CHAPTER 4

SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems. **Also covers: SCSh1, SCSh2, SCSh3, SCSh4, SCSh5, SCSh6, SCSh9**

Español

Population Ecology

Section 1
Population Dynamics
MAIN Idea Populations of species are described by density, spatial distribution, and growth rate.

Section 2
Human Population
MAIN Idea Human population growth changes over time.

BioFacts

- Deer can be found in most parts of the United States except the southwest, Alaska, and Hawaii.
- Parasites that attack deer include fleas, ticks, lice, mites, and tapeworms.
- Diseases such as Lyme disease, chronic wasting disease, and hemorrhagic disease can kill deer.

(t)Eye of Science/SPL/Photo Researchers, (b)K. Kjeldsen/Photo Researchers, (bkgd)George McCarthy/CORBIS

Start-Up Activities

LAUNCH Lab

A population of one?

Ecologists study populations of living things. They also study how populations interact with each other and with the abiotic factors in the environment. But what exactly is a population? Are the deer shown on the previous page a population?
Is a single deer a population?

Procedure

1. Read and complete the lab safety form.
2. In your assigned group, brainstorm and predict the meaning of the following terms: *population, population density, natality, mortality, emigration, immigration,* and *carrying capacity.*

Analysis

1. **Infer** whether it is possible to have a population of one. Explain your answer.
2. **Analyze** your definitions and determine whether a relationship exists between the terms. Explain.

Biology Online

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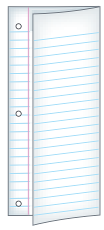
- study the entire chapter online
- explore the Interactive Time Line, Concepts in Motion, the Interactive Table, Microscopy Links, Virtual Labs, and links to virtual dissections
- access Web links for more information, projects, and activities
- review content online with the Interactive Tutor and take Self-Check Quizzes

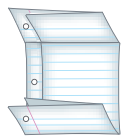
FOLDABLES™ Study Organizer

Population Characteristics Make this Foldable to help you learn the characteristics used to describe populations.

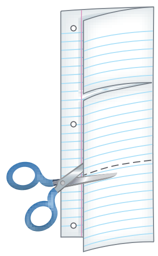
STEP 1 Fold a sheet of paper vertically with the edges about 2 cm apart.



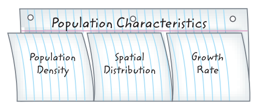
STEP 2 Fold the paper into thirds.



STEP 3 Unfold and cut the top layer of both folds to make three tabs.



STEP 4 Label each tab as shown: *Population Density, Spatial Distribution, Growth Rate.*



FOLDABLES **Use this Foldable with Section 4.1.** As you study this section, write what you learn about each characteristic under the correct tab.

SB4a. Investigate the relationships among organisms, populations, communities, ecosystems, and biomes.
SB4f. Relate animal adaptations, including behaviors, to the ability to survive stressful environmental conditions.
Also covers: SCSh3d, SCSh6b, SCSh9c, SB4d–e

Objectives

- **Describe** characteristics of populations.
- **Understand** the concepts of carrying capacity and limiting factors.
- **Describe** the ways in which populations are distributed.

Review Vocabulary

population: the members of a single species that share the same geographic location at the same time

New Vocabulary

population density
dispersion
density-independent factor
density-dependent factor
population growth rate
emigration
immigration
carrying capacity

Population Dynamics

MAIN Idea Populations of species are described by density, spatial distribution, and growth rate.

Real-World Reading Link Have you ever observed a beehive or an ant farm? The population had certain characteristics that could be used to describe it. Ecologists study population characteristics that are used to describe all populations of organisms.

Population Characteristics

All species occur in groups called populations. There are certain characteristics that all populations have, such as population density, spatial distribution, and growth rate. These characteristics are used to classify all populations of organisms, including bacteria, animals, and plants.

Population density One characteristic of a population is its **population density,** which is the number of organisms per unit area. For example, the population density of cattle egrets, shown with the water buffalo in **Figure 4.1,** is greater near the buffalo than farther away. Near the water buffalo, there might be three birds per square meter. Fifty meters from the water buffalo, the density of birds might be zero.

Spatial distribution Another characteristic of a population is called **dispersion**—the pattern of spacing of a population within an area. **Figure 4.2** shows the three main types of dispersion—uniform, clumped groups, and random. Black bears are typically dispersed in a uniform arrangement. American bison are dispersed in clumped groups or herds. White-tailed deer are dispersed randomly with unpredictable spacing. One of the primary factors in the pattern of dispersion for all organisms is the availability of resources such as food.

P. Kahl/Photo Researchers

Figure 4.1 The population density of the cattle egrets is greater near the water buffalo.
Identify *What type of dispersion do these birds appear to have?*

Visualizing Population Characteristics

NATIONAL GEOGRAPHIC

Figure 4.2
Population density describes how many individual organisms live in a given area. Dispersion describes how the individuals are spaced within that area. Population range describes a species' distribution.

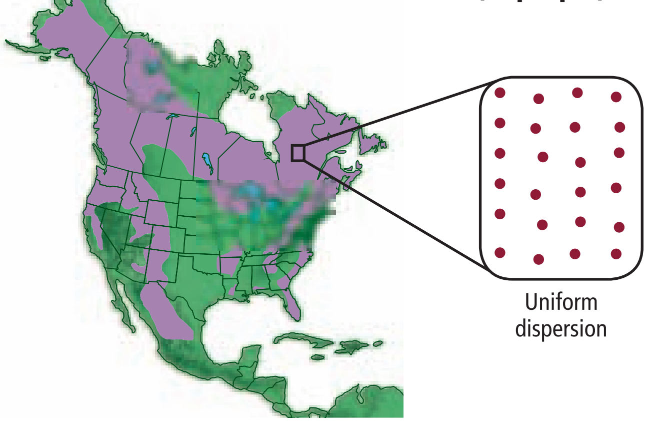
CLICK HERE

Black Bear

Dispersion: American black bear males usually are dispersed uniformly within territories as large as several hundred square kilometers. Females have smaller territories that overlap those of males.

Density: one bear per several hundred square kilometers

Black Bear Distribution (in purple)

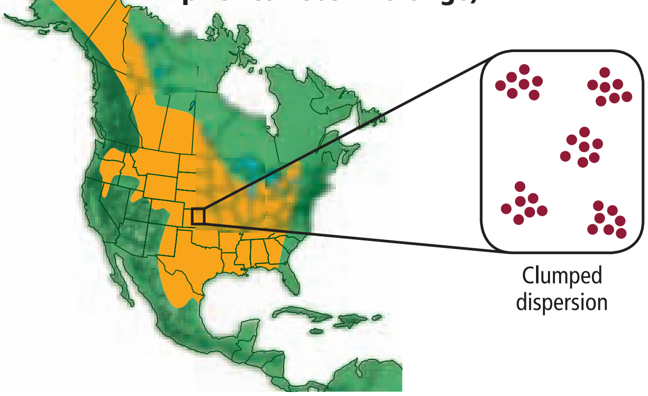


American Bison

Dispersion: American bison are found in clumped groups called herds.

Density: four bison/km^2 in Northern Yellowstone in 2000

Bison Distribution (historic range prior to 1865 in orange)

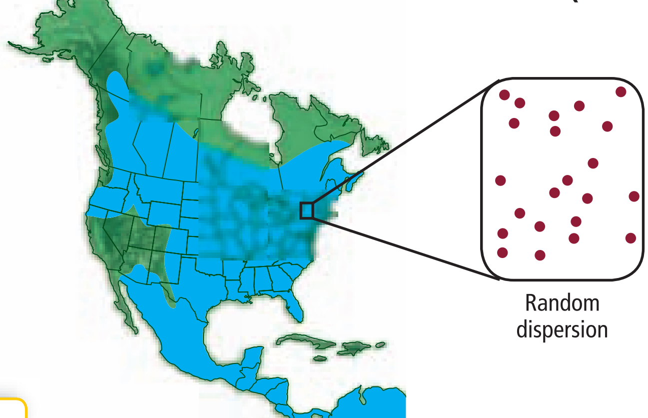


White-tailed Deer

Dispersion: White-tailed deer are dispersed randomly throughout appropriate habitats.

Density: 10 deer/km^2 in some areas of the northeastern United States

White-tailed Deer Distribution (in blue)



Concepts in Motion **Interactive Figure** To see an animation of population distribution, visit biologygmh.com

Biology Online

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Distribution

Science usage: the area where something is located or where a species lives and reproduces
The white-tailed deer has a wide distribution that covers much of the United States.

Common usage: the handing out or delivery of items to a number of people
The distribution of report cards to students occurred today.

