UNIT A

Sustainable Ecosystems

Northern leopard frogs like this one were once common in lakes and ponds across North America. In North America and around the world, populations of frogs and toads have been decreasing. Scientists view this gradual disappearance as a sign that the ecosystems these creatures are part of are in trouble.

Contents

Unit Task

You will be part of a team that is designing a totally sustainable community to be built in your area. You will look into how resources are currently used in your area and research ways to lessen the impact on your local ecosystems.

Essential Question

How do human activities, both positive and negative, affect the sustainability of ecosystems?

Exploring

Cootes Paradise lies on the edge of the city of Hamilton.

Cootes Paradise

By 1985, almost 85 percent of the wetland's vegetation had disappeared.

The lush green of Cootes Paradise bumps up against the hard edge of the city of Hamilton. Cootes Paradise is a wetland located beside the city of Hamilton. A **wetland** is an area in which the soil is saturated with water for at least part of the year. Wetlands provide a home for many different species of fish, plants, insects, and birds. Many people also use wetlands for camping, fishing, and wildlife viewing.

Pollution and urban development have affected Cootes Paradise, but another factor has taken a toll on the wetland — carp. These fish feed in the shallow waters by pulling up the roots of water plants, damaging the plants and muddying the waters as they go. This makes it difficult for water plants and other fish species to survive. By 1985, almost 85 percent of the wetland's vegetation had disappeared. This was never supposed to happen.

In the 1800s, the federal government stocked the Great Lakes with carp, a fish that is native to Asia. But adult carp have few predators in the Great Lakes, and their populations exploded. As many as 50 000 adult carp used to feed and spawn each year in Cootes Paradise.

Carp like this one invaded Cootes Paradise.

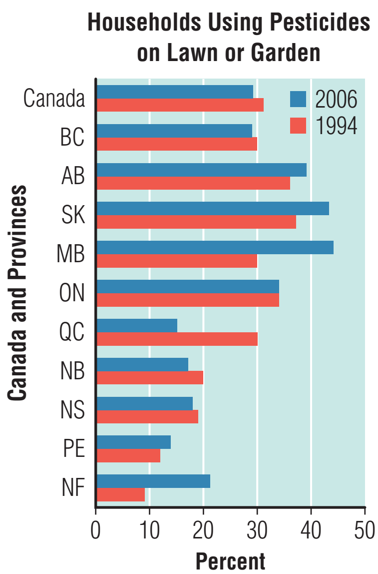
Taking Action

In 1993, the municipal government of Hamilton and the local community joined together to take on the challenge of restoring Cootes Paradise. One of the many things they did was to install a fishway at the entrance to Cootes Paradise. It allows small fish to enter the wetland but prevents large fish from entering. The large fish are then captured and inspected. Wetland fish species are returned to Cootes Paradise, but adult carp are not. The fishway project has been a tremendous success, and wetland plant and fish species are recovering.

The fishway at the mouth of Cootes Paradise

A1 STSE *Science, Technology, Society, and the Environment*

Pesticide Use Across the Country



Pesticide use by Canadian households

Pesticides are substances used to kill pests, such as dandelions or grubs. Some pesticides do not break down quickly, and they may enter local streams and wetlands, killing wild organisms. In response, some communities have banned the use of pesticides on lawns and gardens.

1. Work with a partner to analyze the information about pesticide use contained in the graph. Use the following questions as a guide.

(a) Over what span of time does the graph show pesticide use?

(b) Why does each region show two bars?

(c) Which one of the regions on the graph is the average of all of the other regions?

(d) Which province had the highest pesticide use in 1994? in 2006?

(e) Which province had the lowest pesticide use in 1994? in 2006?

(f) What percentage of households used pesticides in New Brunswick in 1994?

(g) Which province did not change pesticide use over the period of the study?

(h) Did pesticide use in Canada increase or decrease between 1994 and 2006?

2. An important skill is inferring information from a graph. Consider the following questions.

(a) One province put strict limits on pesticide use on lawns after 1994. Infer from the graph which province did this. Be prepared to explain your inference.

(b) In 2006, more pesticide was used in Ontario than in Manitoba, Saskatchewan, and Alberta combined. How is this possible given the data in the graph?

3. Banning pesticides may have benefits. Are there any drawbacks to banning pesticides? Are there any people or organizations that might not welcome a pesticide ban? Explain why.

1 Ecosystems are complex, self-regulating systems of organisms and their abiotic environments.

This woodchuck and the wildflowers are parts of a complex ecological system, a meadow.

Skills You Will Use

In this chapter, you will:

- interpret data from undisturbed and disturbed ecosystems and graph the results, and explain the importance of biodiversity for all sustainable ecosystems

Concepts You Will Learn

In this chapter, you will:

- describe the complementary processes of photosynthesis and cellular respiration with respect to the flow of energy and the cycling of matter within ecosystems, and explain how human activities can disrupt the balance achieved by these processes
- describe the limiting factors and explain how these factors affect the carrying capacity of an ecosystem
- identify Earth's four spheres (biosphere, hydrosphere, lithosphere, and atmosphere), and describe how these spheres interact to maintain sustainability and biodiversity

Why It Is Important

There are many different ecosystems on Earth. If we know how an ecosystem functions as a system, we can analyze how human activities sometimes disrupt ecosystems and make them unsustainable. We can then help to repair or restore ecosystems.

Before Reading

Thinking Literacy

Visualize to Understand

Good readers picture words and whole phrases of text in their minds. Preview the key terms and main subheadings in section 1.1, and use the words or parts of words you know to begin constructing a picture of ecosystems.

Key Terms

• abiotic • atmosphere • biodiversity • biosphere • biotic
• carrying capacity • cellular respiration • energy pyramid
• equilibrium • hydrosphere • limiting factor
• lithosphere • nutrient cycle • photosynthesis
• population

1.1 Ecosystems

Here is a summary of what you will learn in this section:

- Systems have components that interact.
- Ecosystems are systems with abiotic and biotic components that interact.
- Ecosystems combine to form biomes, and the biosphere contains all the biomes on Earth.
- The biosphere is composed of the atmosphere, the lithosphere, and the hydrosphere.

Figure 1.1 A view of Earth from space

Planet Earth

High above the planet, the International Space Station offers a breathtaking view of Earth (Figure 1.1). Canadian astronaut Dave Williams has been privileged to see that view first-hand. After returning to Earth, he had this to say about his experience:

> "I am truly in awe of the beauty of the planet, and it's something I've been able to experience in so many different environments, whether in space, underwater, camping, hiking, climbing mountains, or whatever. For me, it generates a sense of planetary stewardship."

Stewardship is a way of acting that involves taking personal responsibility for the management and care of something. Planetary stewardship means working to take care of the whole world. A more common term for this is environmental stewardship. The **environment** is all the living and non-living things that exist on Earth as well as their interactions with each other. The beautiful blue sphere that astronauts have photographed from space helps us to remember that the resources in our environment are limited. All life depends on what is contained on that sphere. While the view from space is new to us, the idea of the importance of environmental stewardship is far from new.

Many cultures, especially those with a history of living close to the land, hold a deep respect for the natural world. For example, Cree and other First Nations teach that the members of each generation must be careful stewards of the Earth to ensure the survival of at least the next seven generations. For this to be possible, the natural environment must be used in a sustainable way. **Sustainability** in the environment means that populations of plants, animals, and other living organisms can continue to interact and to reproduce indefinitely. It also means that biodiversity is preserved. **Biodiversity** is the number of different types of organisms in an area. The more types of organisms there are in an area, the more biodiversity the area has. High levels of biodiversity are associated with a healthy, sustainable environment.

WORDS MATTER

"Bio-" is a prefix derived from the Greek word *bios*, which means life.

A2 Quick Lab

Representing Earth's Biodiversity

There are many different types of organisms on Earth. To study Earth's biodiversity, similar species are placed into categories. For example, foxes, bears, and mice can be grouped under "mammals." In this activity, you will make a visual representation of the 14 categories of organisms shown in Table 1.1.

Table 1.1 Earth's Biodiversity

Category	Number of Species
Mammals (e.g., deer)	4 500
Reptiles and amphibians (e.g., snake, frog)	10 500
Fish (e.g., trout)	22 000
Crustaceans (e.g., shrimp)	40 000
Molluscs (e.g., clam)	70 000
Sponges (e.g., glass sponge)	10 000
Birds (e.g., crow)	10 000
Insects (e.g., fly)	963 000
Arachnids (e.g., spider)	75 000
Plants (e.g., cherry tree)	270 000
Fungi and lichens (e.g., mushroom)	100 000

Purpose

To visually represent the numbers of each group of organisms living on Earth

Procedure

1. Work with a partner to brainstorm a method of representing the numbers of each type of organism in a visual way. It may be a two-dimensional representation such as a graph, or a three-dimensional model.
2. Once you have decided on a method, check with your teacher, and then create your representation.

Questions

3. Look for and try to explain any relationship you can find between the numbers of species in a group and the type of organisms that are in that group.
4. Compare your representation with that of other students in your class. Which features of each model did you like best, and which could be improved?
5. How could you improve your representation?

Systems in the Environment

Imagine a wild bee moving from flower to flower on a spring day. The bee busily visits many flowers, then, suddenly, it darts back to its hive (Figure 1.2). There, it unloads the tiny drop of nectar that it has gathered on its journey. This activity seems very straightforward: the bee is simply collecting food for itself and its hive.

Figure 1.2 Bees visit flowers to collect nectar, which they convert into honey at the hive.

However, there is something more to this interaction between the bee and the flower. Producing flowers and nectar takes a lot of energy and resources. Yet flowering plants produce vast numbers of colourful and fragrant flowers, each stocked with nectar to attract bees and other animals.

The answer is that pollinators such as bees help plants to reproduce. In order to produce seeds, most flowers need to be fertilized with pollen from another plant. The plants cannot move to get the pollen. That is where bees and other pollinators come in. When a bee visits a flower to get nectar, pollen sticks to its fuzzy coat. When it visits another flower, the pollen on its coat fertilizes the flower. Once fertilized, the flower can produce seeds, which will eventually grow into the next generation of plants.

During Reading — Thinking Literacy

Little Pictures Lead to the Big Picture

The story of the bee helps you to understand the larger picture of how organisms interact within a system. Draw and label a picture in your mind as you read about the bee, the hive, and flowering plants. How does this picture help you to understand the concept of ecological systems?

Systems Have Components and Interactions

A bee fertilizing a flower is an example of an interaction between different organisms. Such interactions are not always positive. If you have ever been stung by a bee, then you know that the interaction between you and the bee is painful. The bee also dies once it has stung you. It may seem that you and the bee both lose in this interaction, but this is not necessarily the case. The bee may have successfully defended its hive by encouraging you to move away from the area. You may even have benefitted if the sting prevented you from accidentally walking right into the hive, risking hundreds more stings.

A **system** is a group of individual parts that interact as a whole to accomplish a task. The parts of a system are called **components**. For example, a bicycle is a mechanical system (Figure 1.3). All of the components of a bicycle interact to do something that none of the parts can do alone, which is to move the rider along a road.

Figure 1.3 The wheels, chain, pedals, and the rider interact to perform a task: movement.

Systems exist in the natural world as well. Returning to the bee example, think of all the interactions that happen in the life of a worker bee. The worker supports the hive by building it, bringing in nectar, or defending the entrances to the hive. These interactions give the drones, the male bees, a place to live until the queen bee needs to mate with them. The queen bee's role is to produce eggs. Each bee is driven by instinct to perform various tasks. The result of all the individual bees' interactions is a complex and self-sustaining system: the hive.

A Holistic Approach

Although ecologists have to identify the components of ecological systems, such as water temperature and the number of fish, they also have to take a holistic approach as well. In a **holistic approach**, the entire system is emphasized. If you took a bicycle apart and just looked at all the pieces, you could know everything about all the parts and yet still not know that a bicycle's function is to move a rider along a road (Figure 1.4). This is because "riding" is not something that has meaning to any of the individual parts. It has meaning only when the system — all the bicycle parts, including the rider — is considered as a whole. The same is true in the study of the environment.

Figure 1.4 The individual parts of a bicycle give you no clue about how they work as a whole.

Many Aboriginal ways of knowing have long taught the importance of a holistic approach to the environment. Many Aboriginal people believe that everything is connected through interactions. They also take the view that we are all part of the environment that we live in. These beliefs result in a deep respect for Earth.

Figure 1.5 The more components a system has, the more complex the system becomes. A coral reef is a very complex system.

Traditional ways of living require that everything in nature, from water to organisms, be treated with respect and used wisely.

Ecological Systems Are Complex

Ecology is the study of how organisms interact with each other as well as with their environment. A person who studies ecology is called an ecologist.

Consider, for example, how an ecologist might study a coral reef. Coral reefs are one of the world's most important and sensitive ecological systems (Figure 1.5). An ecologist might want to find out such things as which kinds of fish live there permanently, and which stay for short periods and then leave. They might also study the physical parts of the system, such as the amount of salt dissolved in the water or the water temperature, and how they affect reef organisms.

Currently, ecologists are examining how reefs respond to rising water temperatures. Early results suggest that warmer water can be very harmful to a reef. It is often impossible to predict what will happen when one component changes because the components of the system are so interconnected. A coral reef has a large number of components and an even larger number of interactions. Most ecological systems are similarly complex.

