2.3 Populations

Figure D2.17: Many Roman ruins are still standing.

If you were to go back in time and visit Rome 2000 years ago at the height of its empire, you would see a huge, advanced city. As this great capital grew and became the first metropolis to reach a population of one million people, so too did its need for resources. Aqueducts were built to bring in water, land was cleared for farms, culture expanded, and wars were fought elsewhere to gain control of enough food and other resources. For example, the Romans conquered Cleopatra's Egypt because of Egypt's ability to produce large quantities of grain.

However, the size of Rome caused problems: the city experienced overcrowding, there were outbreaks of disease, and huge fires destroyed sections of the city. The ever-growing need to supply water, food, and other resources to support its population stretched Rome's resources. There were repeated invasions and food shortages. Rome was not able to sustain itself as a city. As a result, both the city and its empire shrank in size and power to a population of only 20 000 people as the period of history called The Dark Ages began. Cities would not again reach the size of Rome until the Industrial Revolution of the 1800s, when London's population grew to 1.5 million people.

Continual advances in health technology and improved nutrition mean that people of your generation will—on average—suffer from fewer diseases, grow taller, and live longer than their parents. Technological advances, such as vaccines and pesticides, have enabled the human population to increase in numbers at an enormous pace. Cities of a million or more people are now common on all populated continents.

As the worldwide human population grows, people will soon face even greater problems meeting the demand for resources than the ancient Romans did. What modern examples can you think of where shortages of resources have caused increasing evidence of wars, disease, and famine? Do you think the human population can continue to grow at its current rate without a Roman-like decline?

Utilizing Technology

Graphing Populations

Year	Canada (millions)	Alberta (thousands)
1901	5.4	73
1921	8.8	588
1941	11.5	796
1961	18.2	1332
1981	24.3	2238
2001	30.0	2975

Science Skills

✓ Analyzing and Interpreting

Purpose

You will create line graphs to show how the populations of Alberta and Canada have changed in the past 100 years.

Materials

You may generate the graphs using a pencil and graph paper, a graphing calculator, or a spreadsheet.

Procedure

step 1: Set up the axis of each graph so that Year is on the horizontal axis and Population is on the vertical axis.

step 2: Plot the data and draw best-fit curves.

Analysis

1. A quick glance at the data table might lead you to the mistaken conclusion that the population of Alberta is and was larger than the population of Canada. Identify the source of this error.
2. Describe the trends for overall population for both Alberta and Canada.
3. List similarities between the two population graphs you created. List some differences.
4. Infer some possible reasons for the large increase in the number of births, called the baby boom, in Canada during the period from the mid-1940s to the mid-1960s.
5. Are the growth rates for Alberta's and Canada's populations a cause for concern? Support your answer.

Exponential Growth

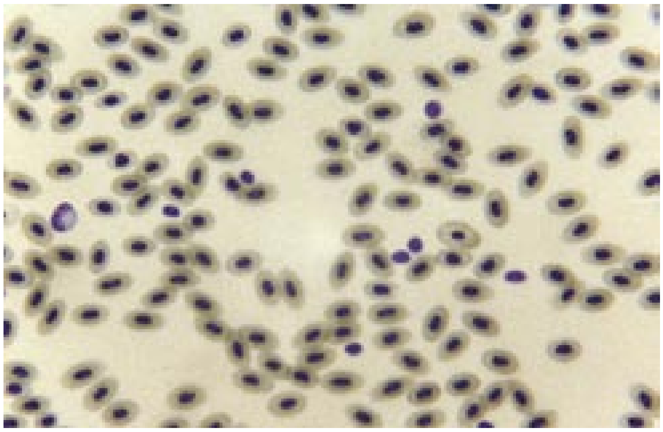


Figure D2.18: Many types of bacteria reproduce rapidly.

Counting the number of individuals is not limited to people living in cities or countries. In biological terms, the total number of a certain species found in an area at a particular time is called a population.