Population ranges No population, not even the human population, occupies all habitats in the biosphere. Some species, such as the iiwi (EE ee wee) shown in **Figure 4.3,** have a very limited population range. This songbird is found only on some of the islands of Hawaii. Other species, such as the peregrine falcon shown in **Figure 4.3,** have a vast distribution. Peregrine falcons are found on all continents except Antarctica. Note the distribution of the animals in **Figure 4.2.**

Recall from Chapter 2 that organisms adapt to the biotic and abiotic factors in their environment. A species might not be able to expand its population range because it cannot survive the abiotic conditions found in the expanded region. A change in temperature range, humidity level, annual rainfall, or sunlight might make a new geographic area uninhabitable for the species. In addition, biotic factors, such as predators, competitors, and parasites, present threats that might make the new location difficult for survival.

Reading Check **Describe** two different types of population ranges.

Population-Limiting Factors

In Chapter 3, you learned that all species have limiting factors. Limiting factors keep a population from continuing to increase indefinitely. Decreasing a limiting factor, such as the available food supply, often changes the number of individuals that are able to survive in a given area. In other words, if the food supply increases a larger population might result, and if the food supply decreases a smaller population might result.

Density-independent factors There are two categories of limiting factors—density-independent factors and density-dependent factors. Any factor in the environment that does not depend on the number of members in a population per unit area is a **density-independent factor.** These factors usually are abiotic and include natural phenomena such as weather events. Weather events that limit populations include drought or flooding, extreme heat or cold, tornadoes, and hurricanes.

Figure 4.3 The iiwi lives only on some of the Hawaiian islands. The peregrine falcon is found worldwide.

Iiwi

Peregrine falcon

Crown fire damage

Managed ground fire damage

■ **Figure 4.4** A crown fire is a density-independent factor that can limit population growth. However, small ground fires can promote growth of pines in a pine forest community.

Explain ***Why do these two situations involving fire have different results on the pine tree populations?***

Figure 4.4 shows an example of the effects that fire can have on a population. Fire has damaged this ponderosa pine forest community. Sometimes the extreme heat from a crown fire, which is a fire that advances to the tops of the trees, can destroy many mature ponderosa pine trees—a dominant species in forests of the western United States. In this example, the fire limits the population of ponderosa trees by killing many of the trees. However, smaller but more frequent ground fires have the opposite effect on the population. By thinning lower growing plants that use up nutrients, a healthier population of mature ponderosa pines is produced.

Populations can be limited by the unintended results of human alterations of the landscape. For example, over the last 100 years, human activities on the Colorado River, such as building dams, water diversions, and water barriers, have significantly reduced the amount of water flow and changed the water temperature of the river. In addition, the introduction of nonnative fish species altered the biotic factors in the river. Because of the changes in the river, the number of small fish called humpback chub was reduced. During the 1960s, the number of humpback chub dropped so low that they were in danger of disappearing from the Colorado River altogether.

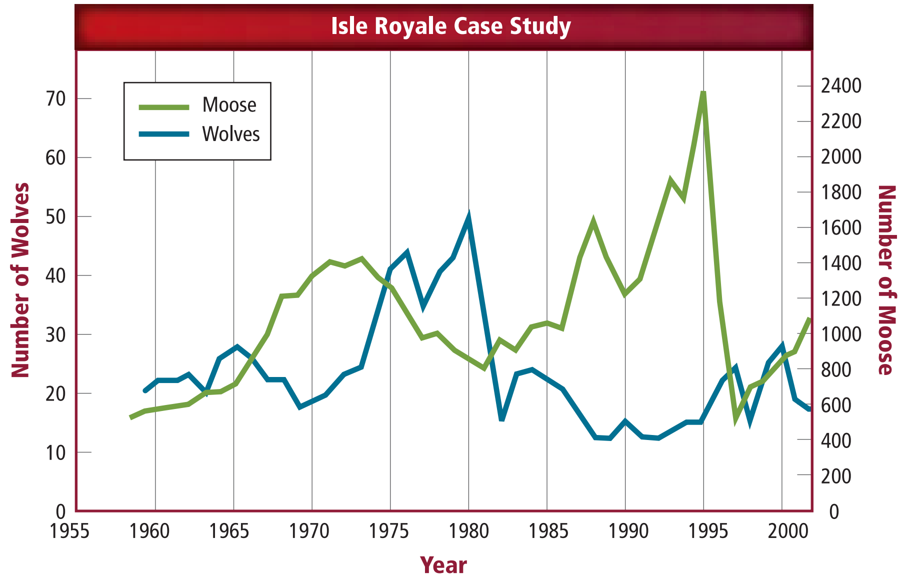
Air, land, and water pollution are the result of human activities that also can limit populations. Pollution reduces the available resources by making some of the resources toxic.

Density-dependent factors Any factor in the environment that depends on the number of members in a population per unit area is a **density-dependent factor.** Density-dependent factors are often biotic factors such as predation, disease, parasites, and competition. A study of density-dependent factors was done on the wolf–moose populations in northern Michigan on Isle Royale, located in Lake Superior.

CAREERS IN BIOLOGY

Population Biologist A population biologist studies the characteristics of populations, such as growth, size, distribution, or genetics. For more information on biology careers, visit biologygmh.com.

■ **Figure 4.5** The long-term study of the wolf and moose populations on Isle Royale shows the relationship between the number of predators and prey over time.
Infer ***What might have caused the increase in the number of moose in 1995?***



FOLDABLES Incorporate information from this section into your Foldable.

Prior to the winter of 1947–48, apparently there were no wolves on Isle Royale. During that winter, a single pair of wolves crossed the ice on Lake Superior, reaching the island. During the next ten years, the population of wolves reached about twenty individuals. **Figure 4.5** shows some of the results from the long-term study conducted by population biologists. Notice that the rise and fall of the numbers of each group was dependent on the other group. For example, follow the wolves' line on the graph. As the number of wolves decreased, the number of moose increased.

Disease Another density-dependent factor is disease. Outbreaks of disease tend to occur when population size has increased and population density is high. When population density is high, disease is transmitted easily from one individual to another because contact between individuals is more frequent. Therefore, the disease spreads easily and quickly through a population. This is just as true for human populations as it is for populations of protists, plants, and other species of animals.

Competition Competition between organisms also increases when density increases. When the population increases to a size so that resources such as food or space become limited, individuals in the population must compete for the available resources. Competition can occur within a species or between two different species that use the same resources. Competition for insufficient resources might result in a decrease in population density in an area due to starvation or to individuals leaving the area in search of additional resources. As the population size decreases, competition becomes less severe.

The lemmings shown in **Figure 4.6** are an example of a population that often undergoes competition for resources. Lemmings are small mammals that live in the tundra biome. When food is plentiful, their population increases exponentially. As food becomes limited, many lemmings begin to starve and their population size decreases significantly.

Parasites Populations also can be limited by parasites, in a way similar to disease, as population density increases. The presence of parasites is a density-dependent factor that can negatively affect population growth at higher densities.

■ **Figure 4.6** Lemmings are mammals that produce offspring in large numbers when food is plentiful. When the food supply diminishes, lemmings starve and many die.

Population growth rate An important characteristic of any population is its growth rate. The **population growth rate** (PGR) explains how fast a given population grows. One of the characteristics of the population ecologists must know, or at least estimate, is natality. The natality of a population is the birthrate, or the number of individuals born in a given time period. Ecologists also must know the mortality—the number of deaths that occur in the population during a given time period.

The number of individuals emigrating or immigrating also is important. **Emigration** (em uh GRAY shun) is the term ecologists use to describe the number of individuals moving away from a population. **Immigration** (ih muh GRAY shun) is the term ecologists use to describe the number of individuals moving into a population. In most instances, emigration is about equal to immigration. Therefore, natality and mortality usually are most important in determining the population growth rate.

Some populations tend to remain approximately the same size from year to year. Other populations vary in size depending on conditions within their habitats. To better understand why populations grow in different ways, you should understand two mathematical models for population growth—the exponential growth model and the logistic growth model.

Exponential growth model Look at **Figure 4.7** to see how a population of mice would grow if there were no limits placed on it by the environment. Assume that two adult mice breed and produce a litter of young. Also assume the two offspring are able to reproduce in one month. If all of the offspring survive to breed, the population grows slowly at first. This slow growth period is defined as the lag phase. The rate of population growth soon begins to increase rapidly because the total number of organisms that are able to reproduce has increased. After only two years, the experimental mouse population would reach more than three million mice.

Connection to Math Notice in **Figure 4.7** that once the mice begin to reproduce rapidly, the graph becomes J-shaped. A J-shaped growth curve illustrates exponential growth. Exponential growth, also called geometric growth, occurs when the growth rate is proportional to the size of the population. All populations grow exponentially until some limiting factor slows the population's growth. It is important to recognize that even in the lag phase, the use of available resources is exponential. Because of this, the resources soon become limited and population growth slows.