Learning Checkpoint

1. Explain what is meant by each of the following terms.
   (a) stewardship
   (b) environment
   (c) sustainability
   (d) biodiversity
2. List three possible interactions between a bee and its environment.
3. What is meant by the term "system"? How are a bicycle and a rider a kind of system?
4. Ecology can be described as a holistic science. Explain why this is the case.

Elements of Ecosystems

An **ecosystem** is a complex, self-regulating system in which living things interact with each other and with non-living things. Self-regulating means that the interactions keep the ecosystem healthy and sustainable.

In order to analyze how ecosystems function, ecologists classify all parts, or factors, of ecosystems as either biotic or abiotic. **Biotic** factors are organisms, such as animals, plants, fungi, bacteria, and algae. **Abiotic** factors are everything else (Figure 1.6). Abiotic factors can be physical things, such as rocks, air, and water. Abiotic factors can also be things that are measured, such as air temperature, hours of daylight, and salt concentration in seawater. It is the interactions of the biotic and abiotic elements that help keep the ecosystem self-regulating.

Figure 1.6 The abiotic components in this pond ecosystem include water, air, and dead branches. The biotic components include reeds, bushes, and the duck.

Ecosystems Have Communities

A **species** is a group of similar organisms in an ecosystem. Members of a species can reproduce with each other, and their offspring can reproduce. For example, the grey squirrel is widespread throughout Ontario (Figure 1.7 (a)). All grey squirrels are members of the same species. They can reproduce with each other but not with red squirrels, which also live in Ontario. A **population** is a group of members of the same species that live in the same area (Figure 1.7 (b)). The physical environment of an organism is its **habitat**.

Suggested Activity •
A3 Quick Lab on page 20

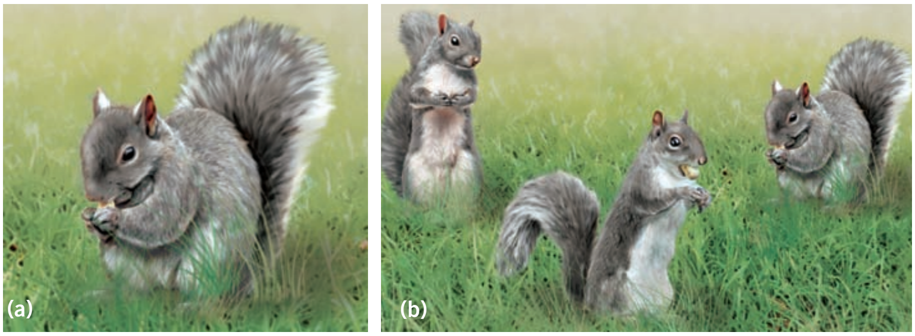


Figure 1.7 (a) A single grey squirrel is a member of the grey squirrel species. (b) A group of grey squirrels living in the same area form a population.

All grey squirrels are part of the same species, but they are not all part of the same population. For example, one group of grey squirrels might live in a pine forest, while another might live in a park in the next valley over. These two groups of squirrels are two different populations.

A **community** is made up of populations of different species that live and interact in an area. For example, a park contains populations of squirrels, robins, trees, and shrubs (Figure 1.8). The interactions of the populations with each other and with the local abiotic factors make up the ecosystem.

All the interactions of a given species with its ecosystem form the species' **niche**. For example, the niche of grey squirrels

Figure 1.8 Populations of different species living in the same area form a community.

includes eating nuts and other seeds, being hunted by foxes and owls, being active during the day, and living and nesting in trees.

Ecosystems Come in All Sizes

Ecosystems vary widely in size. They can be as tiny as a drop of water or as large as a desert or an entire ocean. The size of an ecosystem is not the most important thing about it. What really matters for it to be sustainable is that it is a complete system.

Consider a single drop of water resting on the needle of a fir tree (Figure 1.9). This drop contains millions of tiny organisms, such as bacteria and microscopic algae. These are the biotic components of the ecosystem. The drop contains matter that the bacteria absorb to help them live. The drop also receives sunlight, which is a source of energy that makes it possible for the bacteria to use the matter and to grow. Matter and sunlight are some of the abiotic components of the ecosystem. Even as new bacteria are produced, others die. The matter in the dead bacteria can be recycled. The recycled matter then provides nourishment for the living bacteria.

There can be many interactions between biotic components in the drop. For example, there are probably many different kinds of bacteria in the drop, and they often compete with each other for resources. Some bacteria may eat other bacteria. Other types of bacteria may group together under difficult conditions, such as when the water drop dries out between rainfalls.

Figure 1.9 If the bacteria in the drop of water interact with the water, light, and other abiotic factors, the drop is an ecosystem, even though it may be temporary.

Ecosystems Combine to Make Biomes

Ecosystems can exist within larger ecosystems. For example, a stream is composed of fresh water, rocks, crayfish, fish, and various types of plants. All these abiotic and biotic factors interact as a unit. Suppose, however, that this stream runs through a forest (Figure 1.10). Animals that live in the forest drink and catch fish from the stream, and certain trees, such as cedars, grow along the banks of the stream. Because the forest plants and animals interact with the stream ecosystem, the stream is also part of the forest ecosystem. A single rotting log on

Figure 1.10 This forest ecosystem contains a stream ecosystem and many other smaller ecosystems.

the forest floor is an ecosystem as well because the organisms that live in or on the log interact with one another and with the non-living log. It too is part of the forest ecosystem.

All these ecosystems are interconnected. The forest ecosystem is part of a larger region that contains many similar forests. Similarly, the small stream feeds into a larger river, which is another ecosystem. The river eventually feeds into an ocean, which contains many more ecosystems.

A **biome** is a large geographical region that contains similar ecosystems. On land, biomes are defined by the types of plants that grow in them. They are also classified according to the average temperature and the amount of rainfall. Because the ecosystems in a biome usually have similar plants, animals, and weather and

Figure 1.11 Canadian terrestrial biomes include (a) deciduous forest, (b) boreal forest, (c) tundra, (d) grassland, and (e) temperate coniferous forest. Abiotic factors, such as the amount of rainfall and the average temperature, determine what types of vegetation exist in each biome.

receive similar amounts of precipitation, it can be very helpful in the study of an ecosystem to know which biome it is in. Biomes are often divided into those on land and those in water. Throughout the world there are many types of biomes. In Canada, there are five major land, or **terrestrial**, biomes (Figure 1.11).

Terrestrial Biomes

Canada's five main terrestrial biomes are defined by their dominant vegetation.

- **Deciduous forests** have trees that lose their leaves in the autumn, such as maples and oaks. Southern Ontario is mainly a deciduous forest biome.
- **Boreal forests** (also known as taiga) have trees that have cones and needles, such as spruce and fir. Most of northern Ontario is covered with boreal forests.
- **Tundra** has no trees, only small shrubs, hardy grasses, mosses, and lichens. Even some flowers such as crocuses grow here. Ontario's northern coastline on Hudson Bay, to the west of James Bay, is tundra.
- **Grasslands** have few trees but are covered in various kinds of grasses and shrubs. Ontario has very few grasslands. They are found in Manitoba, Saskatchewan, and a small part of Alberta.
- **Temperate coniferous forests** have different types of needle- and cone-bearing trees than the boreal forest: Douglas fir, Sitka spruce, and western hemlock. Most of western British Columbia is temperate coniferous forest.

Aquatic Biomes

Water-based, or **aquatic**, biomes fall under two main categories: marine and freshwater (Figure 1.12). The water in **marine biomes** has a high salt content, and the water in **freshwater biomes** has a very low salt content.

- Marine biomes are found in the oceans. Coral reefs, the ocean floor, the open ocean, and the intertidal zones are marine biomes. Ontario has marine biomes along Hudson Bay and James Bay.
- Freshwater biomes include lakes, streams, rivers, and wetlands. Some of Ontario's lakes and rivers are huge, such as the Great Lakes and the St. Lawrence River. Ontario has countless smaller lakes, streams, and wetlands.

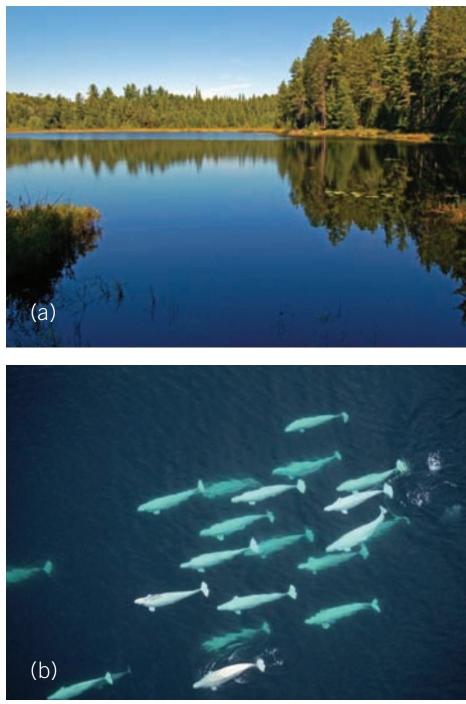


Figure 1.12 Two aquatic biomes. (a) A lake is a freshwater biome. (b) The open ocean of Hudson Bay is a marine biome.

Biomes Combine to Make the Biosphere

This section began with a view of Earth from space. With the whole planet in view, the idea of promoting stewardship and sustainability becomes urgent because we can see that the resources of Earth are limited. We also now know that Earth's biotic and abiotic factors interact in ecosystems. Ecosystems can be large or small, and they overlap and interconnect.

The very largest of these ecosystems, the biomes, combine to make a planetary system. It is the most important system on Earth, and it is our home. It is called the biosphere (Figure 1.13).

The **biosphere** is the part of the planet, including water, land, and air, where life exists. It is very thin relative to the whole Earth. If Earth were represented by a beach ball, the biosphere could be represented by a sheet of plastic wrap laid over its surface one layer thick. Three main interacting components make up the physical environment of the biosphere. They are the atmosphere, the lithosphere, and the hydrosphere (Figure 1.14).

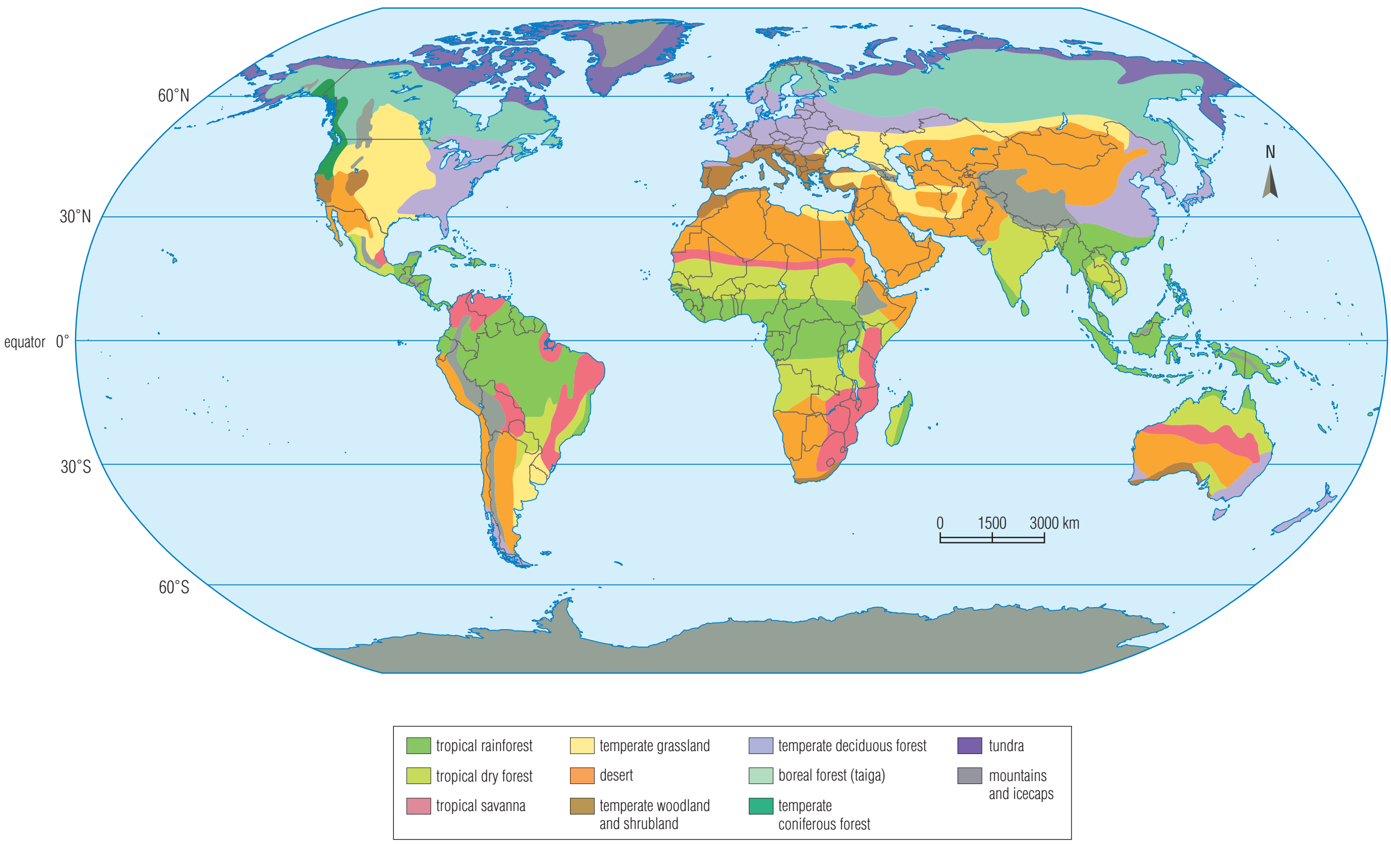


Figure 1.13 Earth's major terrestrial biomes. These biomes, plus the ocean biomes, contain all life on Earth. The biosphere is the part of Earth that contains all the world's biomes.

