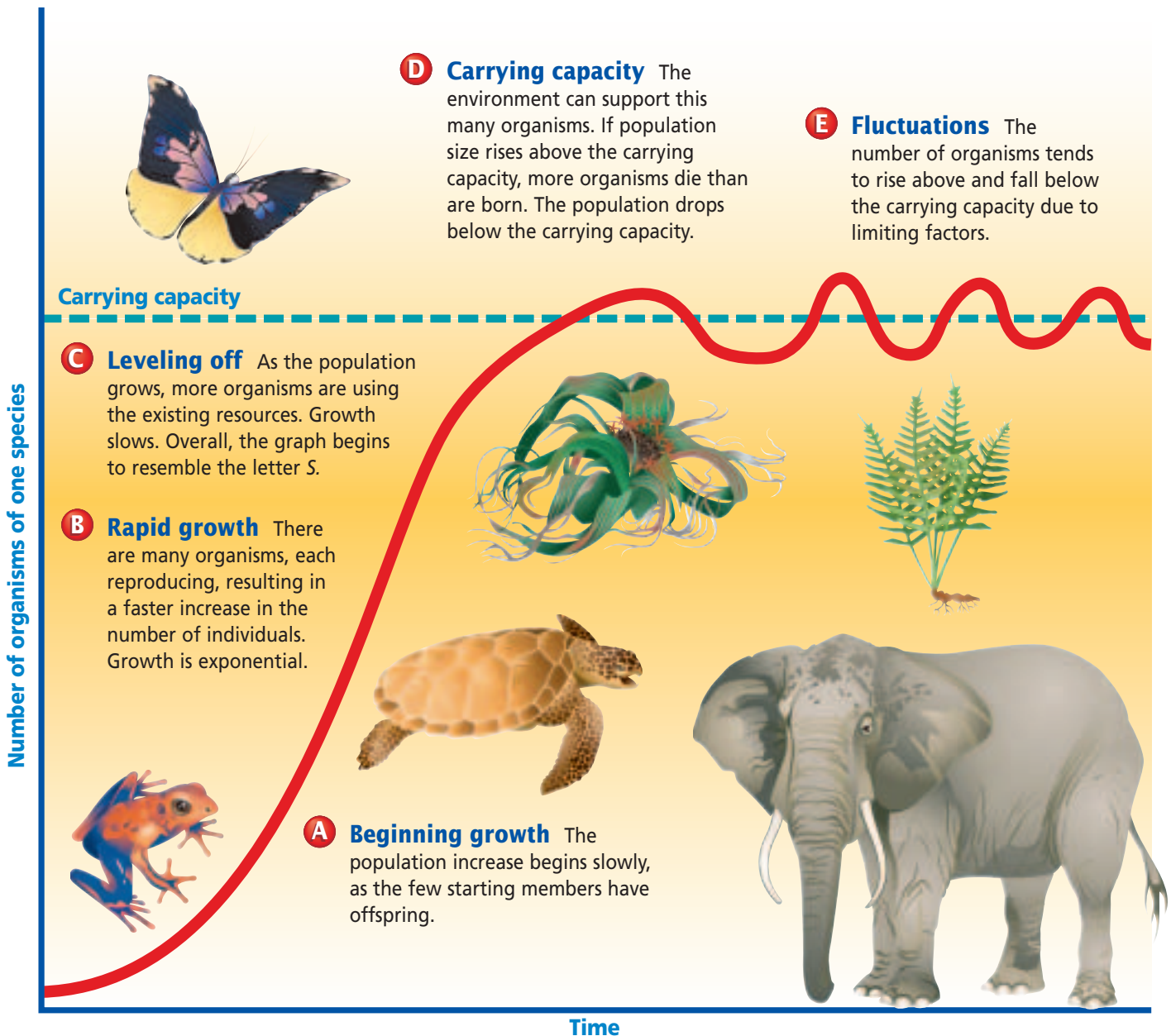
Population Growth

Figure 4.4

When a population is in an environment unaffected by factors such as predators, fire, or drought, and there are sufficient resources, the population increases. Ecologists have discovered that these population increases show a pattern. Whether it is a plant or animal, whether on land or in the ocean, populations grow in predictable manners.

Critical Thinking *Why can a population fluctuate once it reaches carrying capacity?*

Humpback whales have a slow life-history pattern.

D **Carrying capacity** The environment can support this many organisms. If population size rises above the carrying capacity, more organisms die than are born. The population drops below the carrying capacity.

E **Fluctuations** The number of organisms tends to rise above and fall below the carrying capacity due to limiting factors.

Carrying capacity

C **Leveling off** As the population grows, more organisms are using the existing resources. Growth slows. Overall, the graph begins to resemble the letter *S.*

B **Rapid growth** There are many organisms, each reproducing, resulting in a faster increase in the number of individuals. Growth is exponential.

A **Beginning growth** The population increase begins slowly, as the few starting members have offspring.

Number of organisms of one species

Time

Francois Gohier/Photo Researchers

Rapid life-history patterns

Rapid life-history patterns are common among organisms from changeable or unpredictable environments. Rapid life-history organisms have a small body size, mature rapidly, reproduce early, and have a short life span. Populations of rapid life-history organisms increase rapidly, then decline when environmental conditions such as temperature suddenly change and become unsuitable for life. The small population that survives will reproduce exponentially when conditions are again favorable. The *Problem-Solving Lab* on this page explores growth in bacteria, an organism with a rapid life-history pattern.