Studying the populations of other organisms can help you understand human population trends. Many types of bacteria reproduce rapidly and, therefore, make good populations to study. Bacteria are simple organisms that reproduce by dividing into two new cells after they have reached a certain size. If you placed one bacterial cell in a test tube with plenty of nutrients, along with ideal temperatures and moisture, the cell would divide and become 2 cells after a certain time. The 2 bacterial cells would soon both divide, giving you a test tube population of 4 cells. Four cells become 8 cells, 8 become 16, 16 become 32, and so on. The amount of time it takes for a population to double is called the **doubling time**. The rapid increase caused by constant doubling—noted with the bacteria population—is called **exponential growth**. You will see why this trend is called a J-curve in Practice questions 7 to 11.

When you graph the data for a population that regularly increases without restriction, the shape of the line is called an **exponential curve** or **J-curve**.

doubling time: the amount of time it takes for a population to double its size

exponential growth: the rapid growth in population caused by a constant increase

exponential curve or **J-curve:** the distinctive shape of the graph for a population that is regularly increasing and growing exponentially

Practice

Use this table to answer questions 7 to 11.

Time (min)	0	20	40	60	80	100	120	140
Number of Bacteria	1	2	4	8				

7. **a.** Copy and complete the table in your notebook.
   b. Use your table to plot the points on a graph with time on the horizontal axis.
   c. Connect the data points on your graph with a smooth curve.
   d. Explain why this graph is called a J-curve.
8. Determine the doubling time for the data in this table.
9. Estimate the number of bacteria in the population after 12 hours.
10. List the factors that would allow the bacteria population to grow exponentially.
11. List factors that would eventually prevent the bacteria population from continuing to grow exponentially.

Factors Affecting Populations

The number of individuals in a population is affected by four major factors: the number of births, the number of deaths, immigration (movement into the population), and emigration (movement out of the population). In a population living in artificial conditions, like a laboratory test tube of bacteria or a fenced game preserve like Elk Island National Park, immigration and emigration do not occur. Only the number of births and deaths affect a population's overall size. A population affected only by the number of births and deaths is called a **closed population**. Closed populations are different from most natural populations, or **open populations**, because open populations can be affected by all four factors.

closed population: a group of organisms that exists in a natural or artificial setting where immigration and emigration do not occur, and numbers are only affected by births and deaths

open population: a group of organisms that exists in a natural setting where births, deaths, immigration, and emigration affect the population numbers

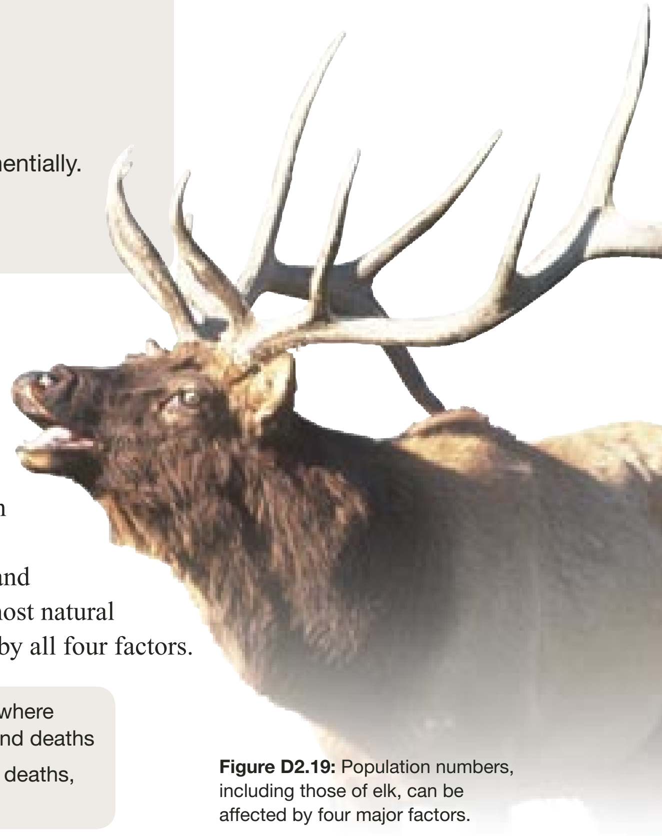


Figure D2.19: Population numbers, including those of elk, can be affected by four major factors.