Logistic growth model Many populations grow like the model shown in **Figure 4.8** rather than the model shown in **Figure 4.7.** Notice that the graphs look exactly the same through some of the time period. However, the second graph curves into an S-shape. An S-shaped curve is typical of logistic growth. Logistic growth occurs when the population's growth slows or stops following exponential growth, at the population's carrying capacity. A population stops increasing when the number of births is less than the number of deaths or when emigration exceeds immigration.

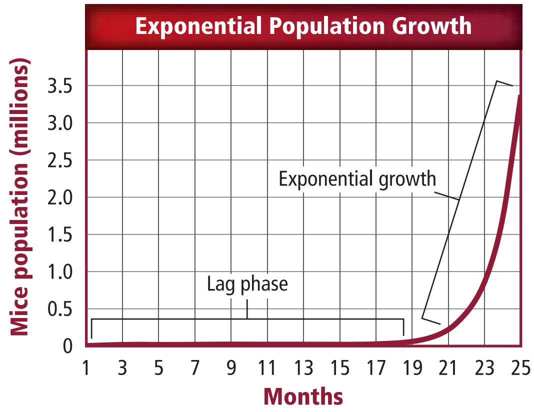
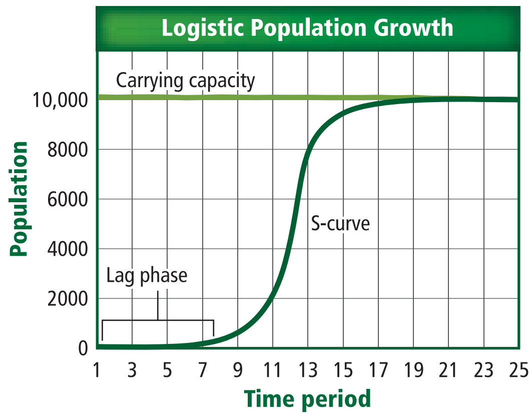


Figure 4.7 If two mice were allowed to reproduce unhindered, the population would grow slowly at first but would accelerate quickly.
Infer ***Why don't mice or other populations continue to grow exponentially?***

CLICK HERE

Figure 4.8 When a population exhibits growth that results in an S-shaped graph, it exhibits logistic growth. The population levels off at a limit called the carrying capacity.

Interactive Figure To see an animation of population growth, visit biologygmh.com.



Pierre Holtz/Reuters/CORBIS

■ **Figure 4.9** Locusts, which are *r*-strategists, usually have a short life span and produce many offspring.
Infer *What specific factors might fluctuate in a locust's environment?*

Carrying capacity In **Figure 4.8** on the previous page, notice that logistic growth levels off at the line on the graph identified as the carrying capacity. The maximum number of individuals in a species that an environment can support for the long term is the **carrying capacity.** Carrying capacity is limited by the energy, water, oxygen, and nutrients available. When populations develop in an environment with plentiful resources, there are more births than deaths. The population soon reaches or passes the carrying capacity. As a population nears the carrying capacity, resources become limited. If a population exceeds the carrying capacity, deaths outnumber births because adequate resources are not available to support all of the individuals. The population then falls below the carrying capacity as individuals die. The concept of carrying capacity is used to explain why many populations tend to stabilize.

Reproductive patterns The graph in **Figure 4.8** shows the number of individuals increasing until the the carrying capacity is reached. However, there are several additional factors that must be considered for real populations. Species of organisms vary in the number of births per reproduction cycle, in the age that reproduction begins, and in the life span of the organism. Both plants and animals are placed into groups based on their reproductive factors.

Members of one of the groups are called the *r*-strategists. The rate strategy, or *r*-strategy, is an adaptation for living in an environment where fluctuation in biotic or abiotic factors occur. Fluctuating factors might be availability of food or changing temperatures. An *r*-strategist is generally a small organism such as a fruit fly, a mouse, or the locusts shown in **Figure 4.9.** *R*-strategists usually have short life spans and produce many offspring.

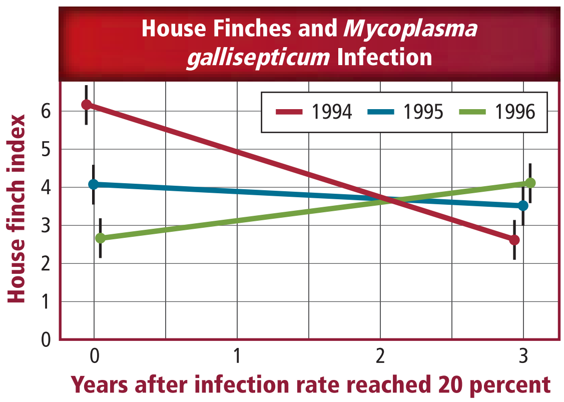
DATA ANALYSIS LAB 4.1

Based on Real Data*

Recognize Cause and Effect

Do parasites affect the size of a host population? In 1994, the first signs of a serious eye disease caused by the bacterium *Mycoplasma gallisepticum* were observed in house finches that were eating in backyard bird feeders. Volunteers collected data beginning three different years on the number of finches infected with the parasite and the total number of finches present. The graph shows the abundance of house finches in areas where the infection rate was at least 20 percent of the house finch population.

Data and Observations



Think Critically

1. **Compare** the data from the three areas.
2. **Hypothesize** Why did the house finch abundance stabilize in 1995 and 1996?
3. **Infer** Is the parasite, *Mycoplasma gallisepticum,* effective in limiting the size of house finch populations? Explain.

*Data obtained from: Gregory, R., et al. 2000. Parasites take control. *Nature* 406: 33–34.

Daryl Balfour/Photo Reseachers

■ **Figure 4.10** Elephants are *k*-strategists that produce few offspring, but they invest a lot of care in the raising of their offspring.

The reproductive strategy of an *r*-strategist is to produce as many offspring as possible in a short time period in order to take advantage of some environmental factor. They typically expend little energy or none at all in raising their young to adulthood. Populations of *r*-strategists usually are controlled by density-independent factors, and they usually do not maintain a population near the carrying capacity.

Just as some environments fluctuate, others are fairly predictable. Elephants on the savanna, shown in **Figure 4.10,** experience a carrying capacity that changes little from year to year. The carrying-capacity strategy, or *k*-strategy, is an adaptation for living in these environments. A *k*-strategist generally is a larger organism that has a long life span, produces few offspring, and whose population reaches equilibrium at the carrying capacity. The reproductive strategy of a *k*-strategist is to produce only a few offspring that have a better chance of living to reproductive age because of the energy, resources, and time invested in the care for the young. Populations of *k*-strategists usually are controlled by density-dependent factors.

VOCABULARY

ACADEMIC VOCABULARY

Fluctuate
to change from high to low levels or from one thing to another in an unpredictable way
The speed of a car fluctuates when you are driving on narrow, winding roads.

Section 4.1 Assessment

Section Summary

- There are population characteristics that are common to all populations of organisms, including plants, animals, and bacteria.
- Populations tend to be distributed randomly, uniformly, or in clumps.
- Populations tend to stabilize near the carrying capacity of their environment.
- Population limiting factors are either density-independent or density-dependent.

Understand Main Ideas

1. MAIN Idea **Compare and contrast** spatial distribution, population density, and population growth rate.
2. **Summarize** the concepts of carrying capacity and limiting factors.
3. **Sketch** diagrams showing population dispersion patterns.
4. **Analyze** the impact a nonnative species might have on a native species in terms of population dynamics.

Think Scientifically

5. *Design an experiment* that you could perform to see if a population of fruit flies—very small insects that feed on bananas—grows according to the exponential growth model or the logistic growth model.
6. *WRITING in* **Biology** Write a newspaper article describing how a weather event, such as drought, has affected a population of animals in your community.

Section 4.2

SB4d. Assess and explain human activities that influence and modify the environment, such as global warming, population growth, pesticide use, and water and power consumption. **Also covers: SCSh1a, SCSh2a–b, SCSh3a–e, SCSh4a, c, SCSh5a, SCSh6c, SCSh9c–d, SB4a**

Objectives

- **Explain** the trends in human population growth.
- **Compare** the age structure of representative nongrowing, slowly growing, and rapidly growing countries.
- **Predict** the consequences of continued population growth.

Review Vocabulary

carrying capacity: the maximum number of individuals in a species that an environment can support for the long term

New Vocabulary

demography
demographic transition
zero population growth (ZPG)
age structure

CAREERS IN BIOLOGY

Demographer A demographer studies human population dynamics such as population growth rates, density, and distribution. For more information on biology careers, visit biologygmh.com.