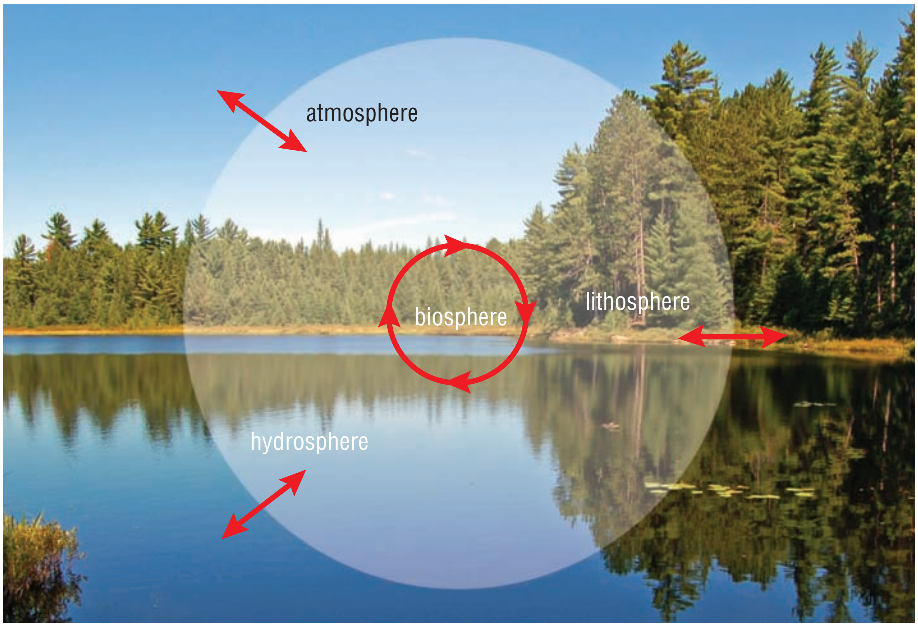


Figure 1.14 The biosphere is composed of all living things on Earth and the physical environment that surrounds them.

- The **atmosphere** is the layer of gases that surrounds Earth. Water vapour and carbon dioxide in the atmosphere absorb sunlight and retain the Sun's energy as heat, warming the planet to temperatures suitable for life. The lower atmosphere contains oxygen, which many organisms need to survive, while the upper atmosphere contains a different form of oxygen called ozone. Ozone protects organisms in the biosphere from the Sun's harmful ultraviolet radiation.
- The **lithosphere** is Earth's solid, outer layer. It includes the rigid crust and the upper mantle, which lies directly below the crust. The lithosphere extends 100 km down from the surface and runs under the continents and oceans. It includes the soil, which is home to many micro-organisms, plants, animals, and fungi.
- The **hydrosphere** is all the water on Earth. About 97 percent of this water is salt water in Earth's oceans. The other 3 percent is fresh water and includes water in lakes and streams and the ice and snow in glaciers. All living organisms need water, and so they depend on the hydrosphere.

Take It **Further**

Around the world there are several other major types of terrestrial biomes, including more forest biomes. Find out more about the world's biomes. Begin your research at ***ScienceSource***.

A3 *Quick Lab*

Natural Versus Artificial

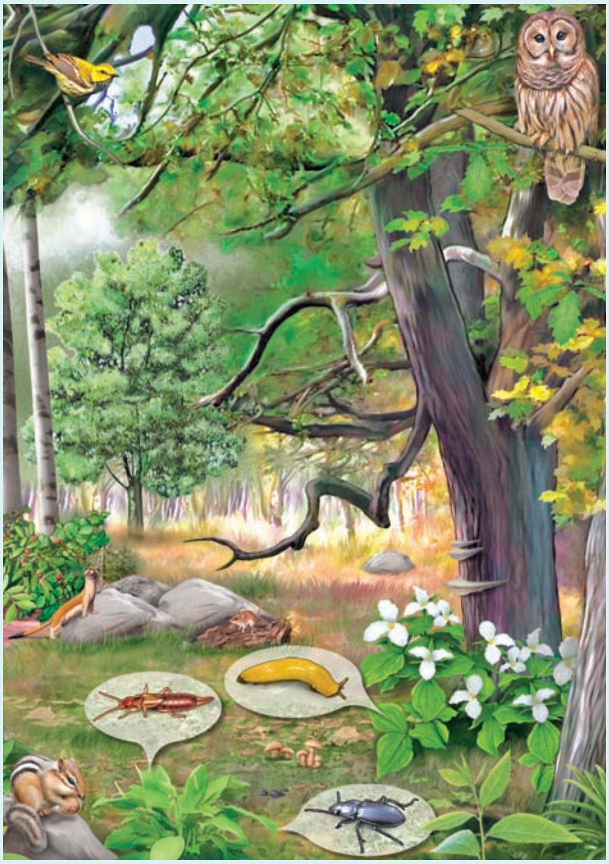


Figure 1.15 A forest

Figure 1.16 A flower garden

A forest and a flower garden are located in the same area. One is a natural ecosystem, and the other is an artificial ecosystem.

Purpose

To determine the differences between artificial and natural ecosystems

Procedure

1. Create a tally chart like the one in Figure 1.17.

Forest	Garden

Figure 1.17

2. Examine the forest ecosystem in Figure 1.15. For each species you find, put a tally mark in the tally chart.
3. Repeat step 2 for the garden ecosystem in Figure 1.16.
4. Create a bar graph that shows both the garden's and the forest's biodiversity.

Questions

5. Which ecosystem has more biodiversity? How do you know?
6. What things do you think humans do in the flower garden to alter the abiotic elements of the ecosystem? What effects do these actions have, if any, on biodiversity?
7. What things do humans do in the flower garden that alter the biotic elements of the ecosystem? What effects do they have on biodiversity?

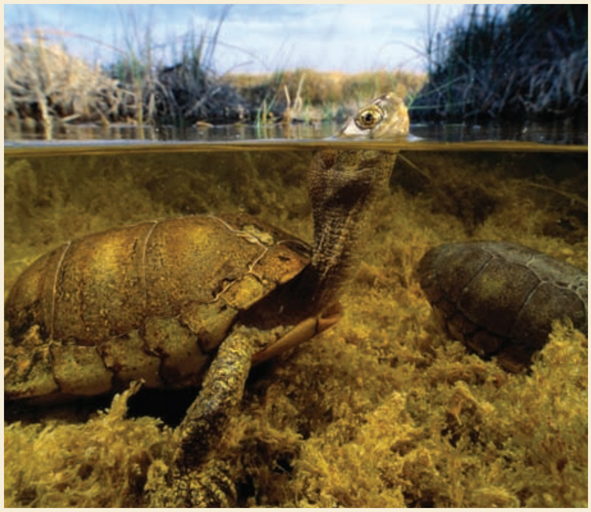
1.1 CHECK and REFLECT

Key Concept Review

1. What is an ecosystem?
2. What is biodiversity a measure of?
3. What are the characteristics of a sustainable ecosystem?
4. Do biomes contain ecosystems, or do ecosystems contain biomes? Explain your answer.
5. What is ecology?
6. What is the difference between a biotic and an abiotic component of an ecosystem?
7. How do marine biomes differ from freshwater biomes?
8. Explain what a population is.
9. What are the three components that support the biosphere?

Connect Your Understanding

10. You interact with abiotic and biotic parts of your environment every day.
    (a) List five abiotic factors in your environment.
    (b) List five biotic factors in your environment.
11. What abiotic factors may affect the growth of an oak tree in an Ontario forest?
12. If you travelled north from southern Ontario to the Arctic, you would pass through several biomes. How would the vegetation change during this trip?
13. A stream is an aquatic ecosystem, but it can also be part of a forest ecosystem at the same time. Explain how this is possible.
14. Our planet has been referred to as Spaceship Earth. Explain how this might be an effective way to describe our planet.
15. Examine the ecosystem in the photograph below.
    (a) Identify three abiotic factors that are part of this ecosystem.
    (b) Identify three biotic factors that are a part of the ecosystem.



Question 15

16. An analogy is a comparison between two different things that are alike in some ways, but different in others. In this section, a bicycle was an analogy used to identify some of the characteristics of an ecosystem. Create another analogy that shows some of the characteristics of an ecosystem.
17. Ecologists must understand the components that make up an ecosystem. Ecologists have to take a holistic view. Explain how both of these statements are true.

Reflection

18. Describe three things you did not know about ecosystems before you started working on this chapter.

For more questions, go to ***ScienceSource***.

1.2 Nutrient Cycles and Energy Flow

Here is a summary of what you will learn in this section:

- Nutrients move through ecosystems in cycles.
- Energy enters ecosystems through photosynthesis, is transferred through cellular respiration, and is eventually lost as heat.
- Producers, consumers, and decomposers are related through food webs and energy pyramids.

Figure 1.18 The wildebeests are wary of the dangers hidden in the water.

A Great Migration

At the end of each summer in Tanzania, Africa, a great migration begins. Over 1 million wildebeests move across the Serengeti Plain in search of food. They move north to Kenya, where rains have watered the plain and lush grasses have emerged from the moist soil. The wildebeests' need for food is so strong that they risk their lives to swim across rivers to get to greener pastures (Figure 1.18). Drowning is not the only danger. The wildebeests also risk being eaten by crocodiles (Figure 1.19).

Figure 1.19 Crocodiles remain under the surface of the cloudy water and ambush wildebeests that enter the water.

All organisms need food to survive. Animals must eat other organisms to survive. The wildebeests eat grasses, and the crocodiles eat some of the wildebeests. Grass and wildebeests are examples of food. Food contains **nutrients**. Nutrients are substances that an organism uses to build and repair the cells of its body. Plants generally draw nutrients up from the soil and extract them from the air. They use sunlight and nutrients to make their own food. In addition to nutrients, food contains energy, which all organisms need to grow and maintain their bodies and to reproduce.

When a crocodile eats a wildebeest, some of the matter in the wildebeest becomes part of the crocodile. When the crocodile dies, some of its body ends up becoming part of the soil. Since grasses get some of their nutrients from the soil, the matter has come full circle. However, energy usually enters the ecosystem as sunlight and leaves it as heat. It is not recycled.

A4 Quick Lab

Finding the Relationships Among Organisms

Purpose

To determine the relationships among organisms

Procedure

1. Study the organisms shown in Figure 1.20. Create a mind map to show how these organisms relate to one another. Once you have finished, share your map with a partner and explain why you made the connections you did.

Questions

2. Which organisms have the most connections in your mind map?
3. A photo of one very important component is missing. Can you figure out what it is?
4. Remove one of the organisms from your mind map. Describe the ways this would affect the community of organisms.

Figure 1.20

Table 1.2 Examples of Nutrients

Nutrient	Examples
carbohydrate	bread, rice, sugar
fats and oils	butter, corn oil
protein	beans, chicken
vitamins	vitamin C, vitamin D
minerals	calcium, potassium

Figure 1.21 The sugar that makes an orange sweet is a carbohydrate.

Suggested Activity •

A5 Quick Lab on page 33

Nutrient Cycles

The nutrients in the food you eat provide energy and matter that your body needs to stay alive. Every living organism needs nutrients to carry out life functions. Nutrients include carbohydrates, fats and oils, proteins, vitamins, and minerals (Table 1.2).

Nutrients are made up of **elements**, which are pure substances that cannot be broken down into simpler substances. For example, sugar, a carbohydrate, is made from the elements carbon, oxygen, and hydrogen (Figure 1.21). Water is made from the elements oxygen and hydrogen. The element nitrogen is a part of proteins. In fact, 95 percent of our bodies are made up of just four elements: carbon, oxygen, hydrogen, and nitrogen.

Humans and other animals obtain the carbon, hydrogen, oxygen, and nitrogen they need from eating carbohydrates, fats, and proteins. Plants obtain them by absorbing carbon dioxide from the air and water and substances called nitrates from the soil.

Nutrients cycle back and forth between the biotic parts of ecosystems (organisms) and the abiotic parts of ecosystems. The process of moving a nutrient back and forth is called a **nutrient cycle**. For example, carbon dioxide is exhaled by a wildebeest. The carbon contained in the carbon dioxide is now in the atmosphere, an abiotic part of the ecosystem. The carbon dioxide is then absorbed by a grass plant, and the carbon particle it contains becomes part of a carbohydrate in the grass's cells. The carbon is now once again in the biotic part of the ecosystem.

Sometimes matter can cycle back and forth between the biotic and abiotic parts of an ecosystem fairly quickly. Sometimes matter can remain in one place for a long time. For example, the ice in glaciers has been there for thousands of years. Any place where matter accumulates is called a **reservoir**. The cycles that water, carbon, and nitrogen follow all have reservoirs.