Practice

12. Describe what effect the following changes would have on the size of an elk population.
    a. The number of births and the number of immigrants into an area are greater than the number of deaths and the number of emigrants out of an area.
    b. The number of deaths and the number of emigrants out of an area are greater than the number of births and the number of immigrants into an area.
    c. The number of births and immigrants are equal to the number of deaths and emigrants.

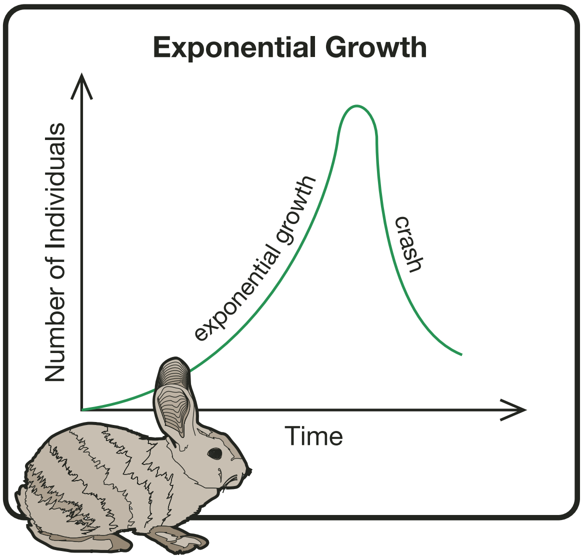
Use the table information to answer questions 13 to 17.

Year	Initial Size	Number of Births	Immigration	Number of Deaths	Emigration
2000	100	15	1	10	1
2001	105	16	1	10	3
2002	109	17	2	11	2

13. Determine whether the data represents an open population or a closed population.
14. Calculate the population change for the year 2000.
15. a. Determine the total number of individuals added to this population in the three-year study.
    b. Use the answer to question 15.a. to calculate the average annual population change for the three years shown in the study.
16. Assuming the average annual population change remains constant, the predicted size of the population in 2010 would be ________________ organisms.
17. Is the growth pattern described in these questions an example of exponential growth?

Population Explosions and Population Crashes

Imagine that two pairs of rabbits are introduced to a small island. The rabbits feed on vegetation, which is also eaten by insects and a few small birds. No predators eat the rabbits. In this situation, the closed rabbit population grows exponentially. Sudden exponential growth is called a population explosion. However, vegetation cannot grow quickly enough to keep up with the amount of grazing from the large rabbit population. The rabbit population overwhelms the island's resources, and the rabbits soon run out of food. The resulting starvation causes the population to drop suddenly and dramatically.



A rapid drop in population size is called a population crash. Caterpillars, rodents, and insects are other organisms whose populations regularly go through explosion and crash cycles of exponential growth followed by a crash in numbers.

In 1859, 24 rabbits from Europe were introduced to Australia. The slow-breeding native marsupials, such as wombats and kangaroos, could not successfully compete for food with the quick-eating rabbits. The non-native rabbits had few natural predators. As a result of these conditions, the rabbit population in Australia increased exponentially. Biologists state that Australia witnessed the fastest colonization by any mammal anywhere in the world. This phenomenon of rabbit growth in Australia was dubbed the *grey blanket*.