Human Population

MAIN Idea **Human population growth changes over time.**

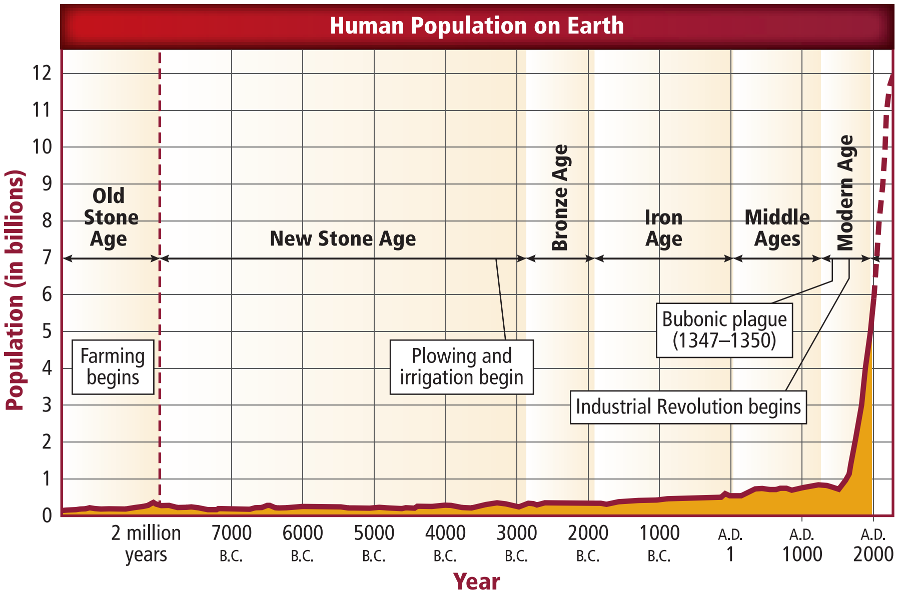
Real-World Reading Link Has someone you know recently had a baby? The odds of surviving to adulthood are greater than ever before for babies born in most countries today.

Human Population Growth

The study of human population size, density, distribution, movement, and birth and death rates is **demography** (de MAH gra fee). The graph in **Figure 4.11** shows demographers' estimated human population on Earth for several thousand years.

Notice that the graph in **Figure 4.11** shows a relatively stable number of individuals over thousands of years, until recently. Notice also the recovery of the human population after the outbreak of the bubonic plague in the 1300s when an estimated one-third of the population of Europe died. Perhaps the most significant feature in this graph is the increase in human population in recent times. In 1804, the population of Earth was an estimated one billion people. By 1999, the human population had reached six billion people. At this growth rate, about 70 million people are added to the world population annually, and the world's population is expected to double in about 53 years.

Figure 4.11 The human population on Earth was relatively constant until recent times, when the human population began to grow at an exponential rate.



Technological advances For thousands of years, environmental conditions kept the size of the human population at a relatively constant number below the environment's carrying capacity. Humans have learned to alter the environment in ways that appear to have changed its carrying capacity. Agriculture and domestication of animals have increased the human food supply. Technological advances and medicine have improved the chances of human survival by reducing the number of deaths from parasites and disease. In addition, improvements in shelter have made humans less vulnerable to climatic impact.

Reading Check **Explain** why an improvement in shelter increased the survival rate of the human population.

Human population growth rate Although the human population is still growing, the rate of its growth has slowed. **Figure 4.12** shows the percent increase in human population from the late 1940s through 2003. The graph also includes the projected population increase through 2050. Notice the sharp dip in human population growth in the 1960s. This was due primarily to a famine in China in which about 60 million people died. The graph also shows that human population growth reached its peak at over 2.2 percent in 1962. By 2003, the percent increase in human population growth had dropped to almost 1.2 percent. Population models predict the overall population growth rate to be below 0.6 percent by 2050. The decline in human population growth is due primarily to diseases such as AIDS and voluntary population control.

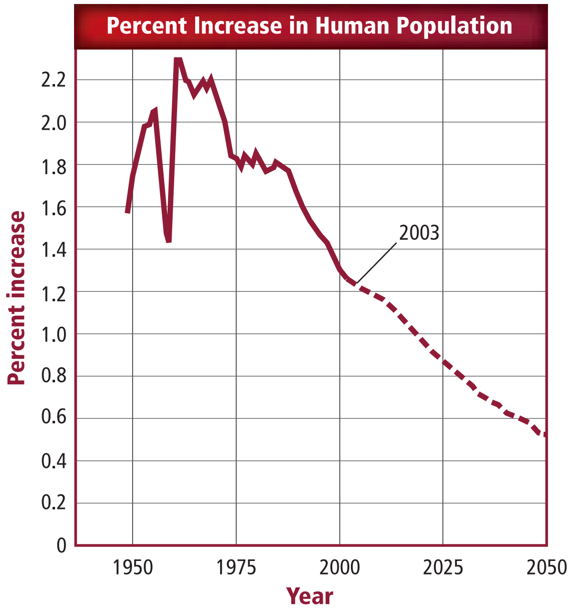


Figure 4.12 This graph shows the percent increase in the global human population using data from the late 1940s through 2003 and the projected percent increase to 2050.
Determine *What is the approximate population increase in the year 2025?*

MiniLab 4.1

Evaluate Factors

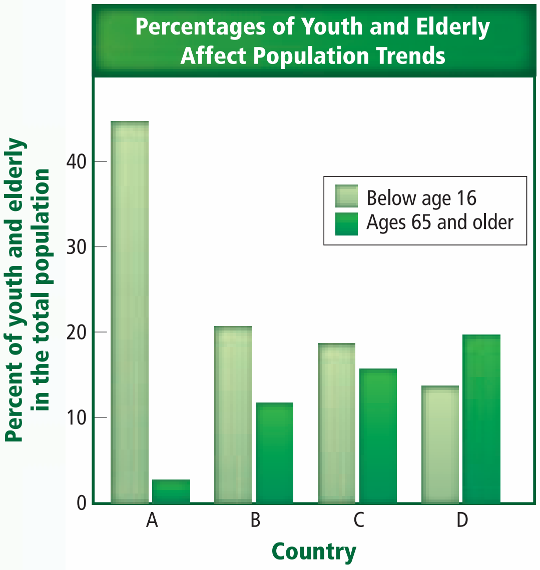
What factors affect the growth of a human population? Technological advances have resulted in a rapid growth in human population. However, human population growth is not equal in all countries.

Procedure

1. The graph shows one factor affecting human population growth. Use the data to predict how this factor will affect the population in each country between now and the year 2050.
2. Brainstorm a list of factors, events, or conditions that affect the growth of human populations in these countries. Predict the effect of each factor on the population growth rate.

Analysis

Think Critically In your opinion, what factors or groups of factors have the greatest impact on population growth? Justify your answer.



VOCABULARY

WORD ORIGIN

Demography

demo– from the Greek word *demos;* meaning *people*

–ography from the French word *graphie;* meaning *writing.*

Trends in Human Population Growth

The graph in **Figure 4.12** is somewhat deceptive. Population trends can be altered by events such as disease and war. **Figure 4.13** shows a few historical events that have changed population trends. **Figure 4.12** could also easily be misinterpreted because human population growth is not the same in all countries. However, there are population growth trends in countries that have similar economies.

For example, one trend that has developed during the previous century is a change in the population growth rate in industrially developed countries such as the United States. An industrially developed country is a country that is advanced in industrial and technological capabilities and whose population has a high standard of living. In its early history, the United States had a high birthrate and a high death rate. It was not uncommon for people to have large families and for individuals to die by their early forties. Many children also died before reaching adulthood. Presently, the birthrate in the United States has decreased dramatically and the life expectancy is greater than seventy years. A change in a population from high birth and death rates to low birth and death rates is a **demographic transition.**

Connection to Math How do population growth rates compare in industrially developed countries and developing countries—countries with a relatively low level of capabilities and a low standard of living? In the United States, the birthrate in 2005 was 14.1 births per 1000 people, the death rate was 8.2 deaths per 1000 people, and the migration rate was 3.3 people entering the country per 1000 people. The population growth rate was 0.92 percent in the United States.

In a developing country such as Honduras—location shown in **Table 4.1**—the situation is different. In the same year, Honduras had a birthrate of 30.4 births per 1000 people, a death rate of 6.9 deaths per 1000 people, and a migration rate of 1.9 people leaving the country per 1000 people. This results in a population growth rate of 2.16 percent. This is among the highest population growth rates of any country in the world.

LAUNCH Lab

Review Based on what you've read about populations, how would you now answer the analysis questions?