The Water Cycle

Water is a substance that moves in a cycle. A cycle has no beginning or end. In the water cycle, water is moved throughout the whole biosphere. The Sun's heat warms the surface water, and the water evaporates into the atmosphere (Figure 1.22). In the atmosphere, the water exists as a gas, called water vapour.

As the water vapour cools, it condenses to form clouds. From there, it may fall to Earth as rain, hail, snow, or sleet. If it falls to the ground, it will tend to run off the surface into nearby streams or rivers. This water is called **run-off**. Some water seeps down through the soil into the ground water. Some ground water may flow into large underground lakes, known as **aquifers**, while some may flow into other bodies of water such as wetlands or oceans.

Some of the water on the surface or in the soil is taken up by animals and plants. Plants play a major role in the water cycle through a process known as transpiration. Transpiration occurs when plants release water vapour into the atmosphere through their leaves. The water vapour rises into the atmosphere, and the cycle continues.

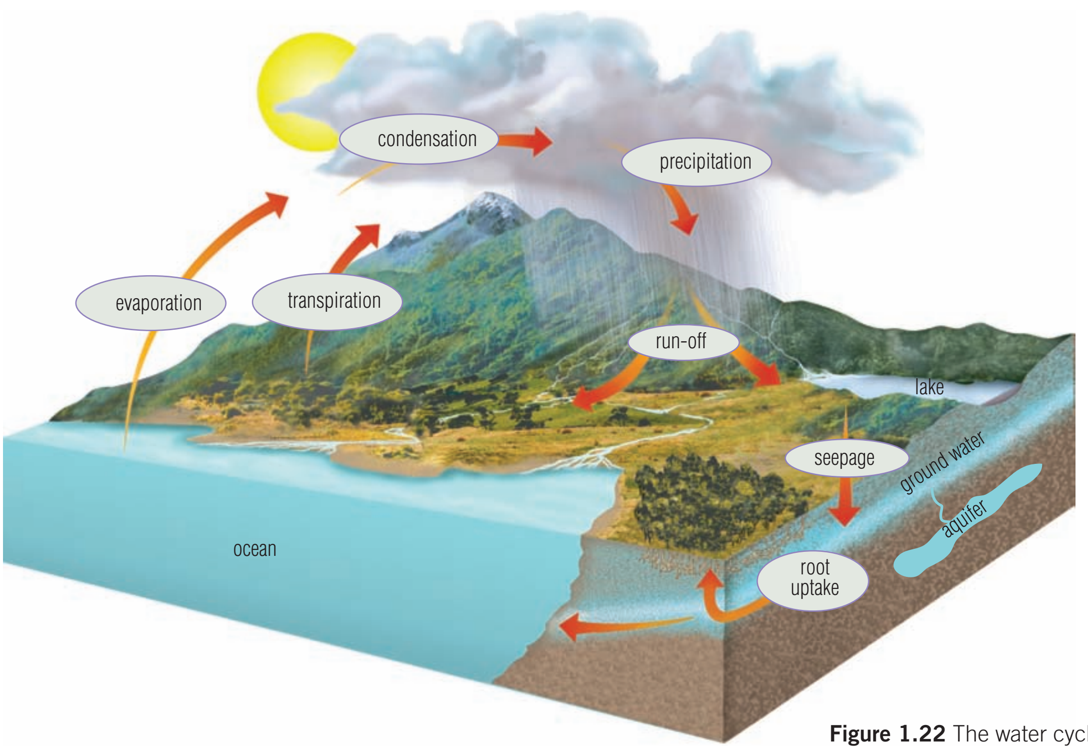


Figure 1.22 The water cycle

The Nitrogen Cycle

All organisms need nitrogen to make proteins. Nitrogen also moves in a cycle. Nitrogen gas makes up 78 percent of the atmosphere, but it cannot be used directly by most organisms. They get their nitrogen from substances such as ammonia that contain nitrogen. Converting nitrogen gas into ammonia is called **nitrogen fixation**. **Nitrogen-fixing bacteria** perform this critical step. Without these bacteria, movement of nitrogen would stop almost completely. Lightning is the only other natural nitrogen-fixing process. It accounts for only about 1 percent of the world's nitrogen fixation.

Plants called legumes (peas, beans, and alfalfa) have nodules on their roots that contain nitrogen-fixing bacteria. The bacteria supply usable nitrogen directly to the plant. Nitrogen-fixing bacteria also live freely in the soil and water (Figure 1.23). Most plants cannot use the ammonia these bacteria produce. **Nitrifying bacteria** convert ammonia into nitrites and then nitrates, which plants absorb through their roots.

Animals get the nitrogen they need by eating plants or animals. When animals digest proteins, a by-product is ammonia. Ammonia is toxic to animals, and they get rid of it in their wastes. Bacteria and fungi in the soil break down the ammonia in wastes and dead organisms into nitrates and nitrites and release them into the soil where they can be absorbed by plants. **Denitrifying bacteria** in the soil convert nitrates back into nitrogen gas, which returns to the atmosphere.

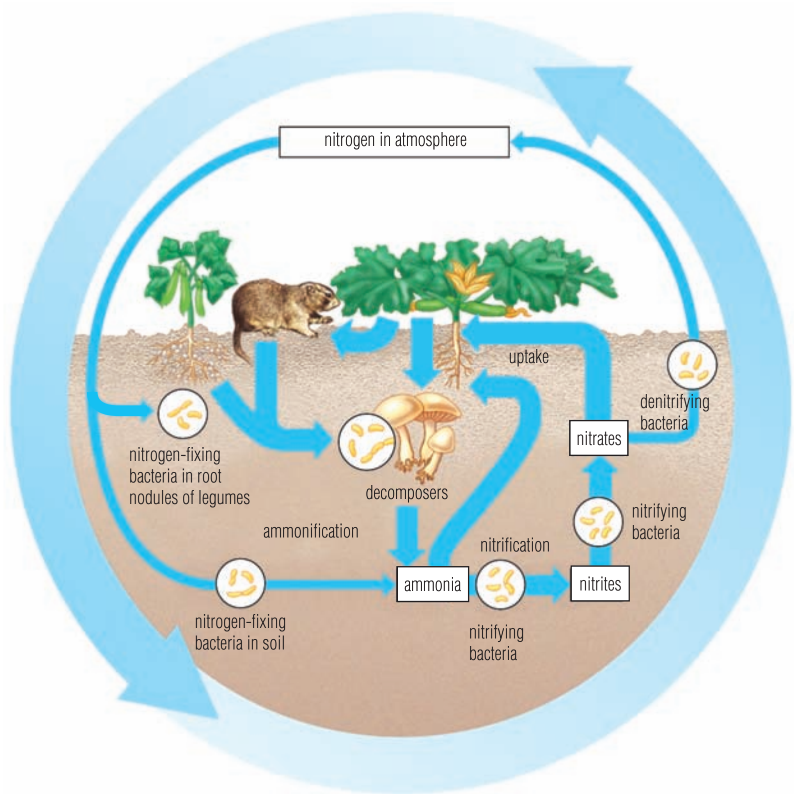


Figure 1.23 The nitrogen cycle

The Carbon Cycle

All living things contain carbon. Carbon dioxide gas contains carbon. Although carbon dioxide makes up only 0.04 percent of the gases in the atmosphere, it is from this that all plants get the carbon they need to grow. For example, a tall oak tree is both massive and solid. A large portion of the matter in the tree is made of carbon, and all of the carbon came from the atmosphere. The world's forests are biotic reservoirs of carbon (Figure 1.24).

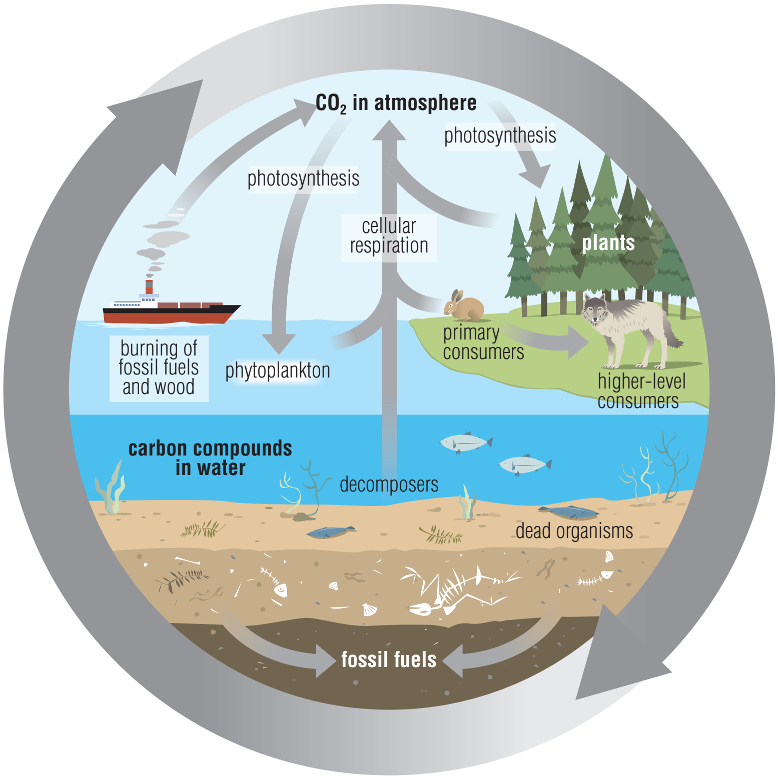


Figure 1.24 The carbon cycle

A huge carbon reservoir sits underground locked up in deposits of coal, which are almost pure carbon, oil, and natural gas which are mostly carbon combined with hydrogen. These deposits were formed from the remains of huge forests that lived hundreds of millions of years ago. Because oil, natural gas, and coal were formed so long ago, they are called fossil fuels.

The other abiotic carbon reservoir is the oceans. Carbon dioxide dissolves in water. Marine organisms use the carbon from the dissolved carbon dioxide to build their tissues.

Many natural processes move carbon between these various carbon reservoirs. Two of the most important processes are photosynthesis and respiration. Not only are both of these processes central to nutrient cycles, they are also closely connected with the flow of energy through ecosystems.

Learning Checkpoint

1. Explain what is meant by each of the following terms.
   (a) nutrient
   (b) element
2. Give an example of the possible steps in a water cycle where water leaves an ocean, moves to land, and then returns to an ocean.
3. What are the types of bacteria involved in the nitrogen cycle?
4. List one biotic and one abiotic reservoir for the element carbon.

Energy Flows Through Ecosystems

The ultimate source of energy for Earth's ecosystems is the Sun. A small fraction of the sunlight that reaches Earth is absorbed by the substance that causes plant leaves to be green. This substance is called **chlorophyll**. Plants use chlorophyll to capture the energy in sunlight and convert it into chemical energy. They then use the chemical energy for all the processes in their cells.

Photosynthesis

The process plants use to capture the energy in sunlight is complex (Figure 1.25). Plants absorb the chemical carbon dioxide gas and combine it chemically with water to produce a third chemical called glucose. Glucose is actually a form of sugar. All sugars are carbohydrates. Carbohydrates contain energy. The process of producing carbohydrates from carbon dioxide, water, and sunlight is called **photosynthesis**.

Photosynthesis can be written out in the form of a short statement, usually called a word equation, as follows:

carbon dioxide gas + water + sunlight → glucose + oxygen gas

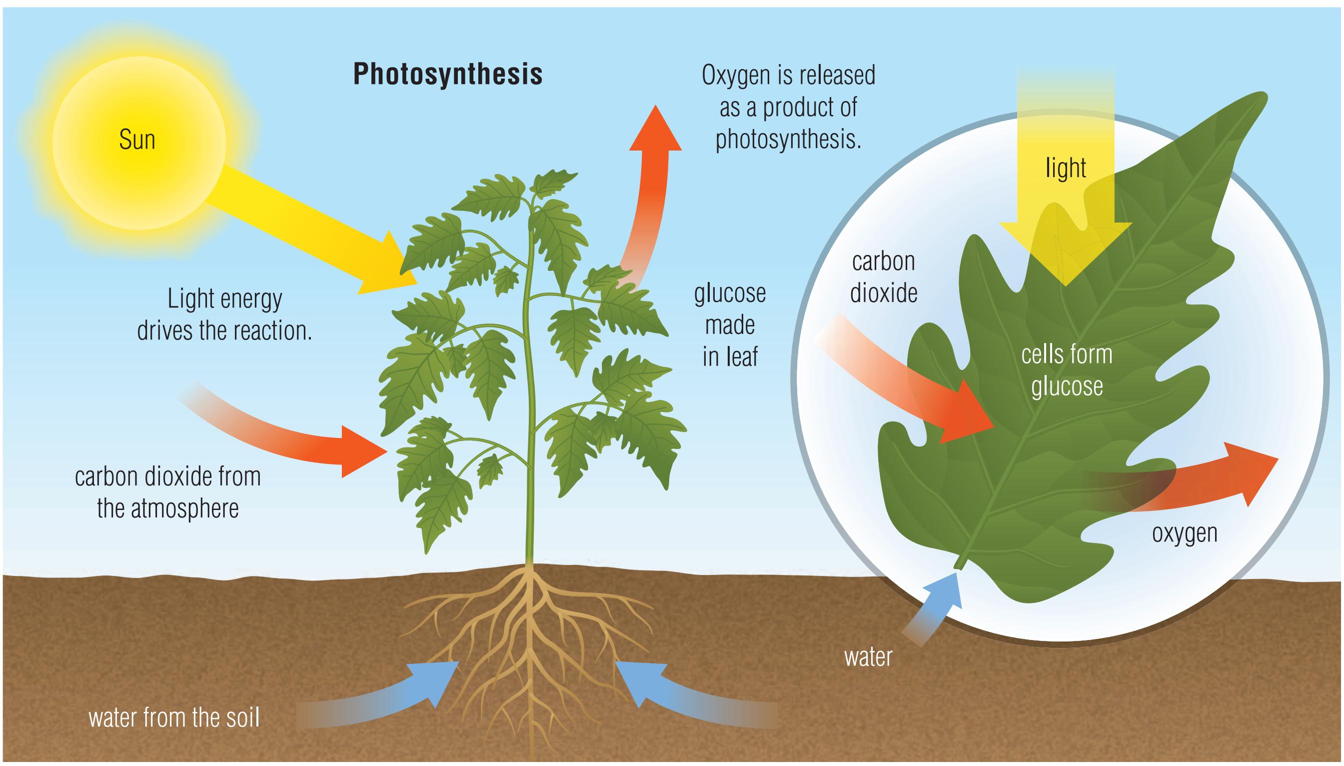


Figure 1.25 Photosynthesis

Carbon dioxide gas and water are shown to the left of the arrow because they are being used, along with sunlight, to make glucose and oxygen gas, shown to the right of the arrow. The plant releases some of the oxygen gas into the atmosphere, and it uses the rest of it to extract the energy from the glucose. The plant then uses the energy for the processes in its cells.