Slow life-history patterns

Large species that live in more stable environments usually have slow life-history patterns. Elephants, bears, whales, humans, and plants, such as trees, are long lived. The pronghorn antelope shown in *Figure 4.5*, are slow life-history organisms.

A

Problem-Solving Lab 4.1

Predict

How rapidly can bacteria reproduce?
Bacteria are examples of rapidly reproducing organisms. They are often used in experiments about population studies or trends.

Reproduction Rate of Bacteria

Number of organisms vs. Time in hours
- 1 072 431 104
- 32 728
- 0
- 0, 5, 10
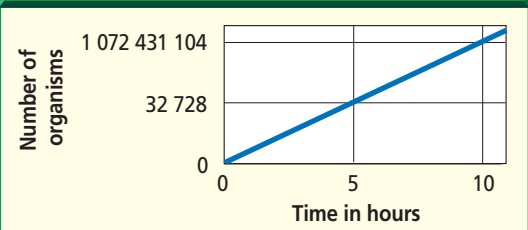
Solve the Problem
Here are some facts regarding unchecked bacterial reproduction:
1. A single bacterium can reproduce to yield two bacteria under ideal conditions every 20 minutes.
2. Ideal conditions for bacterial reproduction include proper temperature, unlimited food, space to grow, and dispersion of waste materials.

Thinking Critically
1. **Calculate** Suppose you start with one bacterium under ideal conditions. If no bacteria die, compute the number of bacteria present after 1 hour, 5 hours, and 10 hours.
2. **Predict Trends** What environmental factors might affect a bacterial population's reproduction?
3. **Error Analysis** The above graph is an example of one group's data.
   a. What error did they make in the *y*-axis of the graph?
   b. Redraw the graph correctly.
4. **Infer** An elephant reproduces once every four to six years. Why are elephants not likely to be used in laboratory population studies?

B

Figure 4.5
Wild mustard plants taking over an abandoned field represent a species with a rapid life-history pattern **(A)**. Organisms that have a slow life-history pattern, such as these pronghorn antelope, provide much parental care for their young **(B). Predict Trends** *Which of these organisms would be more successful in a rapidly changing environment? Explain.*
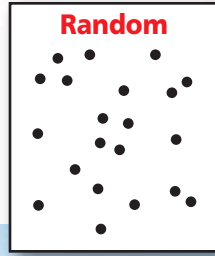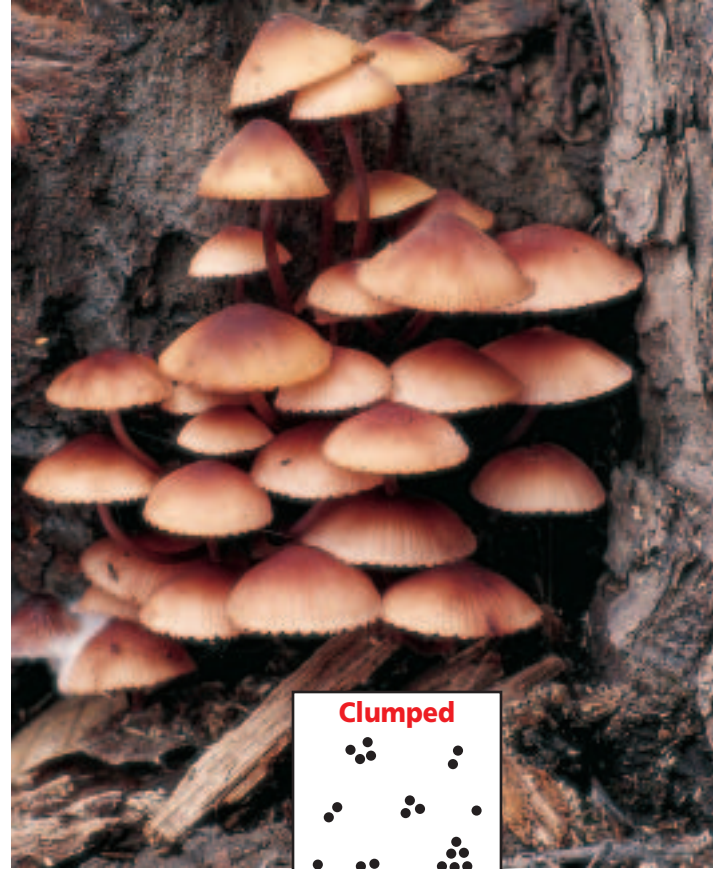
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Figure 4.6

Organisms disperse in a variety of ways: random **(A)**, clumped **(B)**, and uniform **(C)**. Clumping may be the most common. Uniform dispersal may be the least common although it is visible with birds on a wire and among creosote bushes in a desert. The orderly planting of crops, such as rows of corn, is not a natural dispersal.

Random (A)

Clumped (B)

Uniform (C)

Slow life-history organisms reproduce and mature slowly, and are long-lived. They maintain population sizes at or near carrying capacity.

Density factors and population growth

Recall that limiting factors are biotic or abiotic factors that determine whether or not an organism can live in a particular environment. Limited food supply, space, chemicals produced by plants themselves, extreme temperatures, and even storms affect populations.

How organisms are dispersed can also be important. *Figure 4.6* shows three patterns of dispersal: random, clumped, and uniform.

Ecologists have identified two kinds of limiting factors that are related to dispersal: density-dependent and density-independent factors. Population density describes the number of individuals in a given area.

(tl)Envision/B.W. Hoffman, (tr)Matt Meadows, (b)John Kieffer/Peter Arnold, Inc.

