

20 A

Energy and Matter Exchange in the Biosphere

About 50 years ago, the first photographs taken from space allowed us to see our planet as a whole. Traditional Western thought saw Earth's natural resources as infinite and viewed nature as a force to be dominated for our benefit. Such views are now linked to many environmental problems. Satellite images often reveal scars on our planet from human activities, such as forests that are burned away to create agricultural land or the silting of waterways, such in the Mississippi River Delta shown in the photograph. However, we have now learned that the best way to correct and prevent these problems is to ensure our activities are carried out in ways that help to maintain the natural balance of the biosphere. When we view humanity as an integral part of the biosphere, connected to all living things, we begin to consider not only the ways that science and technology can change natural ecosystems, but also how those changes will impact us.

As you progress through the unit, think about these focusing questions:

- How are carbon, oxygen, nitrogen, and phosphorus cycled in the biosphere?
- How is the flow of energy balanced in the biosphere?
- How have human activities and technological advances affected the balance of energy and matter in the biosphere?

UNIT 20 A PERFORMANCE TASK

Environmental Effects of Human Communities

In this Performance Task, you will choose one of three tasks that will demonstrate your understanding of how ecosystems are sustained, and the effects of human activities. The first task considers golf. In many areas, new courses are appearing in what was farmland or forest. How might you create a golf course with minimum impact on local ecosystems? The second task considers community water quality. We use water for many purposes, such as for drinking, building, making chemicals, and transporting goods. How could you monitor the impact of human activities on a local body of water? Finally, you might create an educational board game that will help players learn about ecosystems and how they can be sustained.

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GENERAL OUTCOMES

In this unit, you will

- explain the constant flow of energy through the biosphere and ecosystems
- explain the cycling of matter through the biosphere
- explain the balance of matter and energy exchange in the biosphere as an open system, and how this maintains equilibrium

Unit 20 A

Energy and Matter Exchange in the Biosphere

ARE YOU READY?

These questions will help you find out what you already know, and what you need to review, before you continue with this unit.

Knowledge

1. Use **Figure 1** to identify the following:
 - (a) two biotic and two abiotic factors
 - (b) a producer, a consumer, and a decomposer
 - (c) three different food chains of at least three organisms each

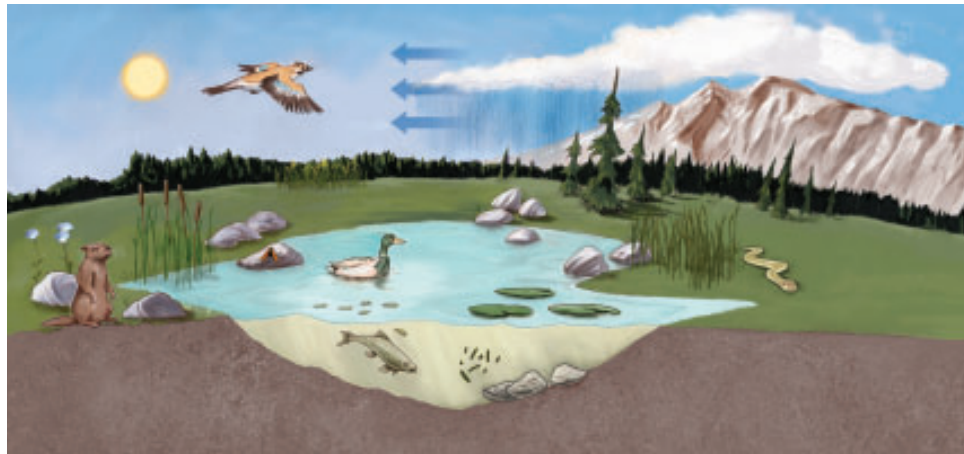


Figure 1
An ecosystem

2. Describe the role of producers in an ecosystem.
3. Could an ecosystem continue if all the decomposers were removed? Why or why not?
4. Describe how water is cycled within ecosystems.
5. Identify two ways that thermal energy (heat) is transferred from one region of Earth to another.
6. Distinguish between an open system and a closed system.

Prerequisites

Concepts

- biotic and abiotic factors
- producers, consumers, and decomposers
- food chains and food webs
- the water cycle
- open and closed systems
- thermal energy transfer in the biosphere

Skills

- select and use appropriate vocabulary to communicate scientific ideas
- use graphs to compile, organize, and interpret data

You can review prerequisite concepts and skills on the Nelson Web site and in the Appendices. 

A Unit Pre-Test is also available online.

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Skills

7. Using a diagram, describe the greenhouse effect.
8. In your notebook, sketch **Figure 2** or write labels to represent the organisms. Draw arrows to complete a food web.







Figure 2

STS Connections

9. Why should we be concerned with air and water pollution that is happening on the side of Earth opposite to where we live?
10. Attitudes toward the environment have changed over time. Using specific examples, describe evidence that Canadians' attitudes have changed over time. Is there still a need for changes in attitude? Explain your answer.
11. Different cultures often look differently at the relationships between living organisms and their ecosystems.
 - (a) Using the wolf as an example, explain the different worldviews of Aboriginal people and early European settlers.
 - (b) Is there any evidence that the view of the early European settlers is no longer held by Canadians?

The Biosphere as a Closed System

► In this chapter

-  Exploration: Earth under a Microscope
-  Web Activity: Dr. David Suzuki
-  Web Activity: Creating a Database of At-Risk Species
-  Explore an Issue: What Is the Value of Wolves?

In the traditional knowledge of Canada's Aboriginal peoples, nature is full of interconnections and complexities. Spiritual stories describe how animals are connected to living things such as plants and other animals, non-living things such as air or water, and natural events such as storms. For example, the Sandy Lake Cree tell of the thunderbird Binay-sih, who protects other animals from the sea serpent, Genay-big. Binay-sih's anger is expressed through black clouds, thunder, and lightning. Humans are just one of the many connected elements.

In contrast, a traditional Western view is that nature is a source of raw materials or products to be exploited for human needs. This narrow viewpoint has sometimes led us to damage the environment and, in turn, damage ourselves. For example, the recent oil spill at Wabamun Lake can be seen as a conflict between our need for oil and the needs of the organisms in that environment.

Today, scientists from various cultures recognize that they must look at the world differently to meet our need and sustain our planet. Although Western scientific thought and traditional Aboriginal culture have different starting points, both offer important insights into how ecosystems work.



STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. Explain this statement: "An ecosystem is constantly changing, yet it remains the same."
2. Describe a typical food web in your region. Be sure to include producers, consumers, and decomposers.
3. Do you think that Earth's ecosystems can withstand the current negative impacts of human activity? What evidence supports your opinion?
4. A commonly held stereotype is that traditional Aboriginal lifestyles had/have no negative impact on the environment. Recently, writers and researchers have acknowledged that buffalo jumps (which killed more buffalo than were needed) and the burning of forests for agricultural land are inconsistent with this perception. Explain why even positive stereotypes can be dangerous.



Career Connection:
Photographer (Scientific)



Figure 1

On August 3rd, 2005, a train derailed at Lake Wabamun, Alberta. More than 1 million litres of oil were spilled, causing severe environmental damage.