When you breathe, it is the oxygen gas in the air that keeps you alive. About 21 percent of the atmosphere is made of oxygen, and almost all of it was produced through photosynthesis. The trees in the world's forest biomes and algae in the marine biomes produce most of the world's oxygen (Figure 1.26).

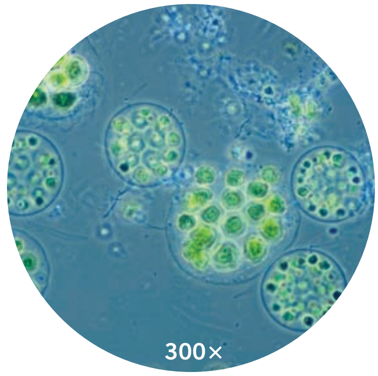


Figure 1.26 Microscopic marine algae

Cellular Respiration

Plants store the energy they capture from the Sun through photosynthesis in the form of glucose. However, plants need a continuous supply of energy for functions such as growth, repair of tissues, and reproduction. The process plants use to obtain the energy from the glucose is called **cellular respiration**. In cellular respiration, glucose combines chemically with oxygen from the air, in what looks like almost the reverse of photosynthesis. The equation for it is:

glucose + oxygen gas → carbon dioxide gas + water + energy

Plants use the energy released by cellular respiration for all the processes inside their cells.

Animals also carry out cellular respiration. Since they cannot carry out photosynthesis, they must obtain glucose by eating food containing carbohydrates. The equation also shows why we need to breathe. Breathing supplies oxygen needed for cellular respiration (Figure 1.27).

Figure 1.27 When we breathe out, we are getting rid of carbon dioxide, one of the products of cellular respiration.

Learning Checkpoint

1. What is the role of photosynthesis in an ecosystem?
2. What substances are produced and consumed in photosynthesis?
3. How are photosynthesis and cellular respiration related?
4. Since plants can capture the energy of sunlight in photosynthesis, why do plants need cellular respiration?

During Reading *Thinking Literacy*

Picture Mapping

As you read about producers and consumers, draw pictures with arrows to confirm your understanding of how producers and consumers connect.

Producers and Consumers

Producers are organisms that carry out photosynthesis. Terrestrial and aquatic plants, algae, and other organisms are producers. Producers are critical to ecosystems because they bring the Sun's energy into biological systems and turn it into chemical energy that plants can use.

Consumers are organisms that eat other organisms to obtain energy because they cannot produce their own food. There are several types of consumers. For example, a caterpillar is a **primary consumer** because it eats producers. A robin is a **secondary consumer** because it feeds on primary consumers. The third level of consumer, which eats secondary consumers, is called a **tertiary consumer**. For example, a hawk or eagle that feeds on a robin would be a tertiary consumer.

Because primary consumers always eat plants, they are called **herbivores**. For example, moose and deer are herbivores. Other consumers eat meat. If they eat mostly meat, they are called **carnivores**. **Scavengers** are carnivores that eat the remains of dead animals. Vultures are scavengers. Some consumers eat both animals and plants. They are called **omnivores**. Bears, raccoons and many humans are omnivores. **Detritivores** are consumers that feed on organic matter. **Organic matter** is the remains of dead organisms and animal wastes. Earthworms and maggots are detritivores.

Animals that catch and feed on other live animals are called **predators**. Animals that the hunter catches are called **prey**. For example, when a robin eats a worm, the robin is the predator and the worm is the prey. However, if a hawk hunts a robin for food, then the robin is the prey.

Decomposers

There is a group of special consumers called **decomposers**. The role of decomposers is to break down organic matter and release the nutrients in the organic matter back into the ecosystem. The major decomposers are fungi and bacteria (Figure 1.28). They do not consume the organic matter directly. Instead, they release special chemicals, called enzymes, into the organic matter to break it down. They then absorb the nutrients that are released.

Figure 1.28 This fungus is feeding on the organic matter in the soil. As it does, nutrients in the organic matter are released into the soil.

Food Chains and Food Webs

Food chains are a way of showing feeding relationships among organisms. They start with a producer and end with a final consumer (Figure 1.29).

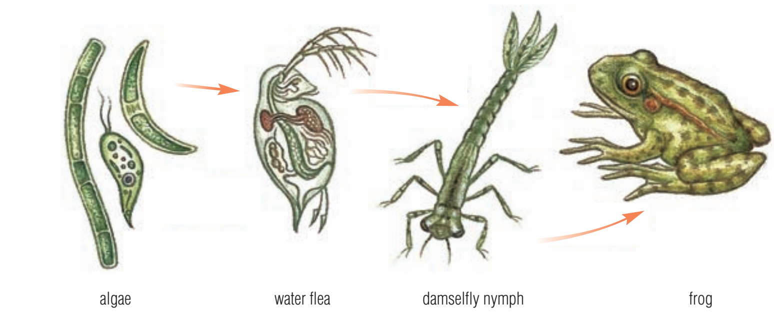


Figure 1.29 An aquatic food chain

However, most consumers usually eat many different types of food. For example, a snowshoe hare eats willow, bog birch, and many other green plants. A fox eats snowshoe hares as well as squirrels, voles, ptarmigan, and many other animals. These complicated feeding relationships can be modelled with a **food web**, as in Figure 1.30.

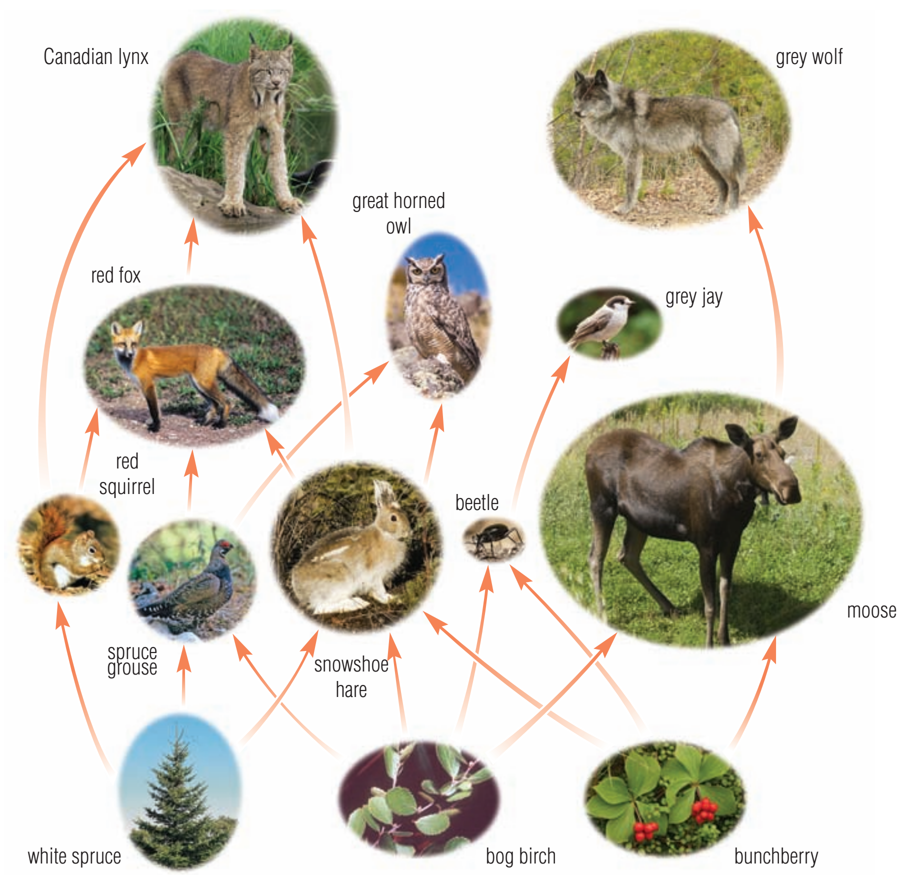


Figure 1.30 This food web of a boreal forest shows how different food chains interconnect.

Both food webs and food chains are limited in the information that they provide. They both clearly show who eats what, but they do not show how much energy is being passed from one organism to the next. Energy pyramids help us understand the flow of energy through ecosystems.

Energy Pyramids

Suggested Activity •
A6 Quick Lab on page 34

Generally, when an animal eats, 60 percent of the energy contained in the food cannot be accessed by the animal and it passes out of the organism in its wastes (Figure 1.31). Thirty percent of the energy is used to run cellular processes. Only about 10 percent of the energy in the food is used to make body tissues such as bones, muscles, and fat. This is very important when tracing the path of usable energy through a food web. It means that only about 10 percent of the energy that the animal eats is available to pass on to an animal that eats it. Put another way, as energy moves along a food chain, about 90 percent of the energy is lost at each transfer, most of it as heat.

Energy pyramids show the amount of available energy the producers and consumers contain as energy flows through the ecosystem (Figure 1.32). The more levels that exist between the producers and the top-level consumer in an ecosystem, the less energy is left from the original amount provided by the producers. Energy pyramids also show how important producers are to ecosystems. The wider the base of the pyramid, the more energy producers provide to the consumers.

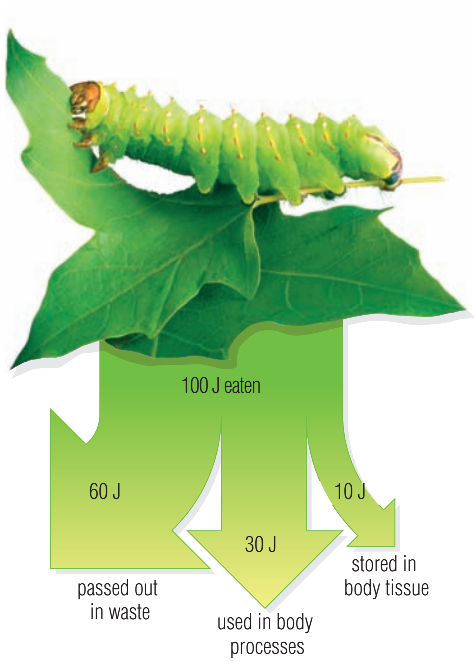


Figure 1.31 Of the 100 J the caterpillar eats, only 10 J is stored in its tissues. Only the energy stored in the caterpillar's tissues is available to the animal that eats it.

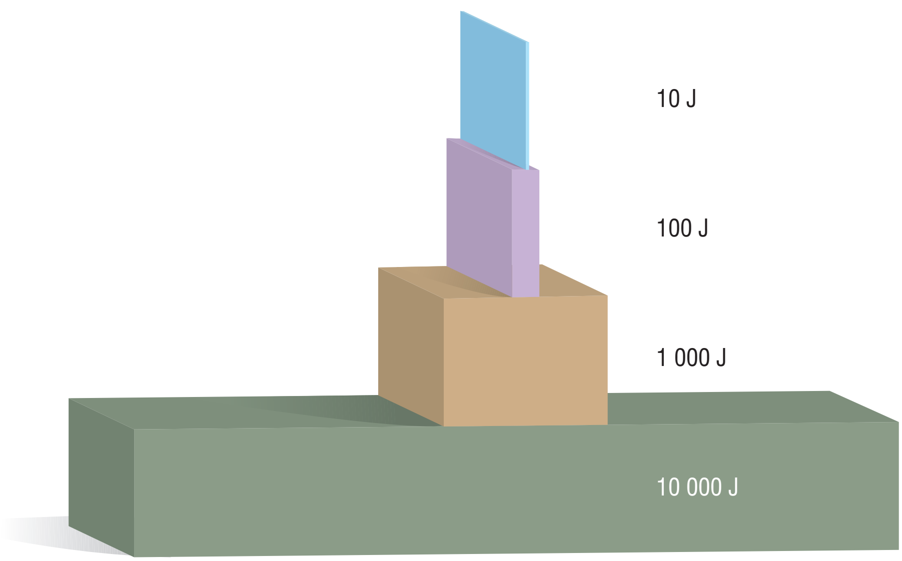


Figure 1.32 An energy pyramid shows the flow of energy through an ecosystem. The top level shows the amount of energy from the bottom level that is still available.