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Density-dependent factors include disease, competition, predators, parasites, and food. These factors have an increasing effect as the population increases. Disease, for example, can spread more quickly in a population with members that live close together. In crops such as corn or soybeans in which large numbers of the same plant are grown together, a disease can spread rapidly throughout the whole crop. In less dense populations, fewer individuals may be affected. Disease is also a factor in human populations. The presence of HIV/AIDS in many of the world's populations is considered by some scientists to be a limiting factor in the growth of those populations.

Density-independent factors can affect populations, regardless of their density. Most density-independent factors are abiotic factors, such as volcanic eruptions, temperature, storms, floods, drought, chemical pesticides, and major habitat disruption, such as that shown in *Figure 4.7*. Although all populations can be affected by these factors, the most vulnerable appear to be small organisms with large populations, such as insects. No matter how many earthworms live in a field, they will drown if it floods. It doesn't matter if there are many or few mosquitoes—a severe winter will kill the adults of most species.

Organism Interactions Limit Population Size

Population sizes are limited not only by abiotic factors, but also are controlled by various interactions among organisms that share a community.

Predation affects population size

A barn owl kills and eats a mouse. A swarm of locusts eats and destroys acres of lettuce on a farm. When the brown tree snake was introduced in Guam, an island in the South Pacific, there were no native predators for the snake. Consequently, it freely preyed on the native birds of the island. These examples demonstrate how predation can affect population sizes in both minor and major ways. When a predator consumes prey on a large enough scale (as in the case of the brown tree snake), it can have a drastic effect on the size of the prey population. For this reason, predation can be a limiting factor on population size.

Populations of predators and their prey are known to experience cycles or changes in their numbers over periods of time. Under controlled conditions, such as in a laboratory, predator-prey relationships often show a predictable cycle of population increases and decreases over time. In nature, these cycles have also been observed. One classic example of this has been demonstrated in *Figure 4.8* on the next page, which shows a graph of 90 years of data about the populations of the Canadian lynx and the snowshoe hare. A member of the cat family, the lynx stalks, attacks, and eats the snowshoe hare as a primary source of food.

Figure 4.7
A flood of catastrophic proportions, such as this flood in San Antonio, Texas in the summer of 2002, can be a limiting factor, especially for human populations. Among other things, flooding affects drinking water and sewage systems. These are limiting factors for modern urban life. **Infer** *What else in this photograph might be affected by flooding?*

Robert McLeroy/San Antonio Express/CORBIS Sygma

The data in *Figure 4.8* show the lynx and hare populations appear to rise and fall fairly closely in a 10-year cycle. When the hare population increases, there is more food for the lynx population, and the lynx population increases. When the lynx population rises, predation increases, and the hare population then declines. With fewer hares available for food, the lynx population then declines. Then, with fewer predators, the hare population increases, and the cycle continues. This example shows how predator populations can affect the size of the prey populations. At the same time, prey populations affect the size of the predator populations. As the snowshoe hare's food supply of grasses and herbs dwindles during the fall and winter months, the hare population decreases. Because there are now fewer hares to hunt, the lynx population also decreases. With the return of spring, the hare's food supply and its population recover. This leads to more hares, allowing the lynx population to increase as well.

Usually, in prey populations, the young, old, or injured members are caught. Predation increases the chance that resources will be available for the remaining individuals in a prey population.
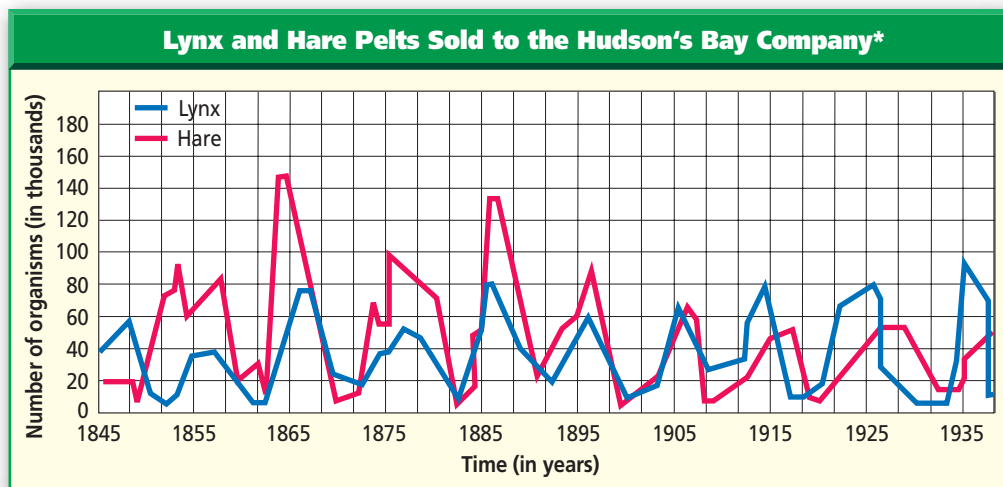
Competition within a population

The hare and the lynx belong to different populations. What happens when organisms within the same population compete for resources? When population numbers are low, resources can build up and become plentiful. Then, as these resources are used, the population increases in size and competition for resources such as food, water, and territory again increases significantly. Competition is a density-dependent factor. When only a few individuals compete for resources, no problem arises. When a population increases to the point at which demand for resources exceeds the supply, the population size decreases.

Figure 4.8
The data in this graph reflect the number of hare and lynx pelts sold to the Hudson's Bay Company in northern Canada from 1845 through 1935. Notice that as the number of hares increased, so did the number of lynx.

* Data from 1844 through 1904 reflects actual pelts counted. Data from 1905 through 1935 is based on answers to a questionnaire.