► Exploration

Earth under a Microscope

Purpose

To investigate how living things interact in a closed system on a small and simple scale, by observing microscopic organisms

Materials: tap water; medicine dropper; microscope slides and coverslips; microscope; cultures of yeast, *Paramecium*, and *Didinium*



Use gloves while making and observing the slides. Dispose of slides and gloves as directed by your teacher. Wash your hands before leaving the lab.



EXTENSION



Using the Light Microscope

Listen to a review of the proper use of a light microscope.

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- Using a medicine dropper, prepare separate wet mounts from each of the three cultures. Examine each slide under a light microscope.
 - (a) For each slide, how many different kinds of living things do you see?
 - (b) Sketch and describe the organism(s) on each slide.
 - (c) Describe the behaviour of the organism(s) on each slide.
- Combine the living organisms to observe how they interact. Prepare the following wet mounts:
 - 1 drop *Paramecium* culture + 1 drop yeast culture
 - 1 drop *Paramecium* culture + 1 drop *Didinium* culture
 - (d) Describe the interactions between the organisms.
 - (e) How would an ecosystem that contained all three organisms be different from one that contained only *Paramecium*?

1.1 Equilibrium in the Biosphere



(a)



(b)




(c)

Figure 1
Interactions among biotic components: (a) a plant and an insect, (b) an insect and an amphibian, (c) an amphibian and a bird

dynamic equilibrium describes any system with constant change in which the components can adjust to the changes without disturbing the entire system

biosphere the narrow zone around Earth that harbours life

“We do not inherit the Earth from our grandparents; we borrow it from our grandchildren.”—Chief Seattle

Imagine how the Apollo astronauts felt when they first set foot on the Moon and saw the spectacle of the living Earth rising above the lifeless lunar rock. From that viewpoint, one might think of our planet as a spaceship. Travelling around the Sun in a slightly elliptical orbit, Earth carries with it the only forms of life confirmed in the universe. As you learned in your previous studies, Earth is a closed system, which is any system in which *matter* is not exchanged with its surroundings. A closed system exchanges *energy* with its surroundings, however. Life is totally dependent on incoming solar energy and the matter available on Earth. 

When we see the whole planet from a distance, we can see that everything on Earth is connected. There are no real boundaries. The atmosphere that envelops Earth is continuous and free to flow. The oceans are continuous, even though we have given the oceans separate names.

This distant view of Earth shows us the big picture. It does not allow us to see the countless continuous interactions among living and non-living components that take place in this system. We do not see the insect feeding on the leaves of a tree, or the frog feeding on the insect, or the bird eating the frog (**Figure 1**), or any other details of a complex web of activity that keeps the system running. Neither can we see the impacts of human activity—the treeless hills; the smog hanging over cities, and the polluted rivers, lakes, and oceans—or the efforts of humans to prevent species extinction or to preserve the natural environment.

J.E. Lovelock, a British scientist, compares Earth to a living body. The metaphor is referred to as the *Gaia* (pronounced “gay-ah”) *hypothesis*, named after the Greek goddess of Earth. Although a controversial idea in the scientific community, it serves to emphasize that all living things interact with each other and with the non-living components of our planet. In much the same way that the brain requires oxygen and nutrients from the circulatory system to function properly, each component of Earth’s environment must be in a state of balance or equilibrium with every other component. What affects one part affects all parts. The expression **dynamic equilibrium** is used to describe any system in which changes are continuously occurring but whose components have the ability to adjust to these changes without disturbing the entire system.

Today’s ecologists have evidence to suggest that Earth is facing a crisis in which its dynamic equilibrium is being upset. However, scientists have not reached a consensus about the magnitude of the predicament or what can be done. The problems appear to result from the activities of a single dominant species: humans. We humans can also be a positive force in preserving the dynamic equilibrium of Earth. We have the ability to understand natural processes and act on this knowledge. As a member of Earth’s community, you can become a knowledgeable decision maker by studying some of the well-established principles of ecology. The decisions you make will, in part, determine the future direction of life on this small and fragile planet.

The Biosphere

Earth has three basic structural zones: the lithosphere (land), the hydrosphere (water), and the atmosphere (air). Living organisms are found in all three zones. Together, these three zones make up the **biosphere**, the narrow zone around Earth that harbours life.

The limits of the biosphere extend from the ocean depths all the way to the atmosphere. Most terrestrial animals are confined to a narrow band where the atmosphere meets the surface of the earth. The regions that are not within the biosphere, such as the upper atmosphere and Earth's core, are also important because they affect living organisms.

Life forms are referred to as the **biotic**, or living, components of the biosphere. Chemical and geological factors, such as rocks and minerals, and physical factors, such as temperature and weather, are referred to as the **abiotic**, or non-living, components. It is the interactions within and between the biotic and abiotic components that the ecologist endeavours to understand and explain.

When biologists investigate how a complex organism functions, they must study its various levels of organization. Moving from the simple to the more complex, these levels are individual cells; then tissues; organs and organ systems; and finally the integrated, functioning body. Ecologists investigating the biosphere proceed in a similar manner. By examining its individual parts, ecologists are able to bring together the various data and provide a picture of how the biosphere operates as an integrated unit.

Ecological studies begin at the organism level. Investigations are designed to determine how the individual interacts with its biotic and abiotic environment. However, an organism does not live in isolation. It tends to group with others of the same species into **populations**. A population influences, and is influenced by, its immediate environment. When more than one population lives in an area, a **community** of organisms is established. An **ecosystem**, the functional unit of the biosphere, has both biotic and abiotic components. The physical and chemical environment, as well as the community of organisms, interact with each other in an ecosystem.

Biodiversity

The number of species in an ecosystem is described as the biological diversity or **biodiversity** of the ecosystem. Because every organism in an ecosystem is connected to all the other organisms, the reduction in biodiversity caused by the extinction of a single species can cause a domino effect. The loss of one part from an ecosystem, like the removal of a moving part from a car, can cause the collapse of an entire food chain. A **food chain** is a step-by-step sequence linking organisms that feed on each other, starting with a food source such as plants (**producers**), and continuing with animals and other living things that feed on the plants and on each other (**consumers**). When a species acts as a predator, it keeps the population of its prey in check; when it acts as prey, it provides an important food source.

For example, the overhunting of sea otters along the Pacific coasts of Asia and North America removed the main predator of the sea urchin. Predictably, the number of sea urchins grew rapidly. Sea urchins eat kelp, a form of seaweed. As the number of sea urchins grew, the amount of kelp declined, and so did the fish that relied on the kelp-bed ecosystem for habitat and food. Sea otters very nearly became extinct as a result of hunting pressure. From the point of view of humans, killing sea otters for their fur resulted in the decline of a valuable fishery. Where the sea otter has been reintroduced, sea urchin populations have fallen, kelp beds are being re-established, and the number of fish is increasing.