Take It Further

Other types of ecological pyramids are pyramids of numbers and pyramids of biomass. Find out what these pyramids model. Begin your research at ***ScienceSource***.

A5 *Quick Lab*

Analyzing Cycles

Figure 1.33 demonstrates how nutrients cycle in an ecosystem. Different nutrients all follow the same general path.

Purpose

To observe the path of nutrients as they move through the atmosphere, lithosphere, hydrosphere, and biosphere

Procedure

1. With a partner, study Figure 1.33.
2. Discuss any patterns that you observe.
3. Even though a nutrient moves through the ecosystem, there are certain locations where it may be stored for a period of time. Identify these locations.

Questions

4. Suggest the ways in which a nutrient moves:
   (a) from the ocean to the atmosphere
   (b) from the land to the ocean
5. If the ocean were removed from this diagram, how would this affect the flow of nutrients?
6. How do producers, consumers, and decomposers contribute to nutrient cycles?
7. Notice that the arrows are all the same width. However, this is not a completely accurate representation of nutrient flow. If a wide arrow represented a high level of flow and a thin arrow represented a low level of flow, which arrows would you make thicker and which arrows would you make thinner?
8. What abiotic factors do you think might affect the cycle (temperature, wind, rain, sunlight)? In what way would each one affect the cycle?

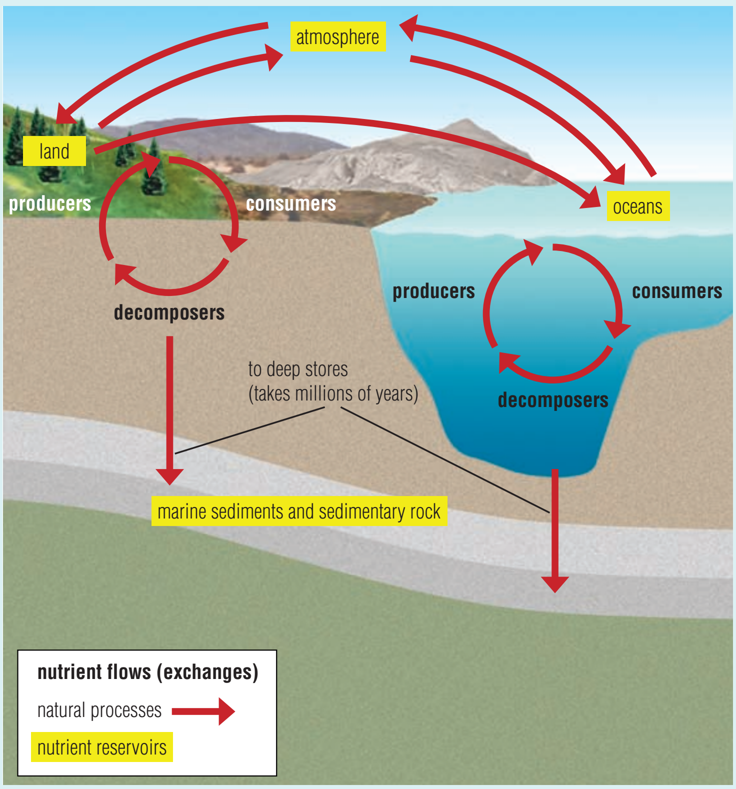


Figure 1.33 A general nutrient cycle

Comparing Energy Pyramids

Purpose

To create and compare energy pyramids for two different ecosystems: a deciduous forest and a boreal forest

Materials & Equipment

- calculator
- eight 2-cm strips of coloured paper
- ruler
- glue
- scissors
- blank sheet of paper

Procedure

1. Copy Table 1.3 into your notebook and write 30 000 for Producers under the "Energy Present" column. This table will be for the deciduous forest.

Table 1.3 Energy Pyramid Data

	Energy Present (kJ/m^2)	Length of Paper Strip (mm)
Producers	30 000	
Primary consumers		
Secondary consumers		
Tertiary consumers		

2. Remember that only 10 percent of the energy in producers is available to the primary consumers that eat the producers. Calculate the amount of energy available to the primary consumers. Record the value in your table.
3. Calculate the amount of energy available to the secondary consumers and tertiary consumers, and record the values in the table.
4. To create the energy pyramid, you will need to use a scale for your model so that 10 mm equals 2000 kJ/m^2. Calculate the length, in millimetres, of paper strips you will need to represent each level of the pyramid. Record the values in your table.
5. Cut a strip of paper to the correct length for the producer level of the pyramid.
6. Repeat step 5 for the remaining levels of the pyramid. If you could not cut a narrow enough strip, use a pencil to draw a 2-cm vertical line and indicate the width, in millimetres, that the line represents.
7. Glue the strips horizontally one above the other to form a pyramid. Make sure that the producer strip forms the base of the pyramid and that the tertiary consumer strip forms the top.
8. Label each level of the pyramid. Give the pyramid a title.
9. Repeat steps 1 to 6 for the boreal forest. (For step 1, write 12 000 for Producers under the "Energy Present" column.)
10. Glue the strips onto the same page below the deciduous forest pyramid.
11. Label each level of the second pyramid, and give the second pyramid a title.

Questions

12. Compared to the height of each pyramid, are the bases relatively large or small? What does this mean about the way energy flows through the ecosystem?
13. Which forest has more energy available to the primary consumers? More energy available to the tertiary consumers?
14. Explain what happens to the energy that is not transferred at each level of the pyramid.
15. Write a statement comparing energy availability in boreal and deciduous forests.
16. Suppose half of the deciduous forest was cut down and not replanted. Explain the consequences to the consumers in the ecosystem. Would the consequences be the same if half of the boreal forest was cut down?

1.2 CHECK and REFLECT

Key Concept Review

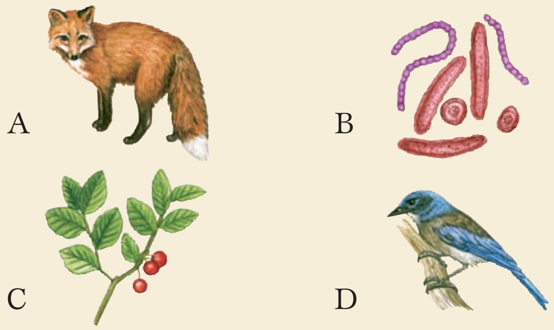
1. What role do producers, consumers, and decomposers each have in ecosystems?

2. Write the equation that summarizes photosynthesis.

3. Look at the organisms pictured below.

(a) Identify the producer, primary consumer, and secondary consumer.

(b) Identify the decomposers in this ecosystem.



Question 3

4. What are two processes that cause carbon to enter the atmosphere?

5. What are two processes that cause water to enter the atmosphere?

6. Give an example of how water moves from the biotic part to the abiotic part of an ecosystem.

Connect Your Understanding

7. When you eat a healthful meal, what two things are you providing your body with?

8. How is an element different from a nutrient?

9. All decomposers are consumers, but not all consumers are decomposers. Explain.

10. Suppose that an unknown disease were to kill all the bacteria and fungi in an ecosystem.

(a) Predict how this would affect nutrient cycling in the ecosystem.

(b) Predict what would happen to energy flow in the ecosystem.

11. How is the cycling of nutrients different from the movement of energy in an ecosystem?

12. Photosynthesis and cellular respiration are called "complementary processes." Explain why.

13. A food web contains green plants, grasshoppers, frogs, snakes, insect-eating birds, and falcons.

(a) Identify the group that contains the most energy.

(b) Rank the remaining groups from most to least in terms of energy content.

14. Suppose a plant could perform photosynthesis but it lost the ability to perform cellular respiration. Explain what would happen to the plant and why.

15. Consider a situation where a squirrel eats a nut.

(a) How much of the energy in the nut will be incorporated into the squirrel's tissues?

(b) Explain what happens to the remaining energy.

Reflection

16. In what ways has studying this section changed your understanding of ecosystems?

For more questions, go to ***ScienceSource***.

1.3 Interactions in Ecosystems

Here is a summary of what you will learn in this section:

- Biotic interactions in a community include predation, competition, and symbiosis.
- Abiotic and biotic factors prevent a population from increasing beyond its carrying capacity.

Figure 1.34 The island of Surtsey near Iceland is less than 60 years old. It is a United Nations World Heritage Site.

Birth of an Ecosystem

On November 14, 1963, an underwater volcano near Iceland erupted and poured lava onto the floor of the Atlantic Ocean, building the volcano ever closer to the ocean's surface. Eventually, it rose above the surface and a new island was born. As Iceland welcomed a new island into its territory, the world welcomed its newest ecosystem. The Icelandic government designated the island, named Surtsey, as an ecological reserve (Figure 1.34). Only scientists visit to document the gradual appearance of new life, seed by seed, plant by plant, bird by bird.

Many factors limit the populations of new species that can live on Surtsey. Seeds can be blown to its shores by the wind, but they first need soil to grow in. Although volcanic rock is rich in many of the elements present in fertilizers, such as potassium, phosphorus, and sulphur, soil has other components, such as organic matter. Birds often carry seeds in their stomachs. When they land on the island, the birds can deposit viable seeds in their wastes. Once they are deposited, the seeds are capable of growing. The birds' wastes make excellent fertilizer. As small plants, lichens, mosses, and other organisms continue to grow, the first soils begin to form.

Figure 1.35 Puffins started to nest on Surtsey in 2002.

Populations Increase

As years go by, the ability of Surtsey to support new species and larger populations continues to increase (Figure 1.35). Populations will increase or decrease depending on the availability of abiotic factors, such as water. Some factors have more impact than others. For Surtsey, the main abiotic factor is water erosion. Since the time it was formed, erosion has already removed half of the island. Erosion will eventually wash Surtsey back into the sea.

A7 Quick Lab

Keeping a Balance

Organisms have to find resources in order to survive.

Purpose

To simulate the competition for resources over several generations and see what happens to a population of animals

Materials & Equipment

- graph paper
- paper and pencil
- ruler

Procedure

1. You will be a member of one of two groups. One group of five will represent the animal population, the other larger group will represent the resources. Record the number in each group.
2. The animal group forms a line down one side of the class. The resource group forms a line down the other side. Each side faces away from the other.
3. Each person in both groups chooses a resource and makes the appropriate hand sign (Table 1.4). (Do not turn around.)

Table 1.4 Symbols

Resource	Sign
Food	Hand over stomach
Water	Hand over mouth
Shelter	Hands over head to make a roof (elbows out and fingertips touching)

4. On the signal from your teacher, turn around to face the other group. Each person in the animal group moves toward a person in the resource group that has the same sign.
5. If an animal successfully finds a match, then the animal escorts the resource back to his or her side and the resource becomes one of a new generation of animals. If an animal is unable to find its resource, then it dies and becomes a part of the resource side.
6. Record the number of animals.
7. Repeat steps 2 to 6 another 10 to 15 more times.
8. Graph the data, and discuss the following questions with a partner.

Questions

9. What are some factors that affected the survival of the animals?
10. Did you notice any trends?
11. Did the animal population rise, fall or stay the same?

During Reading

Thinking Literacy

Create a Picture Glossary

To learn unfamiliar terms, create a three-column chart in your notebook. Write the new term in the first column on the left. Add a definition in the middle column. In the third column, draw a picture that will help you to remember the term.

Ecosystem Interactions

In an ecosystem, many interactions are happening all the time. For example, producers use the Sun's energy to produce carbohydrates, and while they are doing this they also take in nutrients and water from the soil. Rising water levels on a lake can flood birds' nests at the water's edge, preventing the eggs they contain from hatching. Predators hunt, catch, and eat their prey. This reduces the prey population, but this also makes the prey population healthier as a whole because predators often remove the least healthy prey individuals from the ecosystem.

Aboriginal people describe these interactions as "connections." These connections mean that when something changes in an ecosystem, the change will affect other parts of the ecosystem. For example, when a drought occurs, plants that cannot survive in dry conditions die. Populations that depend on those plants may have trouble surviving also.

Biotic Interactions

Organisms in a community interact with one another in many ways. Three main ways are through competition, predation, and symbiosis.

Competition

Competition is the interaction between two or more organisms competing for the same resource in a given habitat. Competition can occur between members of the same species. For example, male mountain goats compete to determine who will mate and produce offspring. Members of different species may also compete for resources. For example, raccoons and ravens might both try to feed on eggs from the same nest of a common loon.

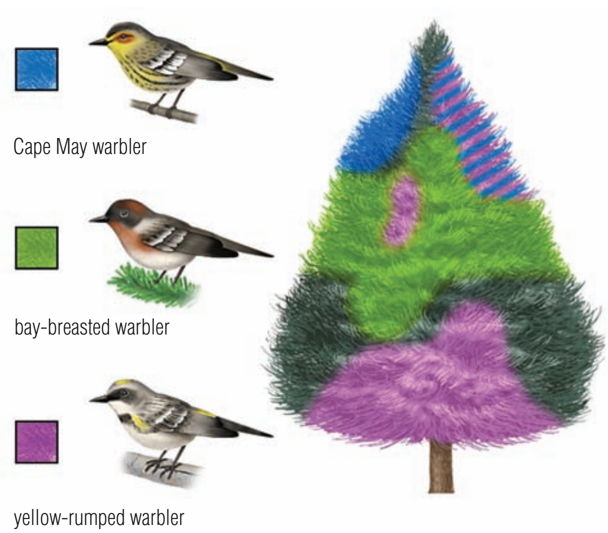


Figure 1.36 These warbler species feed on spruce budworms in different parts of the same spruce tree. Notice that there is some overlap of niches.