Lynx and Hare Pelts Sold to the Hudson's Bay Company*

Number of organisms (in thousands) — Time (in years)

Legend: Lynx, Hare

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The effects of crowding and stress

When populations of certain organisms become crowded, individuals may exhibit symptoms of stress. The factors that create stress are not well understood, but the effects have been documented from experiments and observations of populations of several organisms including fish, deer, rabbits, and rats as shown in *Figure 4.9.*

As populations increase in size in environments that cannot support increased numbers, individual animals can exhibit a variety of stress symptoms. These include aggression, decrease in parental care, decreased fertility, and decreased resistance to disease. All of these symptoms can have negative effects on a population. They become limiting factors for growth and keep populations below carrying capacity.

Section Assessment

Understanding Main Ideas
1. Explain and illustrate how the long-term survival of a species depends on resources that may be limited from time to time.
2. Compare short and long life-history patterns.
3. Describe how density-dependent and density-independent factors regulate population growth.
4. Describe the population growth curve of houseflies.

Thinking Critically
5. How can a density-dependent factor, such as a food supply, affect the carrying capacity of a habitat?

SKILL REVIEW

6. **Get the Big Picture** Graph the following seasonal population data for an organism shown in the table below and analyze whether the organism has a population growth pattern closer to a rapid or slow life-history pattern. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

Seasonal Population Data				
Year	Spring	Summer	Autumn	Winter
1995	564	14 598	25 762	127
1996	750	16 422	42 511	102
1997	365	14 106	36 562	136

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(l)Marcie Griffen/Animals Animals, (r)KS Studios

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Human Population

Keeping Track

Finding the Main Idea Can you imagine having the responsibility of keeping track of how many people there are in the world? Why is it important to know how many people there are and where they are located? These are topics discussed in this section. To help you keep track of the information, it might be a good idea to find the main idea discussed in each paragraph.

Summarize As you study, look at each bold head. Then read the information under it carefully. After each paragraph, write one sentence that summarizes the main idea of the paragraph.
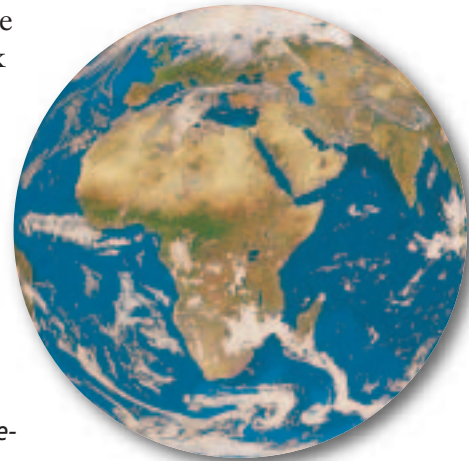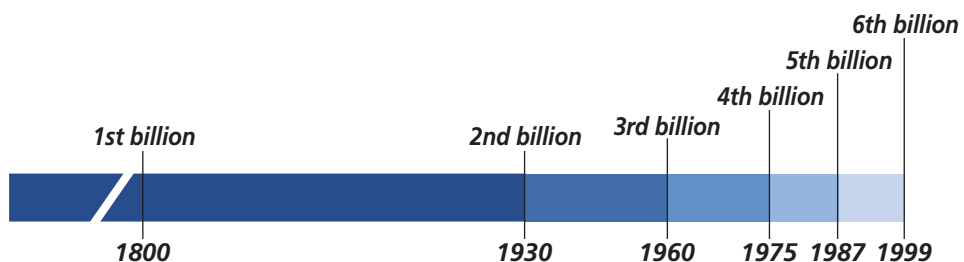
World Population

In the United States, a census is taken every ten years. Among other things, this information provides a picture of how many people there are in the United States, their economic condition, and where they live. Worldwide, the United Nations Population Division tracks similar information on all the countries of the world. One of the most useful pieces of data is the rate at which each country's population is growing or declining. These figures are the basis for **demography** (de MAH gra fee), the study of human population size, density and distribution, movement, and its birth and death rates.

What is the history of population growth for humans? *Figure 4.10* summarizes how world human population has grown since 1800. The graph indicates that until the 1800s, human population growth remained fairly slow. Since the 1930s, world population has grown rapidly, reaching 6 billion in 1999. In 2002, the human population was growing at a rate of 1.3 million people per year.

Figure 4.10
It is estimated that it took from the dawn of human history to 1800 for the world's population to reach 1 billion people. Today, there are more than 6 billion people in the world, and scientists estimate that by the year 2050, there will be more than 9 billion people on Earth.

1st billion		2nd billion	3rd billion	4th billion	5th billion	6th billion
1800		1930	1960	1975	1987	1999

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Human population growth

What factors affect growth of human population? In Section 1 of this chapter, bacteria and housefly populations were shown to continue to grow so long as they had sufficient resources. Human population growth is different because humans can consciously change their environment. During the past century, humans have eradicated diseases such as smallpox. They have developed methods for producing more food. Infant mortality rate has decreased and technological developments have improved the delivery of clean water. When these factors are accounted for, people live longer and are able to produce offspring that live long enough to produce offspring, hence, a population grows.