Figure 4.13

History of Human Population Trends

Many factors have affected human population growth throughout history.

1347–1351 The bubonic plague kills one-third of Europe's population and 75 million people throughout the world.

1800 The industrial revolution leads to a dramatic population explosion.

69,000 BC Researchers believe that as few as 15,000 to 40,000 people survived global climate changes that resulted from the eruption of the Toba supervolcano.

1798 The first essay on human population is written by Thomas Malthus, who predicted exponential population growth leading to famine, poverty, and war.

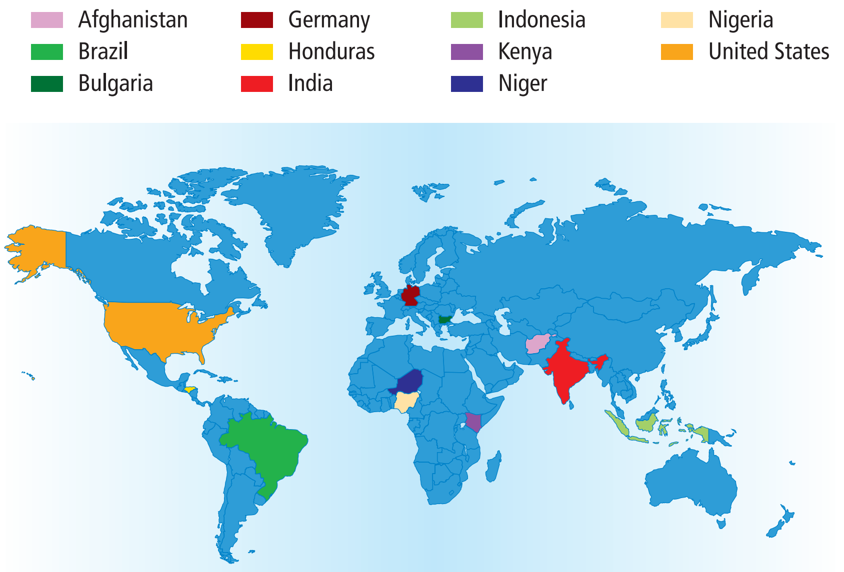
(l)Pete Oxford/Minden Pictures, (r)Bettmann/CORBIS

Table 4.1 Population Growth Rates of Countries

Interactive Table To explore more about population growth of various countries, visit biologygmh.com.

Country	Population growth rate (percent)
Afghanistan	4.77
Brazil	1.06
Bulgaria	−0.89
Germany	0.0
Honduras	2.16
India	1.40
Indonesia	1.45
Kenya	2.56
Niger	2.63
Nigeria	2.37
United States	0.92

Location



Developing countries will add 73 million people to the world population compared to only three million people added in the industrially developed countries. For example, between now and 2050, the developing country Niger—also shown in **Table 4.1**—is expected to be one of the most rapidly growing countries. Its population will expand from 12 to 53 million people. The industrially developed country Bulgaria is expected to have a population decline from eight to five million people in the same time period.

1939–1945 Approximately 58 million people are killed during World War II.

1954 Improved medical care, medicines, and sanitation leads to an increase in human population.

2004 An estimated 2.3 million people die as a result of AIDS in sub-Saharan Africa.

1900 1950 2000

1918 The Spanish Flu kills between 20 and 40 million people.

Interactive Time Line To learn more about these discoveries and others, visit biologygmh.com.

Study Tip

Interactive Reading As you read, write three questions on sticky notes about human population dynamics. The questions should begin with why, how, where, or when. Use the notes to ask a partner questions about the content in the chapter.

Zero population growth Another trend that populations can experience is zero population growth. **Zero population growth** (ZPG) occurs when the birthrate equals the death rate. One estimate is that the world will reach ZPG between 2020 with 6.64 billion people and 2029 with 6.90 billion people. This will mean that the population has stopped growing, because births and deaths occur at the same rate. Once the world population reaches ZPG, the age structure eventually should be more balanced with numbers at pre-reproductive, reproductive, and post-reproductive ages being approximately equal.

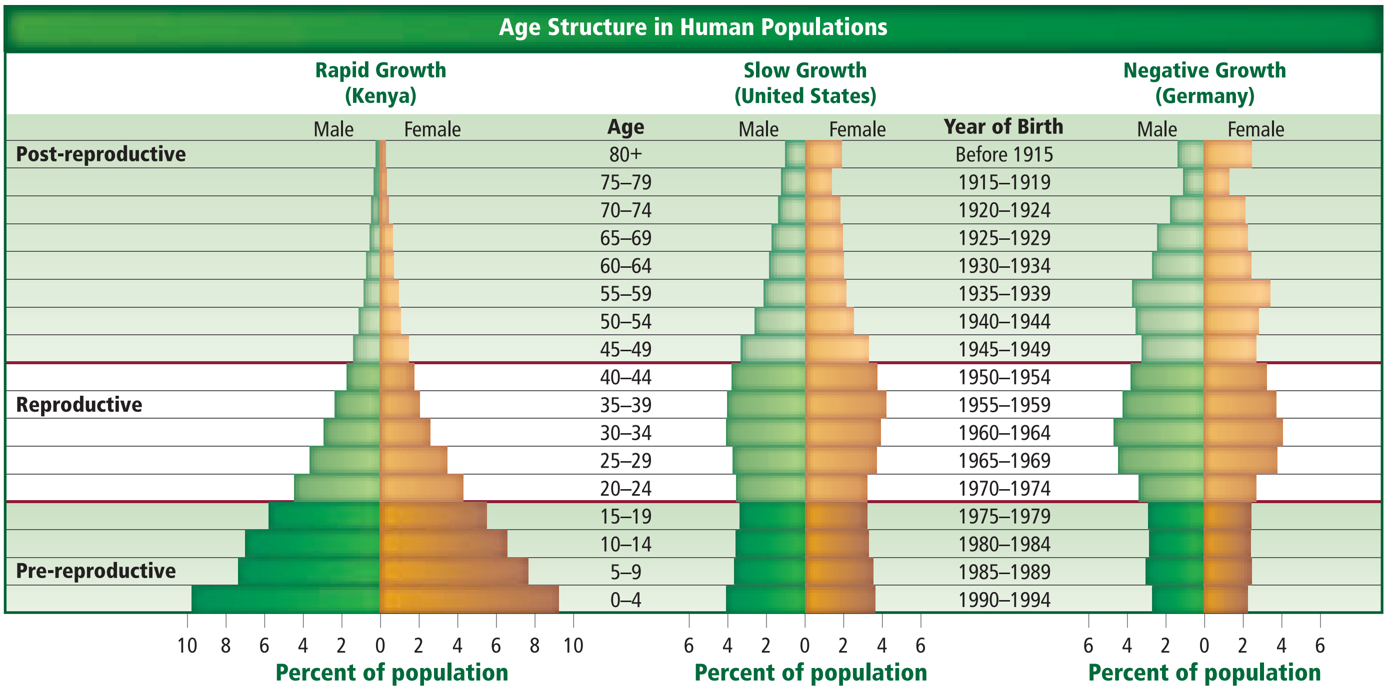
Reading Check **Describe** two trends in human population growth.

Age structure Another important characteristic of any population is its age structure. A population's **age structure** is the number of males and females in each of three age groups: pre-reproductive stage, reproductive stage, and post-reproductive stage. Humans are considered to be pre-reproductive before age 20 even though they are capable of reproduction at an earlier age. The reproductive years are considered to be between 20 and 44, and the post-reproductive years are after age 44.

Analyze the age structure diagrams for three different representative countries in **Figure 4.14—**their locations are shown in **Table 4.1.** The age structure diagrams are typical of many countries in the world. Notice the shape of the overall diagram for a country that is rapidly growing, one that is growing slowly, and one that has reached negative growth. The age structure for the world's human population looks more like that of a rapidly growing country.

Reading Check **Compare and contrast** the age structures of the countries shown in **Figure 4.14.**

Figure 4.14 The relative numbers of individuals in pre-reproductive, reproductive, and post-reproductive years are shown for three representative countries.



Human carrying capacity Calculating population growth rates is not just a mathematical exercise. Scientists are concerned about the human population reaching or exceeding the carrying capacity. As you learned in Section 4.1, all populations have carrying capacities, and the human population is no exception. Many scientists suggest that human population growth needs to be reduced. In many countries, voluntary population control is occurring through family planning. Unfortunately, if the human population continues to grow —as most populations do—and areas become overcrowded, disease and starvation will occur. However, technology has allowed humans to increase Earth's carrying capacity, at least temporarily. It might be possible for technology and planning to keep the human population at or below its carrying capacity.