The story of the whooping crane (**Figure 2**) is another example of an attempt to restore a natural balance. In spring, whooping cranes fly north to live in the marshes and swamps of the prairies and the Canadian north, where they eat crayfish, fish, small mammals, insects, roots, and berries. Efforts by conservationists have helped increase the population from a low of 14 individuals in 1940 to 213 in 2004. Chemical pesticides were the original human threat to the crane, but it was already struggling. Cranes fly a

biotic components the biological or living components of the biosphere

abiotic components the non-living components of the biosphere. They include chemical and physical factors.

population a group of individuals of the same species occupying a given area at a certain time

community the populations of all species that occupy a habitat

ecosystem a community and its physical and chemical environment

biodiversity the number of species in an ecosystem

food chain a sequence linking organisms that feed on each other, starting with a food source and continuing in order with each consumer

producer an autotroph; an organism that makes its own food

consumer a heterotroph; an organism that must eat producers or other consumers to survive



Figure 2

The efforts of wildlife biologists are preventing the whooping crane from becoming extinct. Some young birds are hand-raised but, to prevent the chicks from associating humans with safety, the caregivers disguise themselves as adult cranes.

+ EXTENSION



Why is Biodiversity a Good Thing?

Learn more about how species' survival is connected to the biodiversity of a region.

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long way during their migration, and are vulnerable to hunting and accidents along the way. In addition, the whooping crane reproduces very slowly. Each year females produce two eggs; however, only one will mature. The first fledgling to emerge from its egg kills its brother or sister. This ensures there will be enough food for the survivor, but it also reduces the rate at which the population can increase.

We do not fully understand all the relationships between species in many ecosystems, so we cannot predict reliably what will happen to an ecosystem if its biodiversity is reduced, even by one species.



WWW WEB Activity



Figure 3
Dr. David Suzuki

Canadian Achievers—Dr. David Suzuki

Dr. David Suzuki (**Figure 3**) is perhaps Canada's most recognizable living scientist. Through his many books and his popular CBC television show "The Nature of Things," Suzuki has taken science out of the laboratory and into people's day-to-day lives. One of Dr. Suzuki's main interests is environmental issues. Explore David Suzuki's contributions to environmental studies further, and find out his opinions on Canada's ecosystems. Think about the following questions:

Which ecosystems in Canada are most at risk?

How does the level of risk relate to biodiversity?

What role does human activity play in loss of biodiversity?

What can you do to reverse this trend?

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SUMMARY

Equilibrium in the Biosphere

- Earth supports the only confirmed life forms in existence. Living organisms are found in a limited region of Earth known as the biosphere.
- The expression *dynamic equilibrium* is used to describe any system in which changes are continuously occurring but the components have the ability to adjust to these changes without disturbing the entire system.
- The number of species in an ecosystem is described as the biological diversity or biodiversity of the ecosystem. Since organisms interact with each other in potentially important and unique ways, the reduction in biodiversity caused by the extinction of a single species can cause a "domino effect."

▶ Section 1.1 Questions

1. How can the metaphor of a spaceship be used to describe Earth?
2. What is a closed system?
3. What are the abiotic and biotic components of the biosphere?
4. In what way does a community differ from an ecosystem?
5. Name the levels of organization in the biosphere.
6. Using the organisms in **Figure 1**, on page 8, as an example, explain how ecosystems are in a state of dynamic equilibrium.
7. (a) In your own words define the term *biodiversity*.
(b) Explain why diversity is important for ecosystems.
(c) Give two examples of ecosystems that have high biodiversity, and two that have low biodiversity. Explain your classification.
8. Canadian wildlife biologists have been attempting to preserve the whooping crane. Are they succeeding? In a short essay, evaluate the success of their program.

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Equilibrium Unbalanced 1.2

The first bald eagle born and raised on the shores of Lake Erie in nearly 30 years took flight in 1983. Wildlife officers had moved the parent birds to Long Point peninsula in an attempt to re-introduce the birds to the natural ecosystem in the lower Great Lakes.

During the 1700s and 1800s the bald eagle was common along the northern shores of Lake Erie. By the early 1900s, biologists began to see a decline in their numbers. Early settlers and farmers regarded the birds as a threat to livestock and often killed them. A second, and even more deadly, threat followed. Toxic chemical waste, produced by the many industrial plants that bordered the Great Lakes, entered the eagles' food chain. The high levels of toxins caused eggshells of the bald eagle and some other birds, such as the double-crested cormorant and the herring gull, to become unusually thin. Eggs broke more easily, and many eagles were born with abnormalities. Their birth rate declined significantly.

Eagles depend directly or indirectly on all of the other members of their food chain (Figure 1). The health of top-level consumers like eagles indicates whether toxins are entering an ecosystem. When the dynamic equilibrium of an ecosystem becomes unbalanced for any reason, the health or numbers of organisms in that ecosystem are affected. If the changes are large enough, some organisms may even become extinct. Eagles are one of many species that are providing evidence that changes in ecosystems are affecting the natural equilibrium in a negative way. In Canada, more than 450 species of plants and animals are at various degrees of risk, and 12 species have become extinct.

At-risk species are classified depending on the degree of risk. An *endangered* species is one that is close to extinction in all parts of the country or in a significantly large location. An *extirpated* species is one that no longer exists in one part of the country, but can be found in others. A *threatened* species is any species that is likely to become endangered if factors that make it vulnerable are not reversed. The term *special concern* refers to any species that is at risk because of low or declining numbers at the fringe of its range or in some restricted area. Figure 2 gives some examples of at-risk species across Canada.

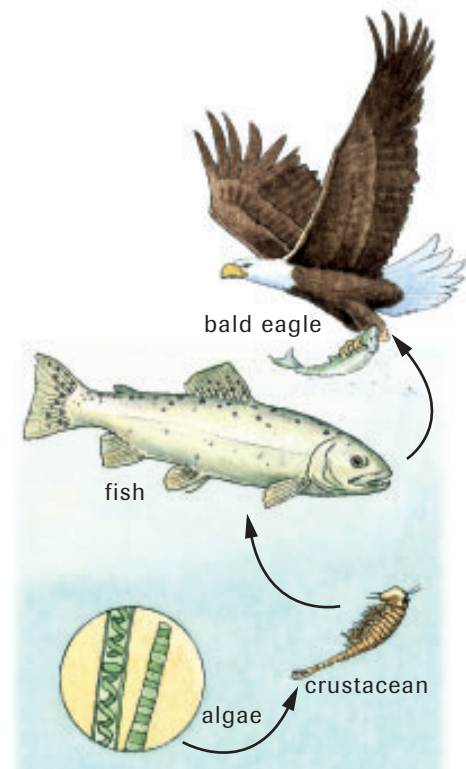


Figure 1
The bald eagle has been reintroduced to the shores of Lake Erie, in an attempt to re-establish a natural ecosystem.