Calculating growth rate

There are a number of factors that determine population growth rate. These are births, deaths, immigration and emigration. **Birthrate** is the number of live births per 1000 population in a given year. **Death rate** is the number of deaths per 1000 population in a given year. Movement of individuals into a population is immigration. Movement out of a population is emigration. You can calculate a country's population growth rate with a formula that takes these four factors into account:

(Birthrate + Immigration rate) −
(Death rate + Emigration rate) =
Population Growth Rate (PGR)

For convenience, and because immigration and emigration rates are not always accurate, this formula is often stated as:

Birthrate − Death rate =
Population Growth Rate (PGR)

If the birthrate of a population equals its death rate, then the population growth rate is zero. If the rate is zero, that doesn't mean that the population

isn't changing. Rather, it means that new individuals enter the population (by birth and immigration) at the same rate that individuals are leaving (by death and emigration) the population. The population is changing, but it is stable. If the PGR is above zero, more new individuals are entering the population than are leaving, so the population is growing.

Problem-Solving Lab 4.2

Make and Use Graphs

How is world population changing? Total world population and the rate at which it is growing are predicted to change in the next 50 years. Plotting this information on a graph can provide a visual that tells you how it is predicted to change.

Total Midyear Population for the World 1950–2050			
Year	Population	Year	Population
1950	2 555 360 972	2010	6 812 009 338
1960	3 039 669 330	2015	7 171 736 193
1970	3 708 067 105	2020	7 515 218 898
1980	4 454 607 332	2025	7 834 028 430
1985	4 850 118 838	2030	8 127 277 506
1990	5 275 407 789	2035	8 397 941 844
1995	5 685 286 921	2040	8 646 671 023
2000	6 078 684 329	2045	8 874 116 015
2005	6 448 684 573	2050	9 078 850 714

The table above contains figures from the U.S. Census Bureau and the United Nations Population Bureau that predict world population change through 2050. Graph the data and answer the questions that follow.

Thinking Critically

1. **Analyze Trends from Data** Study your graph and choose the term that best describes the trend that the graph illustrates: Rising, leveling off, or declining. Explain your choice.
2. **Infer** Based on the data in the table, what can you infer happened to the population growth rate after 1985?
3. **Predict Trends from Data** Based on the data predicted for 2010 through 2050, how would you describe world population? Growing? Declining? Stable? Explain your choice.

MiniLab 4.2

Use Numbers

Doubling Time The time needed for any population to double its size is known as its "doubling time." For example, if a population grows slowly, its doubling time will be long. If it is growing rapidly, its doubling time will be short.

Procedure

1 The following formula is used to calculate a population's doubling time:

$$\text{Doubling time (in years)} = \frac{70}{\text{annual percent growth rate}}$$

2 Copy the data table below.

3 Complete the table by calculating the doubling time of human populations for the listed geographic regions.

Data Table		
Geographic Region	**Annual Percent Growth Rate**	**Doubling Time**
A	2.4	
B	1.7	
C	1.4	
D	0.5	
E	–0.1	

Analysis

1. **Analyze Trends from Data** Which region has the fastest doubling time? Slowest doubling time?
2. **Predict Trends from Data** What are some ecological implications for an area with a fast doubling time?

A PGR can also be less than zero. In 2002, the population growth rate for Europe was negative (−0.1 percent) as fewer individuals are entering the population than are leaving.

The effect of a positive growth rate

If the world population growth rate in the year 1995 were 1.7 percent and had dropped to 1.3 percent in 2001, the population growth rate would have become lower, but world population would have continued to grow, just at a slower rate. In other words, unless the growth rate becomes negative, the population continues to grow, but just not as rapidly as it did before.

Doubling time

Another quantitative factor that demographers look at is the doubling time of a population. **Doubling time** is the time needed for a population to double in size. The time it takes for a population to double varies depending on the current population and growth rate. A slow or negative growth rate means that it will take a country's population a long time to double in size, if ever. A rapid growth rate indicates that a country's population will double in a shorter time. A country that has a slow doubling time is sometimes categorized as a developed country. One with a rapid doubling time may be referred to as a developing country. Doubling time can be calculated for the world, a country, or even a smaller region, such as a city. Learn how to calculate doubling time in the *MiniLab* on this page.

Age structure

Have you ever filled out a survey? Often, one of the questions is about age. Are you between the ages of 10 and 14? 15 and 19? 20 and 24? The survey is trying to pinpoint where you are in the age structure of the population. **Age structure** refers to the proportions of the population that are in different age levels. Based on information from population counts, an age structure graph has been constructed for every country in the world. Look at the age structure graphs in *Figure 4.11*. An age structure graph can tell you approximately how many males and females there are in a population, and how many people there are at each age level. Rapidly growing countries have age structures with a wide base because a large
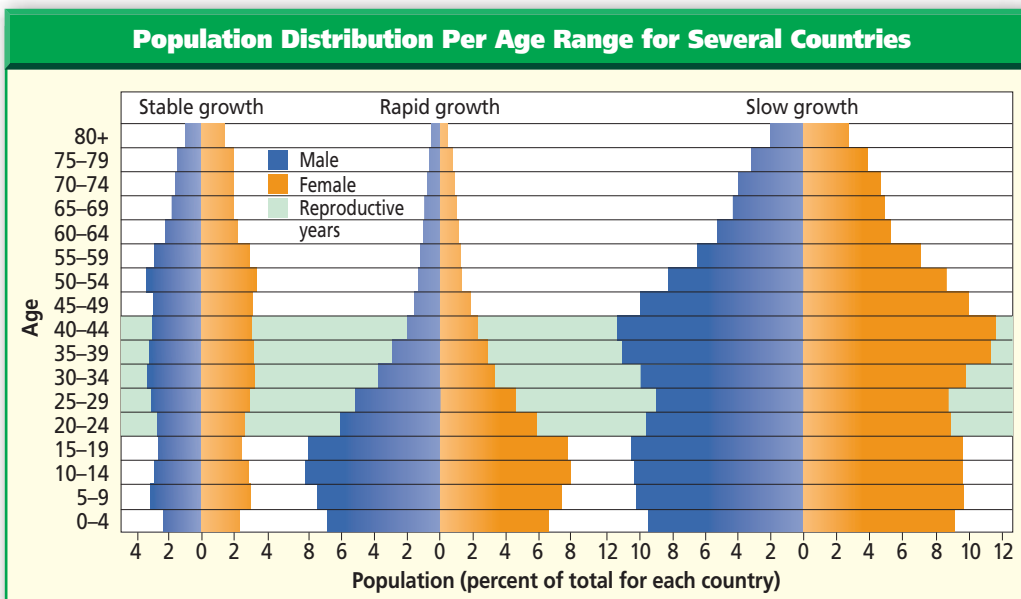
Population Distribution Per Age Range for Several Countries