Another important factor in keeping the human population at or below the carrying capacity is the amount of resources from the biosphere that are used by each person. Currently, individuals in industrially developed countries use far more resources than those individuals in developing countries, as shown in **Figure 4.15**. This graph shows the estimated amount of land required to support a person through his or her life, including land used for production of food, forest products and housing, and the additional forest land required to absorb the carbon dioxide produced by the burning of fossil fuels. Countries such as India are becoming more developed, and they have a high growth rate. These countries are adding more people and are increasing their use of resources. At some point, the land needed to sustain each person on Earth might exceed the amount of land that is available.

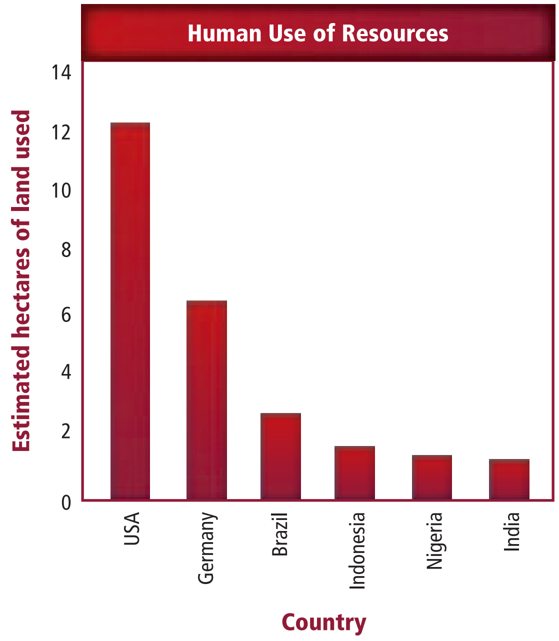


Figure 4.15 The amount of resources used by individual people varies around the world. Refer to **Table 4.1** for the locations of these countries.

Section 4.2 Assessment

Section Summary

- Human population growth rates vary in industrially developing countries and developed countries.
- Zero population growth occurs when the birthrate of a population equals the death rate.
- The age structure of the human population is a contributing factor to population growth in some countries.
- Earth has an undefined carrying capacity for the human population.

Understand Main Ideas

1. MAIN Idea **Describe** the change in human population growth over time.
2. **Describe** the differences between the age structure graphs of nongrowing, slowly growing, and rapidly growing countries.
3. **Assess** the consequences of exponential population growth of any population.
4. **Summarize** why human population began to grow exponentially in the Modern Age.

Think Scientifically

5. *Predict* the short-term and long-term effects of a newly emerging disease on industrially developing and developed countries.
6. MATH in Biology Construct an age-structure diagram using the following percentages: 0–19 years: 44.7; 20–44 years: 52.9; 45 years and over: 2.4. Which type of growth is this country experiencing?

CUTTING-EDGE BIOLOGY

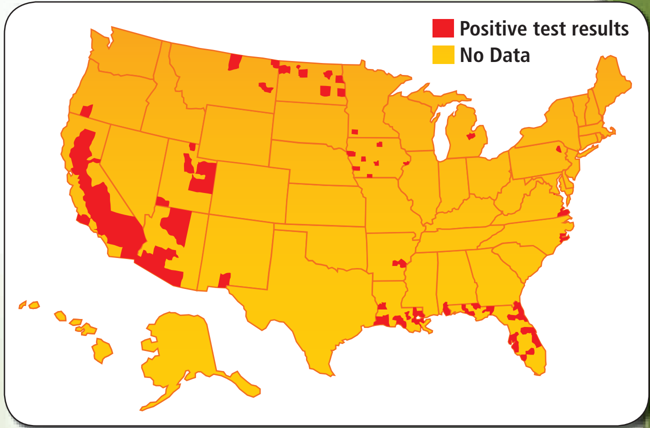
BIOINFORMATICS

In 1999, wildlife pathologist Ward Stone began investigating why a large number of dead crows were found across New York City and Long Island—too many to be attributed to natural causes. He examined the tissue and organs of more than 100 deceased birds to see if he could isolate a cause.

The trend continued and spread to other birds as well, threatening the population of zoo exhibits at the Bronx Zoo. The zoo pathologist, Tracey McNamara, noticed that the birds' brain tissue suggested some form of viral encephalitis. When the news broke that several people in New York had died from a similar malady, McNamara wondered if the two could be related. She sent tissue samples to the National Veterinary Services Laboratory and to the Centers for Disease Control (CDC).

Piecing together the puzzle Bioinformatics is an area of study in which computer science and biology combine to organize and interpret vast amounts of scientific knowledge. Scientists create databases for a wide variety of biological information, such as the sequencing of the human genome, the examination of protein structures, and the development of ways to predict the function of new-found proteins. Scientists used bioinformatics to identify and track the virus.

The last piece Researchers at the CDC, who were working on tissue samples from the people in New York as well, came up with a shocking discovery. The people, crows, and zoo birds had all been victims of the West Nile virus—a virus previously unseen in the United States. Without bioinformatics, this conclusion might have taken longer to reach, because the virus crossed species barriers and involved disciplines that usually do not share information.



This map shows the areas where sentinels were infected with the virus in October 2005.

Tracking the virus today When the West Nile virus was discovered, crows served as a sentinel to alert health care workers that the virus was in the area. A sentinel is an animal whose blood routinely is sampled to check for the presence of the virus. When the blood tests positive for the virus, this is an indication that the virus is in the area. Today, chickens and, to a lesser degree, horses are used as sentinels. Test results from the sentinels, as well as other organisms including confirmed human cases of the virus, are reported to the CDC where the information is collected in a database. The CDC sends the information to the U.S. Geological Survey, where detailed maps showing the areas of infection are made.

WRITING in Biology

Compare Visit biologygmh.com to find current maps showing the areas affected by the West Nile virus. Compare the Sentinel map on the Web site to the map above. Write a short report detailing how the number of areas infected has changed.

BIOLAB

DO PLANTS OF THE SAME SPECIES COMPETE WITH ONE ANOTHER?

Background: **Ecologists often study plant competition by comparing the biomass of individual plants in plant populations. In this lab, you will study intraspecific competition—competition among plants of the same species. As with most ecological studies, you will need to collect data for several weeks.**

Question: *Do plant populations of various densities grow differently due to competition?*

Materials

marigold seeds or radish seeds
9-cm plastic pots (6)
clean potting soil
rulers
shallow tray for pots
small garden trowels
masking tape
permanent markers
balance (accurate to 0.1 g)
watering can

Safety Precautions

Procedure

1. Read and complete the lab safety form.
2. Plant seeds in several pots as instructed by your teacher. Your goal should be to have pots with the following densities of plants: 2, 4, 8, 16, 32, and 64.
3. Place the pots in a shallow tray near a sunny window or under a grow light. Continue to keep the soil moist—not drenched—throughout the course of the experiment.
4. After the seeds have sprouted, weed out any extra plants so that you have the correct density.
5. Write a hypothesis about the effect plant density will have on the average biomass of each pot's population.
6. Construct a data table. Observe the plants once each week for a 5–6 week period. Record your observations.
7. At the end of the experiment, measure the biomass of the plants in each pot by cutting each plant at soil level and quickly weighing all the plants from the same pot together. Record your measurements. Calculate the average per-plant biomass of each pot.
8. **Cleanup and Disposal** Wash and return all reusable materials. Wash your hands after watering or working with the plants. Dispose of the plants at the end of the lab as instructed by your teacher.

Analyze and Conclude

1. **Graph Data** Prepare a graph showing the relationship between the average plant biomass and the density of plants. Draw a best-fit line for your data points. What was the effect of plant density on the average biomass of each pot's population? Does this graph support your hypothesis?
2. **Infer** Draw a second graph that compares the total biomass for each population to the number of plants in each population.
3. **Think Critically** Based on your results, infer how human population growth is affected by population density.
4. **Error Analysis** What sources of error might have affected your results?

GOING FURTHER

Poster Session Create a poster using the graphs you produced as a result of your experiment. If a digital camera is available, take photos of each pot of plants to include on your poster. Add headings and legends for each graph and photograph that explain and summarize your findings. Display your poster in the classroom or a hallway of your school. To learn more about competing plants, visit BioLabs at biologygmh.com.

CHAPTER 4

Study Guide

Download quizzes, key terms, and flash cards from biologygmh.com.

FOLDABLES Research Find the population density of the countries of a continent. Make a color-coded map that shows the population density of each country.

Vocabulary	Key Concepts

Section 4.1 Population Dynamics

Vocabulary

- carrying capacity (p. 98)
- density-dependent factor (p. 95)
- density-independent factor (p. 94)
- dispersion (p. 92)
- emigration (p. 97)
- immigration (p. 97)
- population density (p. 92)
- population growth rate (p. 97)

Key Concepts

MAIN Idea Populations of species are described by density, spatial distribution, and growth rate.