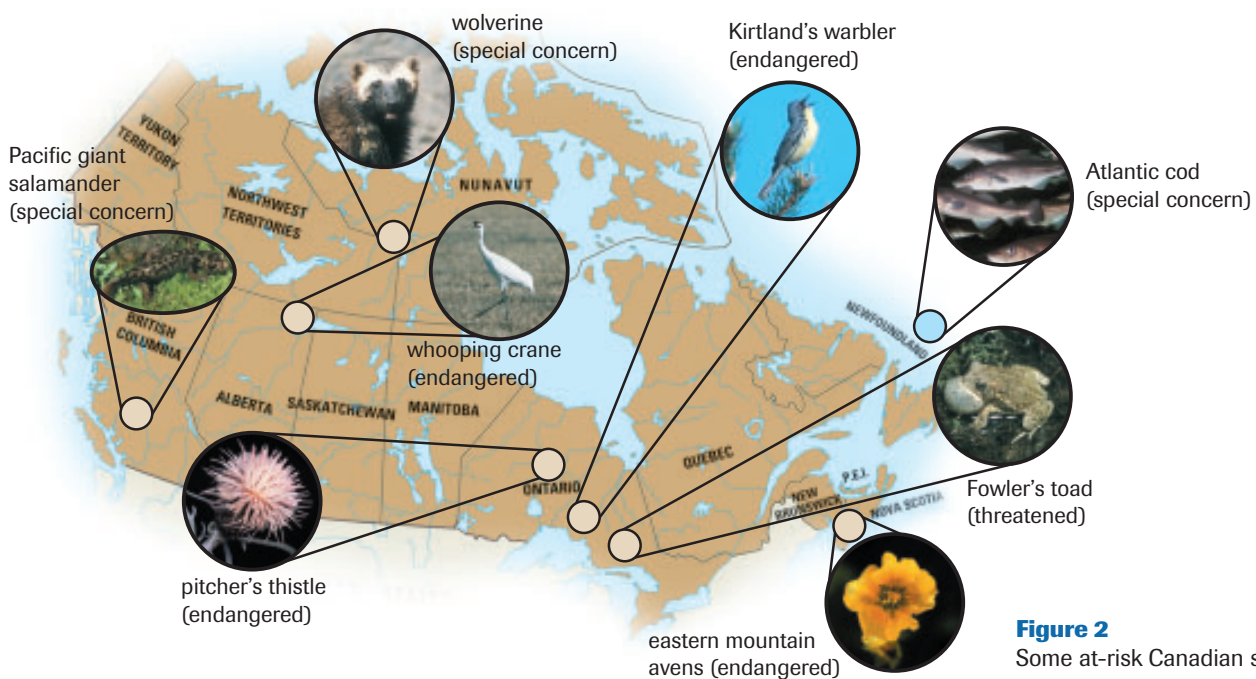


Figure 2
Some at-risk Canadian species

Web Quest—Creating a Database of At-Risk Species

Create an electronic database of endangered species in Canada. First, decide on the categories you will use to describe the information (e.g., type of species, level of risk, and habitat). Then, create a table to define the categories that you want to use to record your data. Include different types of organisms in your database. After you have finished your database, test it by searching according to different categories. Show another group how your database works. Import the data recorded by the other group to make a larger database.

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indicator species a species sensitive to small changes in environmental conditions

herbivore an animal that eats only plants

carnivore an animal that feeds only on other animals

omnivore an animal that eats both plants and other animals

The Disappearance of Frogs

Some species are particularly sensitive to changes in an ecosystem. These **indicator species** can provide an early warning that the balance in an ecosystem is being negatively affected. Some amphibians may be especially important indicator species. Why might this group of animals play such an important role?

The word *amphibian* is a clue. The word comes from two Greek words, *amphi* (“on both sides”) and *bios* (“life”). Amphibians literally have two lives (**Figure 3**). Frogs begin as eggs and grow to tadpoles in ponds, and then enter their second life as adults in forest and grass-land areas. This means they are exposed to hazards in both ecosystems, instead of only one. Any decline in the health of either of the two ecosystems in which they live will have an impact on frogs.

Not only do frogs occupy two different ecosystems, they are also parts of two very different food chains. Adult frogs eat mostly insects and a few small fish. In turn, large fish, predatory birds, reptiles, and small mammals eat frogs. This makes the adult frog a member of a food chain (**Figure 4**, next page) that includes producers (plants), **herbivores** (animals that eat plants), and **carnivores** (animals, like the frog, that feed on other animals). Animals that eat both plants and animals, such as humans, raccoons, and bears, are called **omnivores**.

If frogs became extinct, insect populations would soar. This has already happened in Bangladesh, where frog populations have been decimated to supply restaurants with delicacies. The result is a rise in the number of mosquitoes, and a dramatic rise in cases of malaria among humans. Malaria is a disease that is transmitted by mosquitoes, which are eaten by frogs. The increase in malaria can be traced back to the disappearance of frogs from the local ecosystems.

(a)

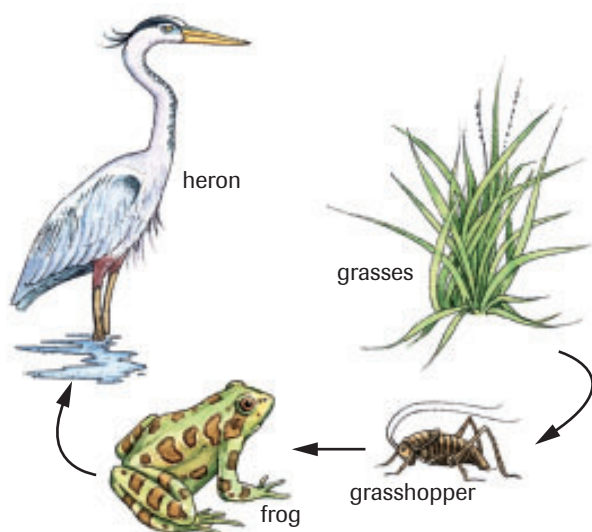


(b)

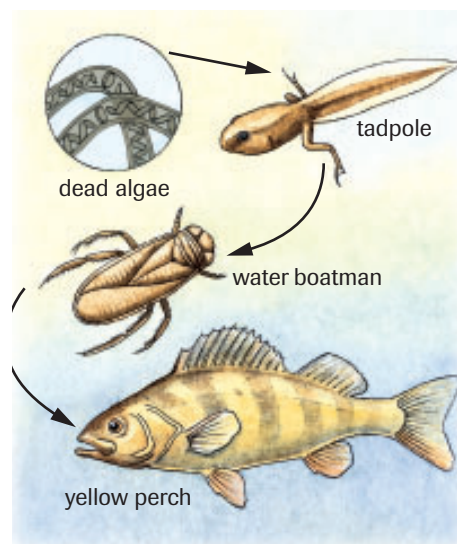


Figure 3

The northern leopard frog, native to Alberta, is one of the threatened amphibian species. **(a)** Leopard frogs lay their eggs in ponds, and tadpoles develop. **(b)** Adult leopard frogs live in fields and around ponds.

**Figure 4**

The adult frog is part of a food chain that includes producers (plants) that make food and consumers (animals) that feed either directly or indirectly on the plants.

**Figure 5**

Waste is recycled within a detritus food chain. Organisms in the chain include fungi, bacteria, insects and other invertebrates, and, in ponds, tadpoles.

Tadpoles eat large amounts of algae (small plantlike organisms), both living and dead. The tadpole is a herbivore, not a carnivore, and is part of a different food chain than that of its parents (**Figure 5**). In this food chain, there are two food sources—producers (the algae) and **detritus** (waste from plants and animals, including their dead remains). Detritus food chains are critical in the recycling of matter in ecosystems. They include **decomposers**, organisms that break down detritus to get nutrients for their own use, but in the process also release nutrients to the soil and water. Plants and algae use those nutrients to grow.

detritus waste from plants and animals, including their dead remains

decomposer an organism that feeds on detritus

Why Are Frogs Disappearing?