| | Stable growth | Rapid growth | Slow growth |

Legend:
- Male (blue)
- Female (orange)
- Reproductive years (green)

Age axis: 80+, 75–79, 70–74, 65–69, 60–64, 55–59, 50–54, 45–49, 40–44, 35–39, 30–34, 25–29, 20–24, 15–19, 10–14, 5–9, 0–4

Population (percent of total for each country)

Figure 4.11
Notice that in a rapid growth country the large number of individuals in the "Under 5 Through 14 years" will add significantly to the population when they reach age 15. Populations that are not growing or are stable have an almost even distribution of ages among the population.

percentage of the population is made up of children and teenagers. If the percentage of people in each age category is fairly equal, the population is stable.

Ecology and growth

The needs of populations differ greatly throughout the world. Some countries are concerned about providing the most basic needs for their growing population. Other, more stable growth populations are concerned about maintaining the healthy conditions that they already have.

What do populations need? Think about the resources that humans depend upon every day. Some of these resources might be uncontaminated water for drinking and agriculture, adequate sewage facilities, and the ability to provide food for a growing population.

Sometimes, a population grows more rapidly than the available resources can handle. Resources that are needed for life, such as food and water, become scarce or contaminated. The amount of waste produced by a population becomes difficult to dispose of properly. These conditions can lead to stress on current resources and contribute to the spread of diseases that affect the stability of human populations both now and to come.

Section Assessment

Understanding Main Ideas
1. What characteristics of populations do demographers study? Why?

2. How do birthrate and death rate each affect the growth of a population?

3. What clues can an age structure graph provide about the future of a country's population growth?

4. Explain the relationship between a growing population and the environment.

Thinking Critically
5. Suggest reasons why the lack of available clean water could be a limiting factor for a country's population.

SKILL REVIEW

6. **Make and Use Graphs** Construct a bar graph showing the age structure of Kenya using the following data: pre-reproductive years (0–14)—42 percent; reproductive years (15–44)—39 percent; post-reproductive years (45–85+)—19 percent. For more help, refer to *Make and Use Graphs* in the **Skill Handbook**.

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CONTENTS

How can you determine the size of an animal population?

Before You Begin

In the field, scientists determine the number of animals in a large population by sampling. They trap and mark a few animals in a specified area. The animals are released and the traps are reset. Scientists wait a period of time before they retrap. This time allows organisms to mix randomly into the population again. Among the animals caught the second time, some will already be marked and some will be unmarked. Scientists then calculate the total population based on the ratio of marked animals to unmarked animals.

PREPARATION

Problem

How can you model a field-measuring technique to determine the size of an animal population?

Objectives

In this BioLab, you will:
- **Model,** using a simulation, a procedure used to measure an animal population.
- **Collect** data on a modeled animal population.
- **Calculate** the size of a modeled animal population.

Materials

paper bag containing beans
calculator (optional)

permanent marker
(dark color)

Safety Precautions

CAUTION: *Always wear goggles in the lab. Wash hands with soap and water after working with plant material and after clean up.*

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PROCEDURE

1. Copy the data table.
2. Reach into your bag and remove 20 beans.
3. Use the marker to color these beans. They represent *caught* and *marked* animals.
4. When the ink has dried, return the beans to the bag.
5. Shake the bag. Without looking into the bag, reach in and remove 30 beans.
6. Record the number of marked beans (recaught and marked) and the number of unmarked beans (caught and unmarked) in your data table as trial 1.
7. Return all the beans to the bag.

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8. Repeat steps 5 to 7 four more times for trials 2 to 5.

9. Calculate averages for each of the columns.

10. Using average values, calculate the original size of the bean population in the bag by using the following formula:
M = number initially marked
CwM = average number caught with marks
Cw/oM = average number caught without marks

$$\frac{\text{Calculated}}{\text{Population Size}} = \frac{M \times (CwM + Cw/oM)}{CwM}$$

11. Record the *calculated population size* in the data table.

12. To verify the *actual population size*, count all the beans in the bag and record this value in the data table.

13. CLEANUP AND DISPOSAL Make wise choices as to how you will dispose of the beans. Can some be recycled?

Data Table

Trial	Total Caught	Number Caught With Marks	Number Caught Without Marks
1	30		
2	30		
3	30		
4	30		
5	30		
Averages	30		

Calculated population size = _____

Actual population size = _____

ANALYZE AND CONCLUDE

1. Think Critically Explain why this type of activity is best done as a simulation.

2. ERROR ANALYSIS Compare the calculated to the actual population size. Explain why they may not agree exactly. What changes to the procedure would improve the accuracy of the activity?