- There are population characteristics that are common to all populations of organisms, including plants, animals, and bacteria.
- Populations tend to be distributed randomly, uniformly, or in clumps.
- Populations tend to stabilize near the carrying capacity of their environment.
- Population limiting factors are either density-independent or density-dependent.

Section 4.2 Human Population

Vocabulary

- age structure (p. 104)
- demographic transition (p. 102)
- demography (p. 100)
- zero population growth (ZPG) (p. 104)

Key Concepts

MAIN Idea Human population growth changes over time.

- Human population growth rates vary in industrially developing countries and developed countries.
- Zero population growth occurs when the birthrate of a population equals the death rate.
- The age structure of the human population is a contributing factor to population growth in some countries.
- Earth has an undefined carrying capacity for the human population.

Vocabulary PuzzleMaker biologygmh.com

CHAPTER 4 Assessment

Section 4.1

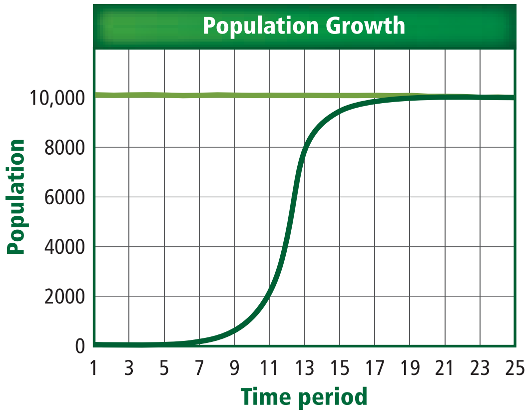
Vocabulary Review

Replace the underlined words with the correct vocabulary term from the Study Guide page.

1. The number added to a population by movement can considerably increase a population's size.
2. Drought is a density-dependent factor.
3. Were it not for the long-term limit, a population would continue to grow exponentially.

Understand Key Concepts

Use the illustration to answer questions 4–6.



4. Which population growth model does this graph illustrate?
   A. exponential growth
   B. lag phase
   C. logistic growth
   D. straight-line growth
5. What is the horizontal line on this graph called?
   A. carrying capacity **C.** geometric growth
   B. exponential growth **D.** straight-line growth
6. What do the time periods 1–7 represent?
   A. acceleration phase **C.** exponential growth
   B. carrying capacity **D.** lag phase
7. If angelfish produce hundreds of young several times a year, which statement below is true?
   A. Angelfish have a *k*-strategy reproductive pattern.
   B. Angelfish have an *r*-strategy reproductive pattern.
   C. Angelfish probably have a low mortality rate.
   D. Angelfish provide a lot of care for their young.
8. If an aquarium holds 80 L of water and contains 170 guppies, what is the approximate density of the guppy population?
   A. 1 guppy/L **C.** 3 guppies/L
   B. 2 guppies/L **D.** 4 guppies/L
9. Which is a density-independent factor?
   A. a severe drought
   B. an intestinal parasite
   C. a fatal virus
   D. severe overcrowding

Use the photo below to answer questions 10 and 11.

10. Which is a possible reason for the relatively quick spread of the shown disease?
    A. an abiotic factor
    B. a decreased food supply
    C. increased population density
    D. increased immunity
11. Why is the life span of this finch with an eye disease most likely reduced?
    A. The bird cannot mate.
    B. The bird cannot find food or water.
    C. The bird spreads the disease to others.
    D. The bird cannot survive a temperature change.
12. What is the dispersion pattern of herding animals, birds that flock together, and fish that form schools?
    A. clumped **C.** uniform
    B. random **D.** unpredictable

Constructed Response

13. **Short Answer** Female Atlantic right whales can reproduce at ten years of age and live more than fifty years. They can produce a calf every three to five years. Assuming that a right whale begins to reproduce at age ten, produces a calf every four years, and gives birth to its last calf at age fifty, how many whales will this female produce in her lifetime?

14. **Short Answer** What is the population density of Canada and the United States if they have a combined area of approximately 12.4 million square kilometers and a combined population of approximately 524 million?

15. **Short Answer** How does the carrying capacity affect *k*-strategists?

16. **Open Ended** Give two examples of how two different density-independent factors can limit a specific population.

17. **Open Ended** Give two examples of how two different density-dependent factors can limit a specific population.

18. **Short Answer** Explain how competition limits a population's growth.

Think Critically

19. **Predict** the shape of a population growth curve for a game park in which a male and female rhinoceros are released.

Use the photo below to answer question 20.

20. **Infer** the reproductive strategy of the animal in the photo. Explain your answer.

21. **Generalize** Opossums are solitary animals that usually meet in nature only to mate. What is their probable dispersion pattern?

22. **Select** from the following list the species that are *r*-strategists: minnow, giraffe, human, beetle, bacteria, eagle, and cougar.

Section 4.2

Vocabulary Review

Using the list of vocabulary words from the Study Guide, identify the term described by the scenario.

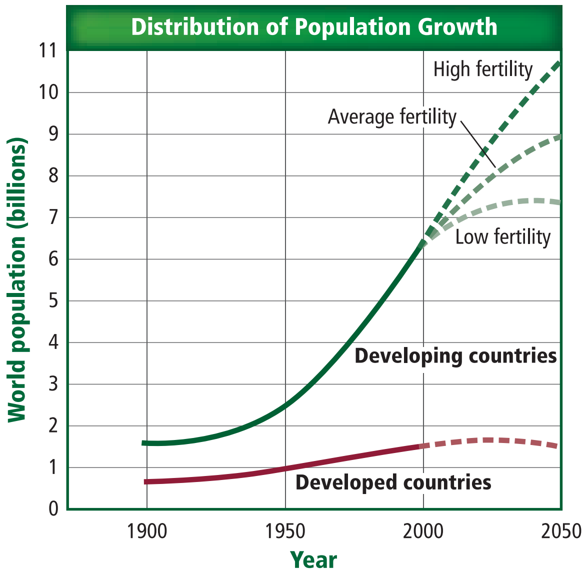
23. A population has an equal number of births and deaths.

24. Twenty percent of a population is in pre-reproductive years, 50 percent is in the reproductive years, and 30 percent is in the post-reproductive years.

25. The size, density, and birth and death rates of a human population are studied.

Understand Key Concepts

Use the graph below of the growth of the human population through history to answer questions 26 and 27.



26. What is the projected population of developed countries by 2050?
    A. 1.5 billion
    B. 7.3 billion
    C. 9 billion
    D. 10.5 billion

27. What is the approximate population difference between developing countries that have low fertility rates and developing countries that have high fertility rates in 2050?
    A. 1.5 billion
    B. 1.7 billion
    C. 3.2 billion
    D. 9 billion

Chapter Test biologygmh.com

28. When did the human population begin to increase exponentially? Use **Figure 4.11** as a reference.
   A. 2 million years ago **C.** 1800 B.C.
   B. 6500 B.C. **D.** 1500 A.D.

29. Asia (excluding China) had a birthrate of 24 and a death rate of eight in 2004. What was the PGR?
   A. 0.16 percent **C.** 16 percent
   B. 1.6 percent **D.** 160 percent

30. Georgia, a country in Western Asia, had a birthrate of 11 and a death rate of 11 in 2004. What was the PGR of Georgia in that year?
   A. 0 percent **C.** 1.1 percent
   B. 0.11 percent **D.** 11 percent

Constructed Response

31. **Open Ended** Do you think the birthrate or the death rate is more important to human populations? Explain your answer.

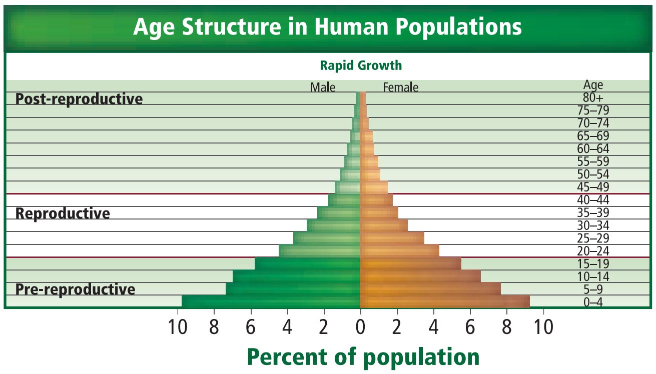
32. **Short Answer** Why won't the population stop growing immediately when ZPG is reached?

33. **Short Answer** Study **Figure 4.11** and identify which phase of growth occurred between the Old Stone Age and the Middle Ages.