Amphibians have been around for more than 400 million years. They survived the catastrophe that killed all the dinosaurs 65 million years ago. They have adapted to ice ages and extended periods of global warming, withstanding drought, flood, and winter ice. They can be found in most ecosystems that include water. Amphibians live on the peaks of the Canadian Rockies, in the city parks of Winnipeg, and in the swamps of Newfoundland. They have even done well dealing with the growth of the human population, at least until recently. Biologists have become aware of the gradual disappearance of amphibians such as frogs, toads, and salamanders. These animals seem to be dying at unprecedented rates. About 30 % of North America's frogs and toads are in trouble. The worldwide disappearance of frogs is puzzling scientists around the globe. In some areas, they have identified a few probable causes.

Loss of Habitat

In Canada, frogs in more heavily populated areas seem to be in great danger. The loss of **habitat**, places where a species can live, is usually thought to be the main cause. Frogs need wetlands, ponds, or lakes with clean water so they can breed and lay their eggs. As adults, they need a place where they can catch insects, such as a forest or a field. They also need a safe path between the two. The growth of cities, and human activities such as

habitat a place or type of environment with conditions suitable for the survival of an organism or population of organisms

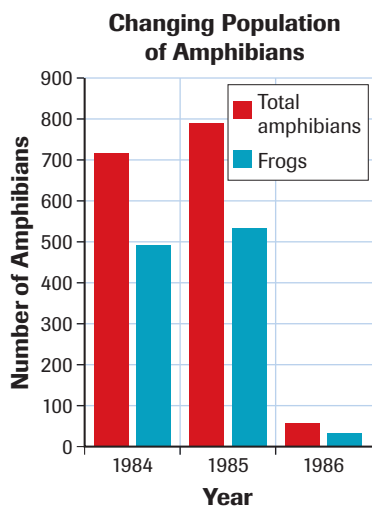


Figure 6

In the first year of the study, researchers counted 716 amphibians, 493 of which were frogs. After the trees were cut in 1986, they found very few.



CAREER CONNECTION

Photographer (Scientific)

Scientific photographers use high-tech equipment to take specialized photographs, such as photomicrography and time-lapse photography. Forensic photography is one specialization that is used to provide evidence for criminal investigations. If using computers, high-tech cameras, and media equipment interests you, research more about this career.

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ultraviolet radiation

electromagnetic radiation from the Sun that can cause burning of the skin (sunburn) and cellular mutations

ozone

O_3 , an inorganic molecule. A layer of ozone found in the stratosphere helps to screen out ultraviolet radiation.

farming and industry, take away all of these things. Humans drain wetlands, cut down trees, build on fields, and build roads between ponds and woods.

A highway separating a woodlot from a pond or lake can claim the lives of many frogs as they move between their feeding and breeding areas. Cutting down some of the trees that surround a lake creates problems for amphibians by exposing them to increased UV radiation and predation. **Figure 6** shows data from one study, carried out from 1984 to 1986, in which scientists studied an area where a swamp and a forest were separated by a road. When trees bordering the road were cut in 1986, researchers noticed a huge decline in the number of frogs and other amphibians.

Air and Water Quality

A second cause for the decline in frog numbers is pollution. This is because frog skin is thin and is not protected by feathers, fur, or scales. Frogs have lungs, but they also breathe through their skin, which must be thin to allow oxygen through. Pollutants can also pass through their thin, moist skin. The pollutants in acid rain are known to harm frogs.

Acidity also affects frogs' ability to reproduce. Researchers have noted that if the water in which eggs are laid is even slightly acidic, it reduces the mobility of frog sperm cells. This makes it less likely that eggs will be fertilized. Even if mating is successful, acid affects the frog's development. Embryos, if they develop at all, grow slowly in acidic water. Some ponds may dry up before tadpoles can become adult frogs, and the tadpoles die. Acidic water can cause other problems, such as deformed limbs. Tadpoles with such limbs do not survive for very long.

Climate Change

Climate change may be another factor in the disappearance of frogs. Evidence of global warming is growing. Increasing global temperatures have been linked to the increased use of fossil fuels such as coal, oil, and gasoline. Climate change can cause important changes in local ecosystems. For example, if the climate becomes drier, frog populations will decline. No frog can stay in direct sunlight too long or completely separate itself from fresh water.

Ultraviolet Radiation

The thin skin of the frog is also susceptible to **ultraviolet (UV) radiation**. This invisible radiation from the Sun causes sunburns, but it has also been linked with more serious cell damage. The amount of UV radiation reaching Earth's surface is increasing because of damage to the protective **ozone** layer surrounding our planet. A thin layer of ozone (O_3) blocks harmful solar radiation. The layer is getting thinner. Atmospheric scientists believe that chlorofluorocarbons (CFCs), which were widely used in spray cans and refrigerators, are at least partly responsible for the thinning.

Frog species that live at higher altitudes, where the UV radiation is greater, seem to be most vulnerable to changes in the ozone layer. Many of these species have adaptations to protect them from high levels of UV radiation. For example, some species lay black eggs and have a black covering lining their internal organs. However, biologists are concerned that these adaptations may not be enough if change in the ozone layer continues to increase UV radiation levels in this habitat.

The frog is not the only animal whose skin is exposed to UV radiation. Humans also have a delicate skin and are affected by the increase in UV rays. Areas of thinning ozone have been identified above Antarctica and the Canadian Arctic. The concurrent increase in skin cancers and eye problems associated with ultraviolet radiation are raising much concern among ecologists and the general public. The fact that the rate of human skin cancer is rising all over the world underscores the importance of studying the frog as a "bioindicator" of the health of the planet.

▶ EXPLORE an issue

What Is the Value of Wolves?

Few animals stir as many emotions as the wolf (**Figure 7**). Some Aboriginal peoples saw the wolf as a traveller, a guide, and a teacher, capable of appearing and disappearing at will. People saw many similarities to humans in the way wolves co-operate.

In contrast, the wolf of European stories chased three little pigs, disguised itself in the fleece of a lamb, and ate the grandmother of Little Red Riding Hood. Unlike the Native peoples of the plains, Europeans saw the wolf as a sharp-toothed villain that preyed on livestock and people.

The Decline of the Wolf

When European settlers reached central North America and found plains covered in bison, they were not willing to compete with the wolf for valuable hides. Thousands of wolves died after they ate poisoned bison carcasses that had been laid out as bait.

After the bison hunters left, having killed most of the bison, there was a break of a few years before ranchers began to kill wolves in the 1880s and 1890s. In both the United States and Canada, anyone bringing a wolf skin to a local government office was paid. In Montana alone, more than 80 000 wolves were destroyed between 1883 and 1918.

However, the effects of removing the wolves were dramatic. It was followed by an increase in the population of the next dominant predator, the coyote. The coyote, a close relative of the wolf, is smaller and rarely forms packs. Bison and elk are much too large for single coyotes to hunt. The coyote eats mostly small mammals, such as mice, voles, and ground squirrels, and the eggs and fledglings of ground-nesting birds. It competes with foxes, badgers, and martens, who eat similar things. As the number of coyotes grew, the numbers of these smaller predators declined.

Wolves frequently left remains from their kills. These leftovers were taken by scavengers such as magpies, ravens, and vultures. Without the wolf, these species began to decline.

Meanwhile, large herbivores such as the elk were safe. The population of elk in the highlands grew so large that they stripped the hills of plants. Diseases spread rapidly within their large herds, causing the population to decline.