3. Make Inferences Explain why this technique is used more often with animals than with plants when calculating population size.

4. Make Predictions Assume you were doing this experiment with living animals. What would you be doing in step 2? Step 3? Step 5?

Apply Your Skill

Field Investigation Assume that you are a field biologist on an island. Plan investigative procedures, including selecting equipment, to determine the deer population on the island.

Web Links To find out more about ecology field research, visit **bdol.glencoe.com/ecology**

connection to Chemistry

Polymers for People

Polymerization is the process in which single molecules of a substance are joined chemically to form long chains called polymers. One polymer that has had a great affect on modern life is polystyrene. Because of polystyrene, we have numerous disposable plastic items in our lives, from plastic grocery bags to jewel cases for CDs.

Polystyrene, in the form of foamed plastic, is about 98 percent air. It is made by blowing tiny air-containing holes, called cells, into a polymer. In the beginning, chlorofluorocarbons, or CFCs, were used to make the cells. In the 1980s, CFCs were outlawed for this and other processes. Since then, most foamed polystyrene has been made using pentane as the blowing agent.

Polystyrene products Foam beverage cups and plates, plastic utensils, some packaging "peanuts," insulation, and many disposable pieces of medical equipment are made from polystyrene. In the food service industry, polystyrene products keep hot foods hot and cold foods cold. These products are popular for their health safety because they are used once and thrown away. This feature reduces the chance of contamination and transmission of disease.

Because of all of its positive characteristics, polystyrene is used extensively. However, the edges of highways and our landfills reflect its widespread use by a growing population. Foamed plastic, as it currently exists, is not biodegradable within a reasonable amount of time. How can the problems created by mass disposal of items made from polystyrene be avoided? Is there a way to make a biodegradable plastic bag, a CD case, toy, or toothbrush?

Biodegradable products For something to be biodegradable, it has to be able to be broken down into simpler components by decomposers. Polystyrene can be broken down, but it takes a long time for that to happen. Is there anything that can be broken down more quickly?

Corn into plastic Have you ever worn a shirt made out of corn resin? Research for more environmentally-friendly substances is an on-going project. Since the 1980s, manufacturing processes for turning corn starch and corn fibers into useful products have become a reality. Corn-based packing "peanuts" have been developed. Molded bottles are being manufactured for use in short-term shelf products such as milk. The hope is that these products and others will conserve fossil fuels, be quickly biodegradable, and therefore, more environmentally friendly. Markets for corn-based polymers are similar to those for petroleum-based polystyrene products—leaf and lawn bags, food packaging, and textiles for clothing. Research is ongoing with regard to how well microorganisms break down the materials.

Writing About Biology

Research Find out about alternative biodegradable materials being developed for the purpose of conserving fossil fuels and for making landfills more useful. Evaluate the impact of polymers by surveying your own home for them. Compare your findings with those of your classmates.
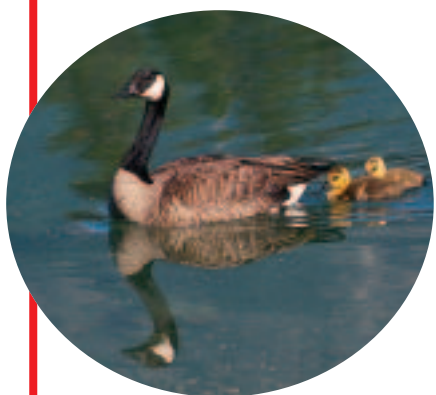
To find out more about plastics and biodegradable products and their role in the environment, visit **bdol.glencoe.com/chemistry**

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STUDY GUIDE

Section 4.1

Population Dynamics

Key Concepts

■ Populations of some organisms do not exhibit linear growth. If there is nothing to stop or slow growth, a population's growth appears as a J-shaped curve on a graph.

■ Populations grow slowly at first, then more rapidly as more and more individuals begin to reproduce.

■ Under normal conditions, with limiting factors, populations show an S-shaped curve as they approach the carrying capacity of the environment where they live.

■ If a population overshoots the environment's carrying capacity, deaths exceed births and the total population falls below the environment's carrying capacity. The number of individuals will fluctuate above and below the carrying capacity.

■ Density-dependent factors and density-independent factors affect population growth. Density-dependent factors include disease, competition for space, water, and food supply. Density-independent factors are volcanic eruptions and changes in climate that result in catastrophic incidents such as floods, drought, hurricanes, or tornadoes.

Vocabulary

carrying capacity (p. 93)
density-dependent factor (p. 97)
density-independent factor (p. 97)
exponential growth (p. 93)
life-history pattern (p. 93)

Section 4.2

Human Population

Key Concepts

■ Demography is the study of population characteristics such as growth rate, age structure, and movement of individuals.

■ Birthrate, death rate, immigration, emigration, doubling time, and age structures differ considerably among different countries. There are uneven population growth patterns throughout the world.

Vocabulary

age structure (p. 102)
birthrate (p. 101)
death rate (p. 101)
demography (p. 100)
doubling time (p. 102)

FOLDABLES
To help you review population biology, use the Organizational Study Fold on page 91.

Vocabulary Review

Review the Chapter 4 vocabulary words listed in the Study Guide on page 107. Distinguish between the vocabulary words in each pair.