For similar species to coexist in an area, they must have slightly different niches. For example, many different species of similar birds called warblers feed on the same spruce budworms, but each species feeds in a different part of the spruce tree (Figure 1.36). This reduces the competition between them.

Predation

Predation occurs when one organism eats another organism to obtain food. Prey animals are well adapted to avoid being eaten. For example, a deer can usually outrun a bear. A porcupine's quills are a formidable defence against lynx and other predators. Many animals use camouflage to avoid predators. For example, a stick insect resembles the twigs that it lives on. By blending into its surroundings, it avoids being eaten.

Other prey animals, such as the monarch butterfly, defend themselves by tasting repulsive. They often have bright colours to warn predators away. Some species use **mimicry** to avoid predators. In mimicry, one species looks like another species. For example, the viceroy butterfly has markings similar to the monarch butterfly (Figure 1.37). Both species taste foul to their predators. By looking similar to each other, they both have a greater chance of not being eaten because their predators recognize their markings and avoid them both.

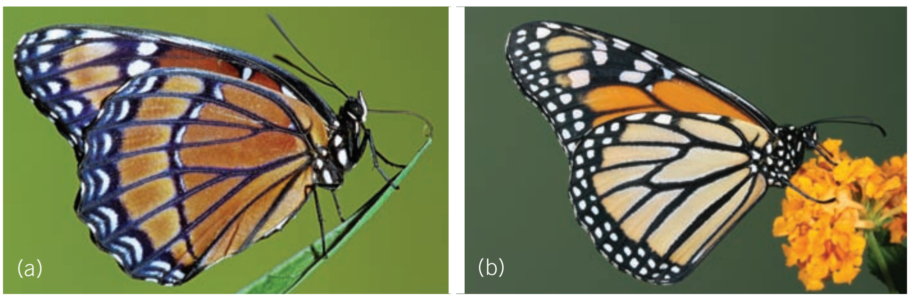


Figure 1.37 (a) The viceroy butterfly looks so similar to the (b) monarch butterfly that predators cannot tell them apart.

Many predators have sharp eyesight, a keen sense of smell, or both. An owl can spot a tiny mouse in the dark from high above and then swoop down to grab it on wings that are adapted to make no sound. (Flapping sounds might scare the mouse away.) The owl's sharp beak and claws are also adapted to snag and kill its prey.

Symbiosis

Symbiosis is a close interaction between two different species in which members of one species live in, on, or near members of another species. There are three main types of symbiosis:

WORDS MATTER

"Symbiosis" is derived from the Greek words *syn*, meaning with or together, and *bios*, meaning life.

Figure 1.38 A leaf-cutter ant brings a piece of leaf into the colony. The white areas are the mould.

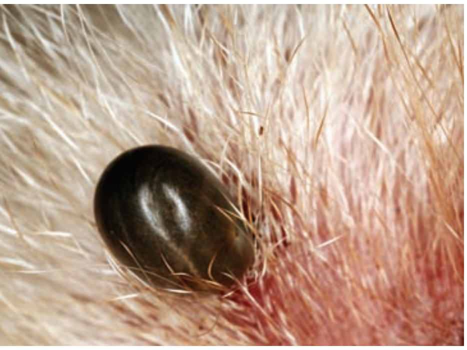


Figure 1.39 A tick burrows into the skin of its host. Only the tick's abdomen is visible.

- In **mutualism**, both species benefit from the symbiotic partnership. For example, there is a South American species of ant called a leaf-cutter ant that has a mutualistic relationship with a certain species of fungus (Figure 1.38). The fungus grows in the ants' underground colony. The ants provide the fungus with a constant supply of leaves, and the ants eat certain parts of the fungus.
- **Commensalism** occurs when one species benefits from a relationship with another species without any harm or benefit to the other species. A bird building a nest on a branch of a tree, where the nest does not harm or help the tree, is an example of this.
- **Parasitism** occurs when one species benefits at the expense of another species. Parasites live on or inside the host species and obtain some or all of their nutrition from the host. Ticks live on the bodies of mammals and feed on the host's blood (Figure 1.39).

Characteristics of Populations

As a population grows, each individual gets a smaller share of the resources in the area. When this happens, the organisms affected become stressed. Some die, while others are not able to reproduce. After a while, there are fewer births and more deaths. Eventually, the number of births equals the number of deaths and the population is in **equilibrium**. In other words, the number of individuals stays the same over time.

Figure 1.40 shows a rabbit population that was introduced into a new habitat. Notice that after a while, the number of rabbits does not change. The habitat has reached its carrying capacity. **Carrying capacity** is the maximum number of

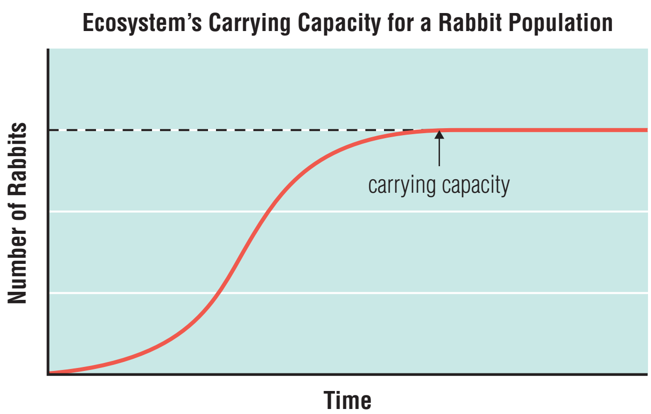


Figure 1.40 Real-world data on a rabbit population over a long period show that the population increases quickly at first but then increases more slowly until an equilibrium is reached and the population is steady. The ecosystem's carrying capacity for rabbits has been reached. At this point, the number of rabbit births equals the number of rabbit deaths.

individuals that an ecosystem can support without reducing its ability to support future generations of the same species. If a population exceeds its carrying capacity for a long time, it usually harms its environment.

Factors that Affect Populations in Ecosystems

Various combinations of abiotic and biotic factors cause populations to increase or decrease. For example, if there is an unlimited amount of food, water, and space, populations can grow very quickly. Without any limits, 10 breeding pairs of rabbits could expand to 10 million breeding pairs in only 3 years. In a healthy, properly functioning ecosystem, limiting factors prevent overpopulation from happening. A **limiting factor** is an environmental factor that prevents an increase in the number of organisms in a population or prevents them from moving into new habitats (Figure 1.41).

- Abiotic limiting factors include the amounts of sunlight, water, soil, and air, natural disturbances such as storms, fires, and droughts, and human disturbances such as logging.
- Biotic limiting factors include competition among organisms for resources, presence of predators, reliance on other organisms for survival, and the presence of disease-causing organisms.

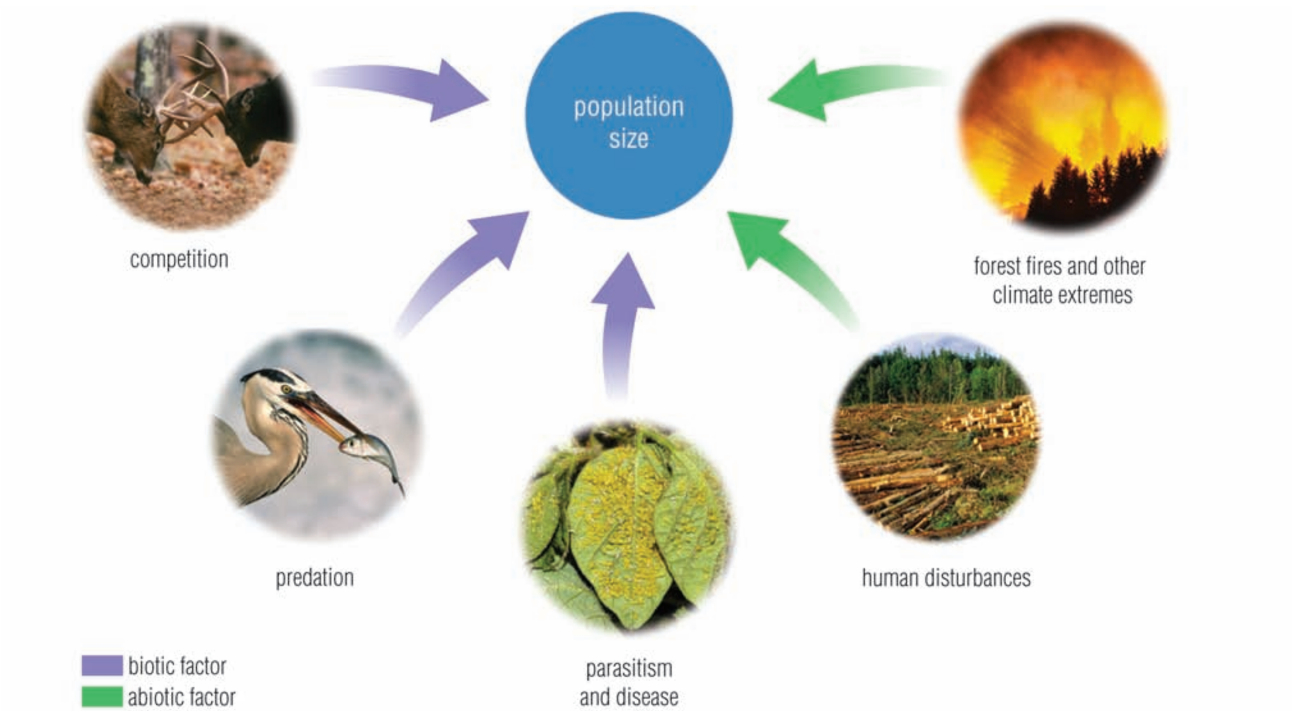


Figure 1.41 Many different factors can limit a population's size.

Take It Further

Find out more about the close link between the lynx and snowshoe hare populations, including the role plants play in the lynx–snowshoe hare population cycle. Begin your research at ***ScienceSource***.

Suggested Activity •
A10 Inquiry Activity on page 44

Consider a population of snowshoe hares, which are prey for lynx. As the population of hares increases, the lynx can capture hares more easily. The lynx are well fed and can have more offspring (Figure 1.42). As a result, their population increases. This increase in the number of lynx causes the number of hares to decrease because they are being eaten by more lynx. As more hares are eaten, the lynx's food supply gets smaller. Some lynx starve, and those that survive may be too malnourished to produce offspring. So, the lynx population declines as well. Finally, with fewer lynx preying on them, the hare population begins to recover and the cycle repeats. This cycling is shown in Figure 1.43.

For an ecosystem to be sustainable, none of the populations in the community can exceed its carrying capacity by very much or for very long. If all the populations remain at their carrying capacity, the ecosystem can usually be maintained without being weakened or losing its important biotic and abiotic factors. The goal of sustainability is to meet the needs of the present generation of individuals without affecting the ability of future generations to meet their needs.

Figure 1.42 The survival of these lynx kittens depends on the size of the hare population.

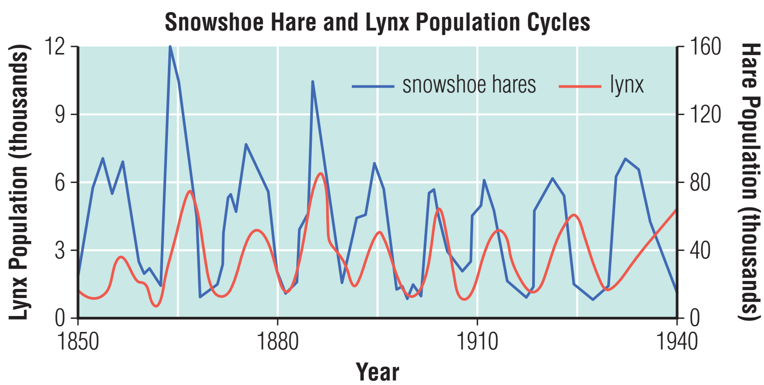


Figure 1.43 The rise and fall of the lynx and showshoe hare populations follows a 10-year cycle.

Learning Checkpoint

1. How does the idea of niches explain how similar species can coexist with a minimum of competition?

2. List and explain the three types of symbiosis.

3. Explain what is meant by the following terms.

(a) limiting factor

(b) carrying capacity

(c) equilibrium

A8 STSE *Science, Technology, Society, and the Environment*

Spotlight on Nature

Internet, television, and print media are powerful technologies advertisers use to sell a wide variety of products. Many corporations use images of organisms and ecosystems in their advertising or in their logos.

Collect three advertisements from media sources that use images of organisms as their company's brand or to sell a product.

1. For each advertisement, suggest a reason or reasons why the company chose the organism it did.
2. Explain whether there is a relationship between the values of the company and the organism being used in its advertising. Does it matter whether a relationship exists?
3. Does the company in any way support these organisms in their natural environment? Does it cause the organisms harm?
4. In your opinion, does a company that uses an organism to help sell its products have any responsibility to that organism? Explain your position.