The Return of the Wolf

The wildlife managers of Yellowstone National Park in the United States saw these signs and recognized that something was seriously wrong. In 1987 they put together a plan: they were going to import wolves from Canada.

Despite continuing resistance from local ranchers, who feared for their sheep and cattle, 35 wolves were transplanted from Alberta in 1996. More have since been added. Signs of change are already evident. Where wolves have been introduced, elk have moved from open fields (where they are more vulnerable), and now stick to tree-covered areas. Vegetation is recovering, and the number of small predators, such as the kit fox, is increasing. As ranchers feared, some of the new wolves have killed livestock. Five cows and 53 sheep

Issue Checklist

- | | | |
|---------------------------------------------|-------------------------------------------|---------------------------------------------|
| <input type="radio"/> Issue | <input type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input checked="" type="radio"/> Resolution | <input checked="" type="radio"/> Evidence | <input checked="" type="radio"/> Evaluation |



Figure 7

In 1996, wolf packs were relocated from Alberta to Yellowstone National Park in an attempt to restore an ecological balance.

were killed by wolves in Idaho in the spring of 1997. Ranchers are compensated for losses to wolves, but they are still not happy about the reintroduction of wolves.

Understanding the Issue

- Classify the at-risk status of the wolf in and around Yellowstone National Park
 - before European settlers arrived,
 - during the bison hunt,
 - after ranchers arrived, and
 - in 1996.
- How might the views of Aboriginal people about the wolf lead them to treat wolves differently than European settlers and hunters did?
- Make a concept map showing how the removal of the wolf caused problems in the local ecosystem.

Different Views

The following are three views on what should have been done about wolves in Yellowstone Park.

The Frontier View: To feed ourselves and the hungry of the world, we must open up, clear, and claim wilderness areas for ranching and other forms of agriculture. Wolves endanger that effort. They kill cattle and sheep. They must be removed wherever they interfere with farming and ranching, and they should not be reintroduced once they have been extirpated.

The Stewardship View: Humans are the most intelligent animals on the planet. It is our duty to take care of other species and preserve our world. Once we recognize that we have damaged an ecosystem, we must try to repair the damage using whatever resources are available to us. Wolves must be preserved in all ecosystems where they are now found, and reintroduced to ecosystems where they once lived.

The Ownership View: Canadians do not own wild animals or plants just because they live in Canada. We have no right to move them around whenever we feel like it. It may have been a mistake to kill the wolves of Yellowstone, but we have no right to take Alberta wolves and move them to a place they've never been before. It is better to let the ecosystem in the park find a new balance. Perhaps one day wolves will find their own way to the park.

Take a Position

- Should we have captured wolves in Alberta and shipped them to Yellowstone National Park? After a group discussion, decide which views you support, or develop an alternative view.
- Using libraries, the Internet, and CD-ROMs, research to find information that will support your position and write a report on the results of your research.

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SUMMARY

Equilibrium Unbalanced

- The frog can serve as an indicator species whose decline signals an unhealthy environment.
- Detritus food chains are critical in the recycling of matter in ecosystems. They include decomposers, organisms that break down detritus to get nutrients for their own use, but in the process also release nutrients to the soil and water. Plants and algae use those nutrients to grow.
- In Canada, 12 species are extinct, while over 450 species are at risk. Some are extirpated (extinct in some former ranges), while others are endangered, threatened, or of special concern.

▶ Section 1.2 Questions

1. Explain how each of the following factors could lead to the extinction of a species. With each explanation include an example of a species threatened by that factor.
 - (a) poor reproductive success
 - (b) competition from a species newly introduced into an ecosystem
 - (c) change in climate
 - (d) hunting by humans
2. Choose one of the species listed in **Figure 2**, on page 11, for further research. Why is the species at risk? Are there any initiatives underway to improve the status of the species? What could you do to help? Report on the results of your research.

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3.
 - (a) Explain why the life cycle and skin of the frog make it a good indicator species if you want to determine the health of local ecosystems.
 - (b) Construct a concept map that links the decline in the number of frogs to factors that may cause the decline.

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4.
 - (a) Design a scientific experiment that would assess the impact of acid rain on one species of frog.
 - (b) If you actually carried out such an experiment, what would happen to the animals on which you experimented? From an ethical perspective, discuss your experimental design.
5.
 - (a) Predict which area of Canada has the greatest number of organisms at risk. Provide a hypothesis that explains why wildlife in this area would have more problems.
 - (b) Do national and provincial parks help alleviate this problem? Explain.
6. The peregrine falcon was once considered endangered. Research Canadian efforts to restore this predator and report on their success.

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Outcomes

Knowledge

- explain the structure of ecosystem trophic levels, using models such as food chains and webs (1.1, 1.2)

STS

- explain that the process of scientific investigation includes analyzing evidence, and providing explanations based upon scientific theories and concepts (1.2)
- explain that science and technology have both intended and unintended consequences for humans and the environment (1.2)

Skills

- analyze data and apply mathematical and conceptual models by: analyzing data on the diversity of plants, animals, and decomposers of an endangered ecosystem and predicting a future outcome (1.2)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms 

1.1

dynamic equilibrium	ecosystem
biosphere	biodiversity
biotic components	food chain
abiotic components	producer
population	consumer
community	

1.2

indicator species	decomposer
herbivore	habitat
carnivore	ultraviolet radiation
omnivore	ozone
detritus	

▶ **MAKE a summary**

1. Using as many key words from the chapter as possible, construct a concept map that links key ideas within the chapter. The following Key Terms must appear in your concept map.

abiotic components	community
biotic components	detritus
consumer	ecosystem
dynamic equilibrium	producer
population	
2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

▶ **Go To** 

The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 1
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

+ EXTENSION 



Does a Bear Shed in the Woods?

Grizzly bears in western North America have a restricted range. Dr. Micheal Procter (University of Alberta) is working on bear DNA, and has found that the southernmost bears are isolated, making them more prone to local extinction. Dr. Procter conducted his research while studying at the University of Calgary.



+ EXTENSION 

Bye, Bye, Blue Bayou

This short video discusses the loss of wetlands in the Gulf Coast area of United States. The wetlands in this area are one example of how human activities, including those that contribute to climate change, can affect ecosystems and lead to extinction of species. The loss of the wetlands also has consequences to human life.



Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

Use the following information to answer questions 1 to 4.

Figure 1 is a diagram of an ecosystem.