Think Critically

34. Hypothesize the shape of the age diagram for Switzerland, a developed country in Europe.

Use the graph below to answer question 35.



35. Describe the advantages and disadvantages of a population that has this type of age structure.

Additional Assessment

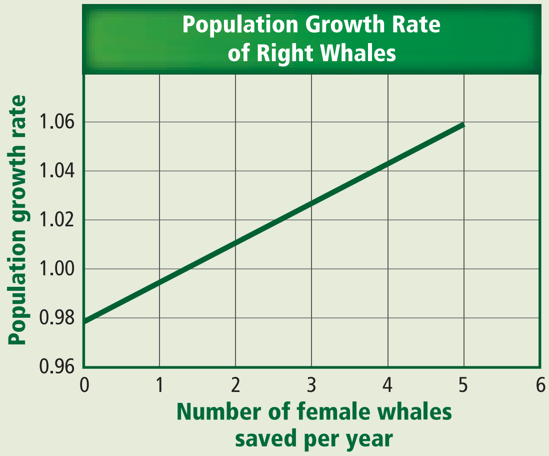
36. **WRITING in Biology** Write a letter to the editor of your student newspaper expressing your views on the effect of human activities on a population of animals in your area.

Document-Based Questions

Northern right whales were once abundant in the northwestern Atlantic Ocean. By 1900, their numbers were almost depleted. Today, there are an estimated 300 individuals remaining.

Use the graph below to answer the following questions.

Data obtained from: Fujiwara, M., et al. 2001. Demography of the endangered North Atlantic right whale. *Nature* 414: 537-540.



37. Predict the population growth rate if six female North Atlantic right whales were saved each year.

38. Saving females isn't the only factor to take into consideration when trying to restore the whale population. Write a hypothetical plan of action that takes into account two other factors that you think might help.

Cumulative Review

39. Predict the probable results to a community if all of the top predators were removed by hunting. **(Chapter 2)**

40. Describe three types of symbiosis. **(Chapter 2)**

Bob Cranston/Animals Animals

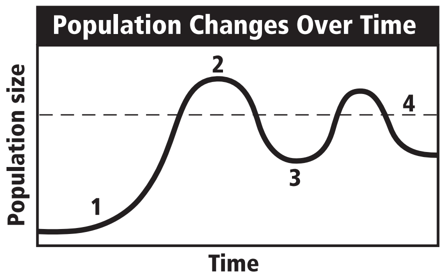
Standards Practice for the EOCT

Cumulative

Multiple Choice

1. Which is the main benefit of scientific debate for scientists?
   - **A.** challenging accepted theories
   - **B.** creating controversy
   - **C.** gaining research funding
   - **D.** publishing results

Use the graph below to answer question 2.



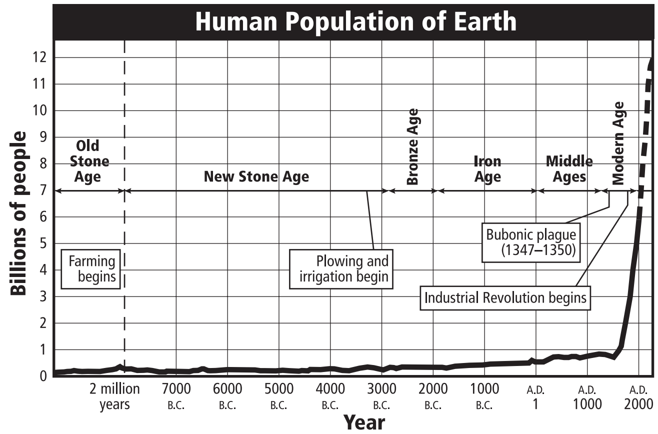
2. Which part of the graph indicates the carrying capacity of the habitat?
   - **A.** 1
   - **B.** 2
   - **C.** 3
   - **D.** 4

3. Which one is likely to be an oligotrophic lake?
   - **A.** a lake formed by a winding river
   - **B.** a lake in the crater of a volcanic mountain
   - **C.** a lake near the mouth of a river
   - **D.** a lake where algae blooms kill the fish

4. Which characteristic of a plant would NOT be studied by biologists?
   - **A.** beauty
   - **B.** chemical processes
   - **C.** growth rate
   - **D.** reproduction

5. Which statement describes the first changes in a forest that would follow a forest fire?
   - **A.** A climax community is established.
   - **B.** New plants grow from seeds that the wind carries to the area.
   - **C.** New soil forms.
   - **D.** Pioneer species are established.

Use this graph to answer question 6.



6. Which event appears to coincide with a gradual increase in human population?
   - **A.** Bubonic plague
   - **B.** farming
   - **C.** Industrial Revolution
   - **D.** plowing and irrigation

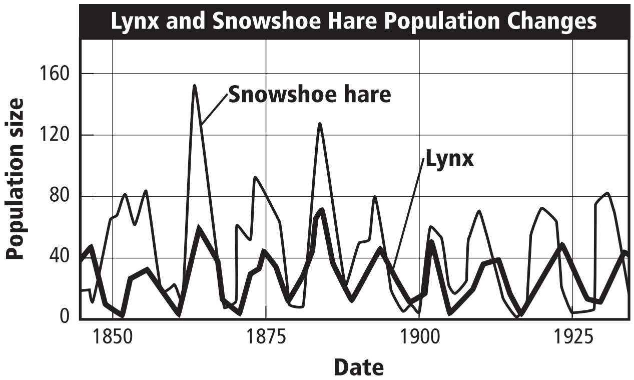
7. Suppose an organism is host to a parasitic tapeworm. Which would be beneficial to the tapeworm?
   - **A.** death of the host from disease caused by the tapeworm
   - **B.** absorbing enough nutrients to sustain the tapeworm without harming the host
   - **C.** treatment of the host with antitapeworm drugs
   - **D.** weakening of the host by the tapeworm

8. Which adaptation would you expect to find in an organism living in an intertidal zone?
   - **A.** ability to live in total darkness
   - **B.** ability to live in very cold water
   - **C.** ability to survive in moving water
   - **D.** ability to survive without water for 24 h

9. Which limiting factor is dependent on the density of the population?
   - **A.** contagious fatal virus
   - **B.** dumping toxic waste in a river
   - **C.** heavy rains and flooding
   - **D.** widespread forest fires

Short Answer

Use this graph to answer questions 10 and 11.



10. Assess what happened to the hare population after a sharp rise in the lynx population.

11. Lynxes hunt hares for food. Predict what would happen to the lynx population if a disease killed all of the hares.

12. Using your knowledge of current events or history, give an example of when ignorance about biology had a harmful effect on people.

13. Compare and contrast how density-dependent and density-independent factors regulate the growth of populations.

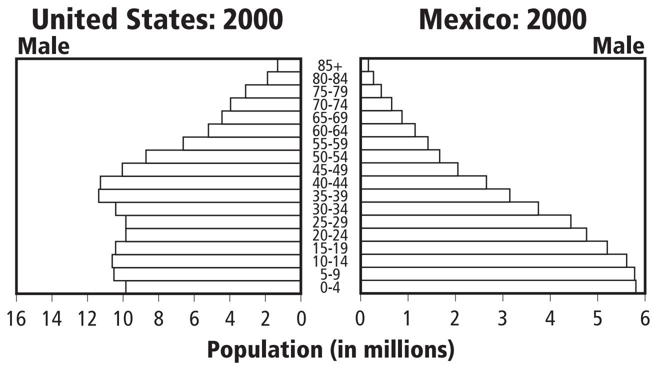
14. Describe what happens to organisms whose optimum temperature zone is between 21°C and 32°C when the temperature rises from 21°C to 50°C.

15. Give some examples of the ways that an environmental factor, such as a forest fire, can affect a population.

16. Explain how a population relates to an ecosystem.

Extended Response

Use these graphs to answer question 17.



17. State what you think is the most significant area of difference between the two populations and justify your reasoning.

18. Many vertebrates that live in temperate forests hibernate in the winter. How do you think this adaptation helps with survival in this biome?

Essay Question

Author Carrie P. Snow once said, "Technology… is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other."
C. P. Snow, New York Times, 15 March 1971

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

19. You are in charge of organizing a debate about whether technology is good or bad. Using your prior knowledge, choose a position and write a summary of the key points you would debate.

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	1.2	4.1	3.2	1.2	3.1	4.2	2.1	3.3	3.1	4.1	4.1	1.1	4.1	3.2	4.1	2.1	4.2	3.2	1.2
Georgia Standards	S7e	S3d	B1d	S3a	B4c	B4a	B4a	B1d	B4a	S3d	B4a	S8e	B4a	B4e	B4a	B4a	B4a	B4f	S6d

B = Biology Content Standard, S = Characteristics of Science Standard