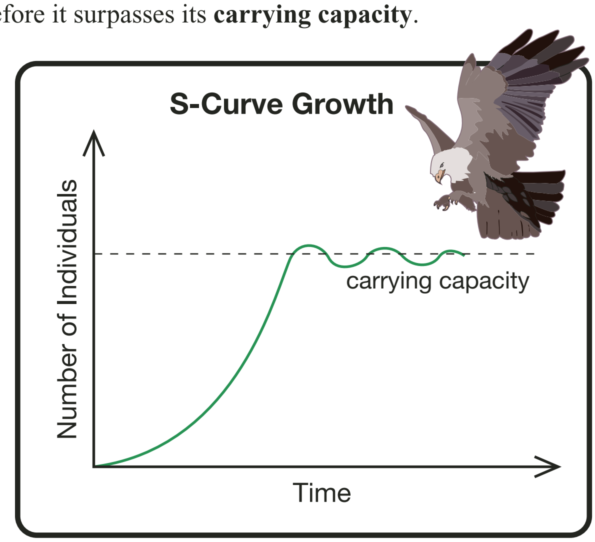
Practice

18. Identify the term for a species that does not normally live in an area but is introduced by human action and expands to become a threat to an area's biodiversity.
19. Provide two possible reasons for the introduction of the rabbit to Australia.
20. Explain why a crash occurred for the imaginary rabbit population on the island but has not occurred in Australia's rabbit population.
21. Predict the environmental and economic effects of a continued increase in the population of rabbits in Australia.
22. One possible solution to the rabbit problem is the introduction of a natural predator, such as the lynx, to control the rabbit population. Evaluate this solution from a variety of perspectives.
23. Describe other methods, apart from the introduction of predator species, that could be used to limit the size of Australia's rabbit population.

Figure D2.20: A closed population of rabbits can grow exponentially until a population crash occurs.

Carrying Capacity

The exponential growth of a population cannot continue forever. For many organisms, factors such as disease, predators, natural disasters, and competition for resources (including light for plants) help limit the size of a population before it surpasses its **carrying capacity**.



Rather than experiencing a population crash and beginning to rise exponentially again, most populations level off at a size that defines the carrying capacity for an ecosystem. The graph of a population being limited by these factors looks like an **S-curve**, rather than a J-curve.

carrying capacity: the maximum number of individuals that can be sustained for an indefinite period in a given ecosystem

S-curve: the distinctive shape of the graph for a population limited by factors such as disease, competition, and famine

Thomas Malthus

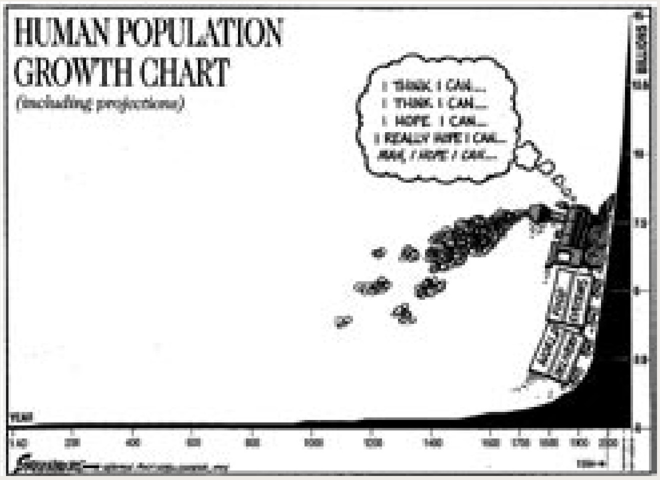
Many of the factors that affected natural populations were identified and described by Thomas Malthus. In 1789, Robert Thomas Malthus published a famous and controversial theory called *Essay on the Principle of Population*. This essay stated that there are natural checks and balances in nature—like famine and diseases—that keep population numbers constant. In unchecked populations, the growth will exceed the amount of food available and a crash in numbers will occur.