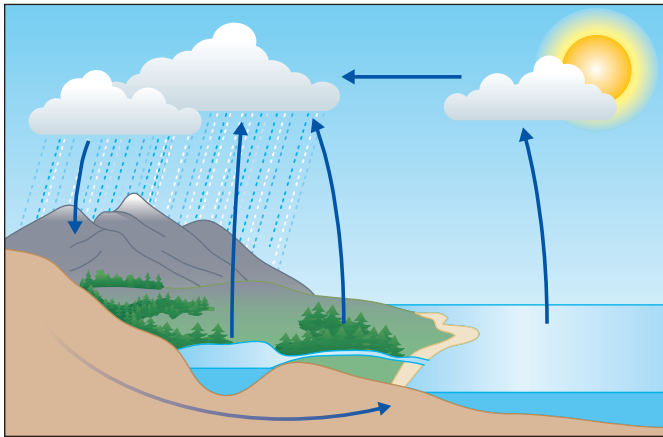


Figure 1

- Identify three abiotic factors of the ecosystem shown in **Figure 1**.
 - rain, sunlight, and soil quality
 - water temperature, water lilies, and minnows
 - poplars, grasses, and earthworms
 - soil quality, bacteria, and earthworms
- Explain how two members of the biotic community affect an abiotic factor.
 - Pine trees and poplar trees affect the growth of grasses.
 - Beavers and shrubs affect the number of poplar trees.
 - Water temperature and pond oxygen levels affect the amount of plankton in the lake.
 - Poplar trees and shrubs lose their leaves, which are decomposed and improve soil quality.
- Identify the statement that lists two decomposers and correctly explains their role in the ecosystem.
 - Clams and algae improve soil quality by returning organic nutrients to the soil.
 - Bacteria and earthworms improve soil quality by returning organic nutrients to the soil.
 - Pine trees and shrubs perform photosynthesis and add oxygen to the ecosystem.
 - Algae and bacteria perform photosynthesis and add oxygen to the ecosystem.

- What is the ultimate source of energy for the ecosystem shown in **Figure 1**?
 - water
 - sunlight
 - producers
 - consumers

- Air temperatures were measured various distances above and below the soil in two different communities, a grassland community and a woodland community. Data was plotted on the graph in **Figure 2**.

Statements:

- Woodland communities offer more shade and lower soil temperatures.
- Woodland communities have more animals because of lower soil temperatures.
- Temperatures increase below the soil surface, so burrowing animals must protect themselves against the heat.
- The greatest variation between temperature readings for the two communities occurs at the soil surface.
- Warmer air temperatures nearer the soil surface indicate that some radiant energy is reflected by the soil.
- An animal could escape the heat by burrowing underground.

Which of these statements are supported by the data in **Figure 2**? (Record all three digits of your answer in lowest-to-highest numerical order.)

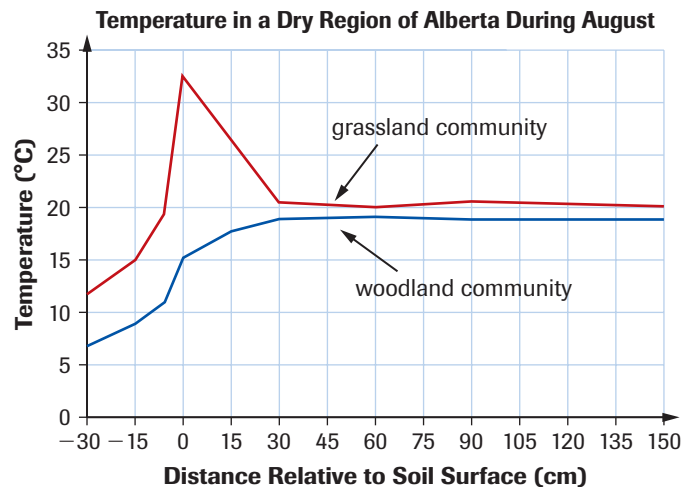


Figure 2

- Biodiversity can be explained as
 - the number of different species found in an ecosystem
 - the different traits found within a species
 - the number of organisms of the same species within a population
 - the number of organisms of different extinct species within a population

7. Identify which choice gives two correct reasons why scientists are concerned about a reduction in the frog population.
- Frogs are indicator species because they are interconnected to all species in an ecosystem. Frogs are sensitive to changes in sunlight.
 - Frogs have survived more than 400 million years. Frog populations cannot withstand the coming of an ice age.
 - Frogs are a part of two different ecosystems (fresh water and terrestrial). Frogs belong to two different food chains.
 - Frog populations have been slowly decreasing for the past 100 million years and now the population is increasing. Frogs are indicator species used to predict changes in the ozone layer.
8. Identify the choice in which the terms *organism*, *population*, *community*, *ecosystem*, and *biosphere* are all correctly defined.
- An organism is a distinct form of life, classified as a separate species. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.
 - An organism is the biotic community and its physical environment. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is a distinct form of life, classified into separate species. The biosphere is the area of Earth in which life is found.
 - An organism is the populations of all species that occupy a habitat. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is a population of the same species, occupying a given area at a certain time. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.
 - An organism is a distinct form of life, classified as a separate population. A population is a group of organisms of different species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.
- (c) how the rapid increase in the population of a species has affected another species.
10. **Why** might a species be classified as endangered?
11. (a) In your own words, **describe** the classification system for at-risk species.
(b) **Why** is a classification system like this useful?
12. **Identify** whether each of the following species is extinct, endangered, extirpated, threatened, or vulnerable. **Explain** your classification.
- The wood turtle is found in pockets throughout southern Ontario, southern Quebec, New Brunswick, and Nova Scotia. The number of wood turtles in Canada seems to be stable, but in the United States their numbers are decreasing as many are being taken from the wild into homes as pets.
 - Furbish's lousewort is a tall herb that grows on riverbanks. In Canada, it grows only on a 200-km stretch of the Saint John River in New Brunswick. Forestry, farming, and flooding caused by hydroelectric dams all affect the area in which it lives.
 - The greater prairie chicken has not been seen in Ontario, Manitoba, or Alberta for many years. It was last seen in Saskatchewan in 1977. It can still be found in the prairie states of the United States.
13. (a) A decline in the number of frogs would affect other species. Using the term *food chain*, explain how the decline would affect insects and algae.
(b) In a paragraph, **explain** the differences between the two food chains to which the frog belongs. **Describe** the role of the frog in each chain.
14. **Outline** in a list things that you could do, or avoid doing, that might help frogs to survive. Identify the things that would be easy for you, and those that would demand sacrifices. Would you be willing to do the hard things to save frogs? **Explain** your answer.
15. The common cockroach is not at risk of extinction. In fact, it is one of the species that have benefited from human activities.
- Hypothesize** about which human activities benefit the cockroach.
 - If a chemical company invented a spray that could kill all cockroaches, would it be acceptable to use the spray to make the cockroach extinct? **Explain** your position in a letter to the chemical company.
16. The bald eagle is not listed as at risk in Canada. Should resources be used to help restore this bird in the prairie provinces? **Justify** your answer.
17. Research the disappearance of the whooping crane from Wood Buffalo National Park along the Alberta–Saskatchewan border and **summarize** your findings in a report.

Part 2

9. Human interference often causes ecosystems to change. **Illustrate** with an example
- how human interference has caused an increase in the population of a species.
 - how human interference has caused a decrease in the population of a species.

Energy Flow in the Biosphere

In this chapter

-  Exploration: Competition between Plants
-  Chemistry Connection: Chemical Bonds
-  Investigation 2.1: Constructing Food Webs
-  Web Activity: Designing Food Webs
-  Investigation 2.2: Light Intensity and Plant Biomass

The source of almost all of the energy on Earth is the Sun. Much of the energy that reaches Earth's atmosphere is filtered out before it reaches the surface (**Figure 1**). Only a tiny portion is actually used by green plants for photosynthesis (**Figure 2**). However, as this chapter will discuss, almost all organisms on Earth depend on this energy.