A9 *Just-in-Time Math*

Choosing a Scale

A graph's scale is the sequence of numbers placed beside the grid points that subdivide the axis. Here are some pointers for choosing a scale, assuming the scale starts at zero.

- Make sure the data point with the largest value falls in the top half of the grid and below the top of the grid.
- Choose useful increments. Good increments include ones (0, 1, 2, 3, 4, . . .), twos (0, 2, 4, 6, 8, . . .), fives (0, 5, 10, 15, . . .), and tens (0, 10, 20, 30, . . .).

For example, suppose there are 14 grid points available (including zero) for your *y*-axis and the largest *y* value in the data set is 20. If you choose increments of two, then the scale will be 0, 2, 4, 6, 8, and so on. The *y* value of 20 will be plotted on the eleventh point (counting the zero) grid point, which is more than halfway up the grid and less than the maximum value that could be plotted, which is 26.

1. Assume you are selecting a scale for the *y*-axis of a graph that begins at zero. For each of the following situations, what increment should you choose and what is the maximum value that could be plotted on your scale?

   (a) There are 33 grid points available (including 0), and the largest *y* value in the data set is 300.

   (b) There are 12 grid points available (including 0), and the largest *y* value in the data set is 52.

2. For each of the following population data sets, choose scales for the *x*- and *y*-axis and plot the data.

(a)

Time (years)	Rabbit	Fox
0	2	0
1	10	5
2	10	4
3	15	5
4	10	4

(b)

Time (years)	Rabbit	Fox
0	10	2
2	50	4
4	100	40
6	190	100
8	10	2

(c)

Time (years)	Rabbit	Fox
0	10	2
10	40	6
20	300	80
30	300	100

DI Key Activity

A10 *Inquiry Activity*

Skills Reference 4

SKILLS YOU WILL USE
- Processing and synthesizing data
- Interpreting data to identify patterns or relationships

Predation Simulation

Lynx are members of the cat family that live by preying on snowshoe hares (Figure 1.44). In this activity, you will simulate the predator-prey interactions between these two animals using a model in which a desk represents a forest and cardboard and paper squares represent the lynx and hares in that forest.

Each lynx is represented by one medium-sized cardboard square, and each snowshoe hare is represented by a smaller paper square. When three small paper squares are tossed onto the desk, it represents three snowshoe hares entering and living in the forest. When a medium-sized cardboard square is tossed onto the desk, it represents a lynx entering the forest to hunt. If a medium-sized cardboard square lands on or touches a small paper square, it means the lynx has eaten the hare.

You will generate and graph population data and use the graph to predict future populations of each species.

Figure 1.44 Snowshoe hare and lynx populations are closely linked.

Materials & Equipment

- desk or other flat surface, 60 cm × 60 cm
- masking tape
- 250 paper squares, 3 cm × 3 cm
- 12 cardboard squares, 10 cm × 10 cm
- graph paper

Question

What are the long-term trends in the lynx and snowshoe hare populations in this model ecosystem?

Table 1.5 Predation Simulation Data Table

Generation	Hares at Start of Generation	Lynx at Start of Generation	Hares Eaten	Lynx Starved	Surviving Hares	Surviving Lynx	Hares Born	Lynx Born
1	3	1						
2								
3								

A10 *Inquiry Activity (continued)*

Procedure

1. Create a data table similar to Table 1.5.
2. Use masking tape to mark a 60-cm square on a desktop. This represents a forest.
3. To start the first generation, toss three paper squares (representing snowshoe hares) at random onto the forest.
4. Toss one cardboard square (representing one lynx) onto the forest. Make sure it does not slide when it lands.
5. Note whether the lynx square touches any of the snowshoe hare squares.
   - Any snowshoe hare in contact with the lynx has been eaten. Count and remove the eaten snowshoe hares. Record the number of hares that were eaten.
   - If the lynx is touching fewer than three hares, it has starved. Count and remove any starved lynx. Record that the lynx starved by putting a 1 in the "Lynx Starved" column of your data table.
6. Determine the number of snowshoe hares and lynx born in this first generation.
   - Any snowshoe hare not in contact with the lynx has survived and reproduced. One new hare is born for each hare that survives. Toss in one new snowshoe hare square for each surviving hare. Count and record the number of hares born.
   - If the lynx is in contact with three or more hares, it has survived and reproduced. One new lynx is born for every three hares eaten by the lynx. Toss in one new lynx square for every three hares eaten by the lynx. Count and record the number of lynx born.
   - If the lynx did not survive in the first generation, wait for three generations before adding another lynx. In those generations, just add hares. Then add one new lynx that has moved in from a neighbouring forest.
7. For the beginning of generation 2, the number of hares will equal the surviving hares plus the new hares born. Enter this number in your data table. The number of lynx will equal the surviving lynx plus any new lynx born. Enter this number in your data table.
8. Continue the simulation until you have completed 15 generations. If the hares are ever wiped out, restart the population with three new hares.

Analyzing and Interpreting

9. Graph the data for the lynx and hare populations. Plot both the lynx and hare data on the same graph to make comparisons easier. Label the *y*-axis "Number of Animals" and the *x*-axis "Generations."
   (a) Describe any pattern you notice in the population of hares.
   (b) Describe any pattern you notice in the population of lynx.
   (c) Explain any relationship that exists between the populations of lynx and hares in your model.
10. Why do changes in the population of lynx lag behind the changes in the hare population?
11. Snowshoe hares eat twigs from willow trees. When snowshoe hare populations are high, overeating of willow twigs occurs. As the hare population begins to decrease due to a lack of food, the population of willow twigs increases, but young replacement twigs contain a toxin and cannot be eaten for two to three years. This can delay hare populations from recovering as quickly. Using this information, create a second graph that represents how the populations of the willow, hares, and lynx may all interact.

Skill Practice

12. Based on patterns in your graph, predict what will happen to the hare and lynx populations over the next 10 generations.

Forming Conclusions

13. State the relationship between the population of hares and the population of lynx.

1.3 CHECK and REFLECT

Key Concept Review

1. Describe three adaptations that different prey species use to avoid being eaten.

2. Suppose that there is a forested park in which squirrels are reproducing very quickly because there is so much food available. In this situation, the population will grow until it reaches the carrying capacity. What will define the carrying capacity of the squirrel population?

Connect Your Understanding

3. Classify the following interactions as mutualism, commensalism, or parasitism.

(a) A yucca moth caterpillar feeds on the yucca plant and pollinates the yucca plant.

(b) Lice feed harmlessly on the feathers of birds.

(c) A cowbird removes an egg from a robin's nest and replaces it with one of its own.

(d) An orchid plant grows on the branch of a tree. The tree remains healthy.

4. Identify the following limiting factors as either abiotic or biotic.

(a) Wind blows the seeds of a dandelion into a pond. The seeds fail to grow.

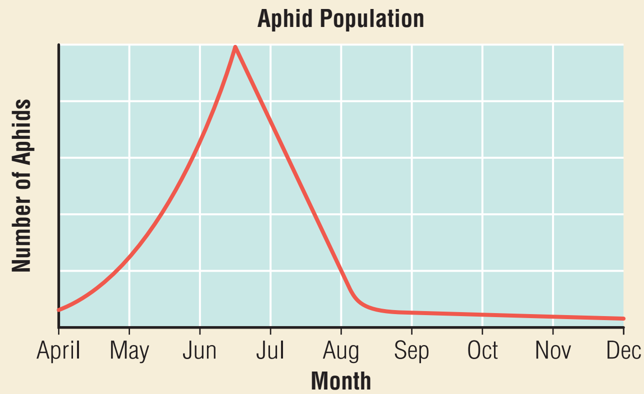
(b) A population of grasshoppers eats all the available food, and their numbers drop dramatically.

(c) A bacterium causes a deadly disease in a herd of reindeer, and some of them die.

(d) Plants growing beneath the trees in a forest are unable to get enough sunlight.

5. Does the success of a prey population depend on its predators? Explain.

6. Aphids are tiny insects that eat plants. What abiotic factors may contribute to the changes in the population that you see in the graph?



Question 6

7. Cockroaches are insects that reproduce very rapidly. Suggest reasons why the world is not covered in cockroaches.

8. Revisit the interactions of the lynx and the hare. Predict how the predator-prey interactions would change if a second prey species that ate the same food as the hare were introduced into the same area. Predict how the cycle might change if a second predator were added. Draw a graph to illustrate your answers.

Reflection

9. Limiting factors normally control a population from expanding past its carrying capacity in a specific area. Most of the limiting factors that would normally control the human population have been removed through various technologies. How does this affect your quality of life? How might it affect your children's or grandchildren's lives?

For more questions, go to ***ScienceSource***.

Cool Symbiosis

This bird is looking for parasites. The bird gets a tasty meal, and the buffalo gets rid of itchy pests such as ticks. However, these birds can also be parasites. If a buffalo is wounded, the birds will pick at the scabs, which keeps the wound open and prevents it from healing.

The adult monarch butterfly feeds on the nectar in the flowers of the milkweed plant and pollinates it. The butterfly also lays its eggs on the plant. When the eggs hatch, the larvae and caterpillars feed on the plant. Milkweed sap contains a large amount of a substance called latex. The monarch larvae and caterpillars incorporate this substance into their tissues. As a result, they taste bad and are poisonous. Monarch butterflies feed exclusively on milkweed plants.

The clownfish and the sea anemone are each other's guardians. The clownfish can swim safely among the anemone's stinging tentacles. This ability protects the clownfish because its predators will not get close to the stinging tentacles. There are several species of fish that can tolerate the anemone's stings and will eat the anemone's tentacles, if given a chance. This is where the clownfish comes in. It will chase away any fish that comes too close to the anemone, and so protects the anemone.

1 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

k Knowledge and understanding
t Thinking and investigation
c Communication
a Application

Key Concept Review

1. List the following terms in order from smallest to largest. k

biome, ecosystem, biosphere, habitat

2. Identify the following items in the photograph.

(a) a species k

(b) a population k

(c) a community k

(d) an ecosystem k

Question 2

3. (a) Describe the role photosynthesis plays in the carbon cycle. k

(b) Describe the role that cellular respiration plays in the carbon cycle. k

4. What term best describes where all life is found? k

5. Name four elements that are found in most organisms. k

6. Give an example of an abiotic reservoir. k

7. (a) What do nitrifying bacteria do?

(b) What do denitrifying bacteria do? k

8. What is the difference between a habitat and a niche? k

9. When similar species live in the same habitat, explain how competition between these species is reduced. k

10. Name the five main terrestrial biomes found in Canada. k

11. The open ocean and a lake are both aquatic biomes. What abiotic factor makes the two biomes different? k

Connect Your Understanding

12. Predict what would happen if a plant from a deciduous forest were transplanted to the tundra. Explain your answer. t

13. Compare a forest to a bicycle. How are they similar, and how are they different? t

14. The black-throated blue warbler migrates from the Caribbean to wetlands in northern Ontario each spring, and then it flies back again in the fall. Why would the bird make such a lengthy journey two times a year? t

15. A crow's niche is being a scavenger. Is this an accurate description of its niche? Justify your answer. t

16. Pick any organism in your area and explain how it has adapted to the specific biotic and abiotic factors of that environment. a

17. Photosynthesis is the most important process on Earth. Justify this statement. a

18. The paths that nutrients and energy take in ecosystems are different.

(a) Draw a symbol to indicate the path energy takes. c

(b) Draw a symbol to indicate the path nutrients take. c

19. Suppose that a herd of reindeer had been introduced to a small island that had no reindeer on it and their population had been monitored. The table below shows the population data.

Reindeer Population 1910–1940

Year	Population
1910	50
1920	250
1930	500
1935	2000
1940	1400

(a) Graph the population data. t

(b) Suggest why the population of reindeer was lower in 1940 than in 1935. t

(c) Extend the graph, predicting the population in 1950 and 1960 by extrapolating from the given data. Several different plausible extrapolations are possible. Suggest one or more, and be prepared to explain your predictions. t

20. When a predator catches its prey, it may appear that the prey species suffers. But there are benefits to this type of interaction for the prey species as well. What are two ways in which the prey species may benefit from the predator hunting them? a

21. Bacteria can reproduce so quickly that, under ideal conditions, one bacterium could produce enough bacteria to cover the entire planet in only a few weeks. Explain why this does not happen. a

22. Suppose you had to create an imaginary animal and its predators are eagles. What adaptations would you give this animal to avoid being caught by an eagle? a

23. Disease-causing organisms can be termed parasites. However, in this chapter, disease and parasites are both listed as biotic limiting factors. Why do you suppose the author chose to separate these two factors? a

Reflection

24. Describe three things you did not know about ecosystems before you started working on this chapter. c

25. You have learned about competition among species. Think of your daily activities, and list some ways you may compete with other species for resources. c

After Reading

Thinking Literacy

Reflect and Evaluate

How did the use of visualization and picture mapping help you to understand new ideas and terms? Share with a partner one of the diagrams or picture maps that you drew, and explain the concept or terms that it illustrates.

Unit Task Link

In the Unit Task, you will be designing a community that will have as low an impact as possible on the surrounding ecosystems. You will have to assess the abiotic and biotic factors in your area. What are the abiotic factors that affect the area where you live (for example, availability of water, average temperatures, and amount of sunlight)? Also think about the energy flow and cycling of matter. Where does your energy come from? How is matter cycled where you live?