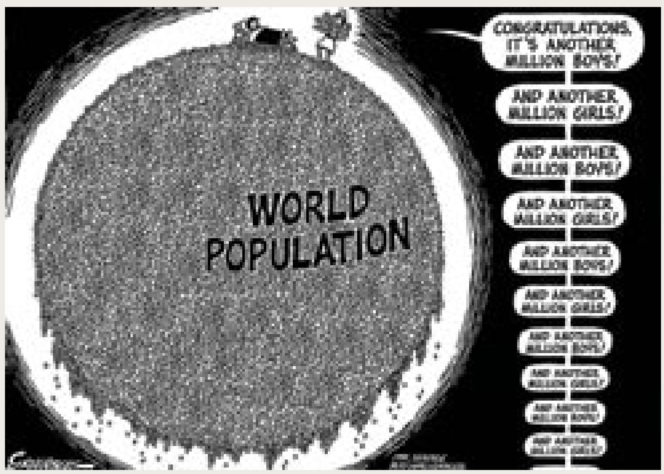
Figure D2.21: Thomas Malthus wrote an essay on the natural checks and balances that keep population numbers constant.

Malthus expressed his concern that while the human population was growing exponentially, the amount of food produced was not. He predicted that shortages of food and resources would cause famine and war. Malthus might be surprised to see that the human population has doubled several times without a drastic crash.

Malthus was not able to account for the impact of science and technology that has enabled greater food production and an increase in the human population's doubling time. Few people predict that the human population will continue to grow in its present pattern, but will Malthus prove to be correct or will people reach a carrying capacity and level off into an S-curve?

Practice





24. Identify the main message the cartoonist is trying to get across in each of these cartoons. In each case, select details from the cartoon to support your assessment.

2.3 Summary

Populations are affected by four major factors: births, deaths, immigration, and emigration. A population affected only by the number of births and the number of deaths is classified as a closed population, whereas a population that also experiences immigration and emigration is considered to be an open population. When organisms are introduced into a new area, their population growth often becomes exponential. This exponential growth—represented graphically as a J-curve—results in either a crash as resources are depleted or a levelling off at the carrying capacity, which is represented graphically as an S-curve. The fact that the human population is growing exponentially is causing concern about the supply of resources.

2.3 Questions

Knowledge

1. Demonstrate the essential features of exponential growth by constructing a simple graph that illustrates its key features.
2. Use examples to distinguish the differences between a closed population and an open population.
3. Sketch and label a graph to illustrate the idea of a population boom followed by a population crash.

Applying Concepts

4. Describe some of the effects on your area's environment caused by the process involved with obtaining and/or using natural resources to produce products for large and growing populations.
5. You buy a sea monkey kit—actually, brine shrimp—and set it up. In a few days, the eggs have hatched and the tank is teeming with at least 50 swimming creatures. You follow the directions and feed them exactly the same amount of food every few days. After a week you have only ten large living sea monkeys and many dead sea monkeys are scattered on the tank's bottom. The next week the population is back up to 70 sea monkeys. A few weeks later there are only about ten adult sea monkeys again. The cycle of population size repeats itself.
   - **a.** Is the population of sea monkeys an example of a closed or an open population?
   - **b.** Use the observations made to estimate the carrying capacity of the tank.
   - **c.** List some of the limiting factors that affect the population of sea monkeys.
   - **d.** Describe a change that could increase the carrying capacity of the sea monkey population.
6. In Chapter 1 you were introduced to some differences between the ecological system and the economic system. Yet another difference concerns ideal patterns of growth. In economic systems, the ideal situation is continual growth—each year production and profits are supposed to increase above previous levels.
   - **a.** How does the ideal model of economic growth in ecological systems differ from the ideal model of population growth?
   - **b.** Explain what eventually happens to populations in ecological systems that attempt a model of continual growth.
   - **c.** Given that the economic system depends upon the ecological system for raw materials and the storage of wastes, is the model of perpetual economic growth sustainable?

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