1. birthrate—death rate
2. density-dependent factor— density-independent factor
3. life-history pattern—age structure
4. population—demography
5. limiting factor—carrying capacity

Understanding Key Concepts

6. Describe what is happening to the growth of the population shown at interval **3** in the diagram below.
   A. slow growth
   B. exponential or rapid growth
   C. slowing growth reaching carrying capacity
   D. population reaching equilibrium near carrying capacity
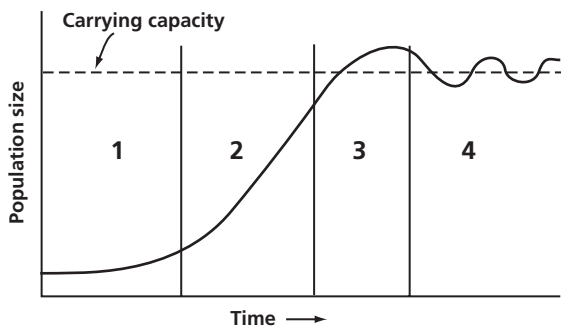
7. Which organisms would be most affected by density-independent factors?
   A. cats
   B. humans
   C. houseflies
   D. deer

8. When plotted on a graph, a population of field mice over time shows a J-shaped curve. This indicates that _____.
   A. the population is decreasing
   B. predators of the mice are increasing
   C. there may be no predators
   D. food supply is low

9. When populations increase, resource depletion may bring about _____.
   A. exponential growth
   B. straight-line growth
   C. increased competition
   D. decreased competition

Constructed Response

10. **Open Ended** A population of animals shows a sudden decline and then recovers. Using ecological principles, discuss two specific reasons why this might occur.

11. **Open Ended** Give at least two reasons why it would be important for the planning board of a city to know the city's doubling time.

12. **Open Ended** For what reasons would a school board need to refer to an age structure chart of the local community when planning a five year budget?

Thinking Critically
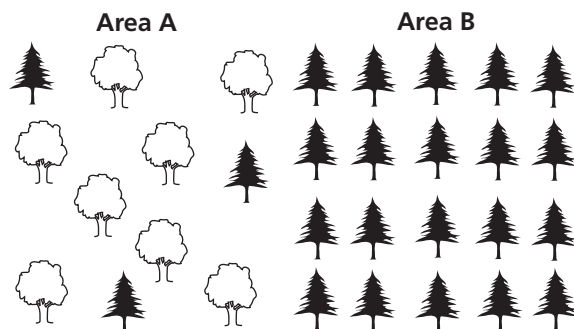
13. **Analyze** Using the diagram above, identify the factor that would cause more trees in Area B to be affected by an invasion of disease-carrying insects than in Area A. Explain your choice.

14. **Infer** Are predators a density-dependent or density-independent limiting factor for the population growth of their prey? Explain.

15. **Infer** Why are short life-history species, such as mosquitoes and some weeds, successful, even though they often experience massive population declines?

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16. **REAL WORLD BIOCHALLENGE** Every 10 years the United States is required by law to complete a census. Visit **bdol.glencoe.com** to find out about the most recent census. Pretend that you are a demographer for your state. What change, if any, occurred in the population of your state from 1990 to 2000? Display these changes on a map. Determine if your state's population is growing, declining, or has reached stability. Research and explain your choice.
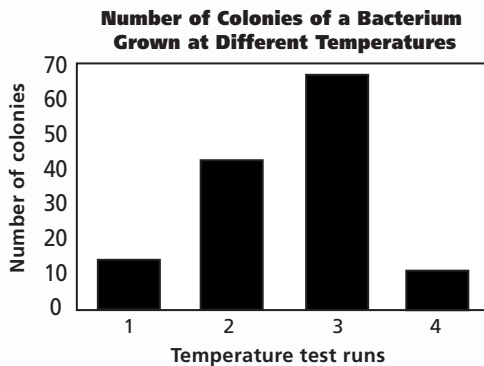
Standardized Test Practice

All questions aligned and verified by **The Princeton Review**

Part 1 Multiple Choice

Use the graph below to answer questions 17 and 18.

Number of Colonies of a Bacterium Grown at Different Temperatures

17. A bacterial species was grown at different temperatures represented in the graph above by cultures 1 through 4. From the graph, identify the culture for which temperature was the greatest limiting factor.
    A. 1
    B. 2
    C. 3
    D. 4

18. Which culture showed the greatest growth rate?
    A. 1   C. 3
    B. 2   D. 4

Use the following diagram to answer questions 19 and 20.

Deer Population Over Time
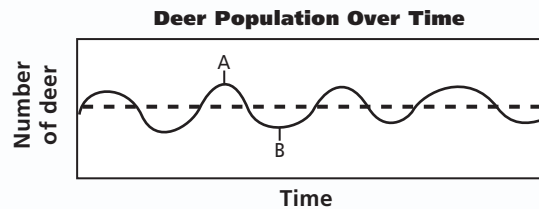
19. The dotted line in the graph above represents the _____ for the deer population.
    A. death rate   C. carrying capacity
    B. birthrate   D. age structure

20. The solid curve in the graph from point A to point B indicates that _____.
    A. more deer are dying than being born
    B. more deer are being born than are dying
    C. there are not enough predators
    D. no limiting factors are at work

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

21. **Open Ended** A small group of mice invaded a new habitat with unlimited resources and their population grew rapidly. A flood then swept through the habitat and three quarters of the mice were lost. Two months later, the population was increasing again. What role did the flood play for the mouse population? Draw a graph depicting the population history of this group.

22. **Open Ended** What is the relationship between a population and a species?

23. **Open Ended** Water hyacinth populations double in 6 to 18 days. Introduced in the 1880s, populations of this plant have clogged major waterways in several states. No predators for it exist in the United States. Does this species have a J-shaped or an S-shaped growth pattern? Explain your choice.