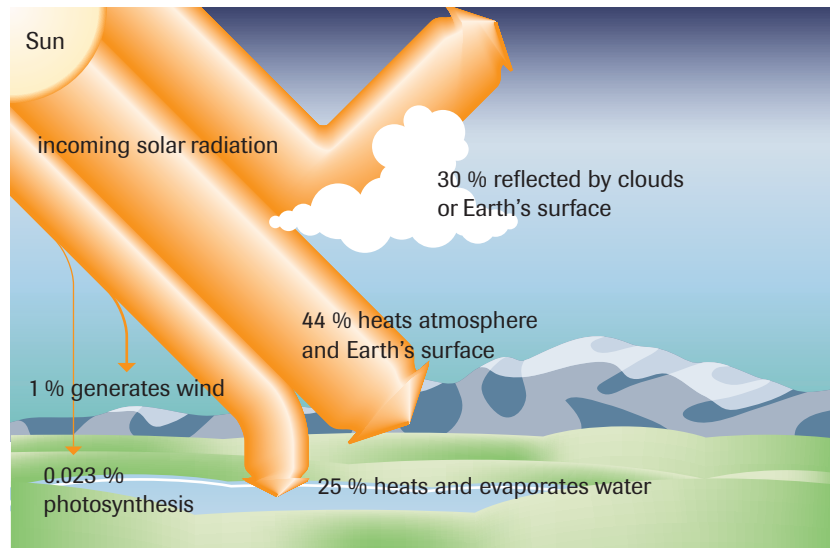



Figure 1

A model of the flow of energy from the Sun, to Earth, and back into space

STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. Predict how increased cloud cover or pollution haze would affect a forest ecosystem.
2. The text above states that the Sun is “the source of almost all of the energy on Earth.” What other source(s) can you think of? How important is each energy source?
3. Is it possible for food chains to exist in a cave or the ocean depths where no sunlight can penetrate? Explain why or why not. 

 Career Connection:
Geographer



Figure 2

Photosynthesis is the process by which green plants use solar energy to produce carbohydrates (sugars), which can then be used as food by other organisms. Plants compete for solar energy. In this mixed forest, the various plant species have adaptations that allow them to avoid or tolerate the shade of the plants around them.

► **Exploration**

Competition between Plants

Changes in the biotic or abiotic factors within an ecosystem often cause one plant community to replace another. In turn, changes in the plant community are accompanied by changes in the animal community. In this activity, you will determine which plant species has an advantage under certain conditions. Each research group can study a different set of variables.

Materials: apron, milk cartons, 9 kinds of vegetable or flower seeds, potting soil, water



Always wash your hands after handling soil.

- As a class, decide on the types of seeds you will plant in each milk carton.
- Fill milk carton with moist potting soil. Divide the soil surface into nine squares.
- In each square, plant two seeds of one of the species according to the instructions on the packets. Water each carton with the same amount of water every second day. Record the amount of water used.
- Once seeds start to germinate, store each carton in a different environment. You could use amount of sunlight, temperature, or amount of water as variables.

- Measure the growth of each plant daily. Record any other observations.
 - (a) Does one type of plant begin to dominate the community? Is it the same type of plant in all cartons?
 - (b) Choose the most successful plant you grew. Do research to answer these questions: In what environment is this plant naturally found? What does this environment have in common with the conditions you set in the exploration?
 - (c) Speculate about why one plant might be better adapted for a specific environment than another.



2.1 Energy Transfer and Food Webs

trophic level a category of living things defined by how it gains its energy; the first trophic level contains autotrophs, and each higher level contains heterotrophs

autotroph an organism that uses the Sun's energy and raw materials to make its own food; a producer

primary consumer in a food chain or food web, an organism that relies directly on autotrophs for its source of energy; organisms at the second trophic level

secondary consumer in a food chain or food web, an organism that relies on primary consumers for its principal source of energy; organisms at the third trophic level

heterotroph an organism that is incapable of making its own food, and so must feed on other organisms to gain energy

You can begin to understand how energy flows through ecosystems by categorizing living things by their **trophic level**, according to how they gain their energy. The term *trophic* comes from a Greek word meaning “feeder.”

Organisms that can make their own food from basic nutrients and sunlight or some other non-living energy source are placed in the first trophic level (**Figure 1**). Not surprisingly, these organisms are also referred to as producers or **autotrophs** (from Greek words meaning “self-feeders”). Plants, algae, and some types of bacteria are in the first trophic level.

The second trophic level contains organisms that feed on the producers. These organisms are referred to as **primary consumers**. Primary consumers rely on autotrophs directly for their source of energy.

Secondary consumers are animals in the third trophic level. They rely on primary consumers for their source of energy, but they are still dependent on the autotrophs in the first trophic level. Although a wolf eats other animals, it still relies indirectly on the photosynthesis of plants for energy. The deer that the wolf eats has eaten grass or the buds of a spruce tree.

Consumers, at whatever trophic level, are sometimes called **heterotrophs**. Heterotrophs cannot make their own food, and so must obtain their food and energy from autotrophs or other heterotrophs. Human beings are heterotrophs.

DID YOU KNOW?

An Alternative View

One Aboriginal approach to trophic levels is to rank them according to dependence. Primary consumers depend on autotrophs, and secondary consumers depend on the primary ones. Humans are the most dependent consumers.

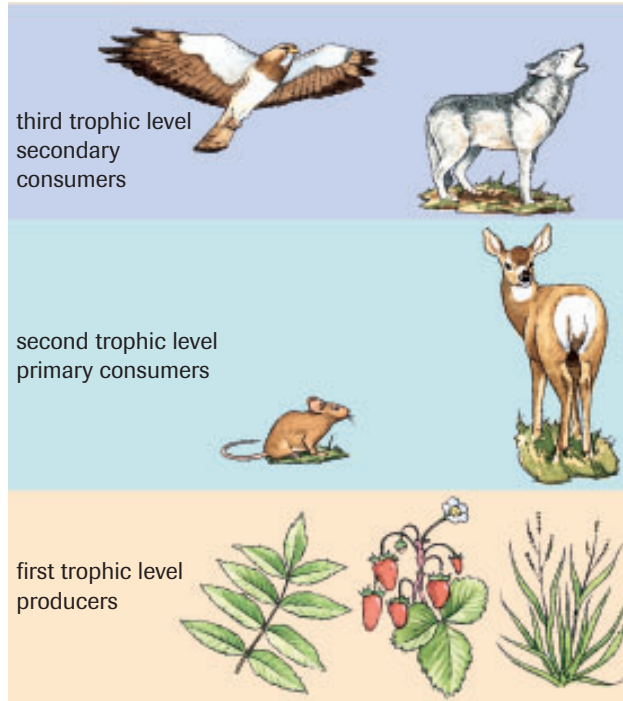


Figure 1 

Trophic levels, showing producers and consumers. An ecosystem may contain more than three trophic levels.

Energy and Food Chains

Every organism within an ecosystem provides energy for other organisms. Food chains are a way of showing a step-by-step sequence of who eats whom in an ecosystem. The sequence in **Figure 2** shows a one-way flow of energy in a simple food chain from producer to secondary consumer. The deer does not make its own energy; instead, it relies on the spruce tree. The deer is a heterotroph. Since the deer receives its energy two steps away from the original source (sunlight), it is in the second trophic level. Using the same reasoning, the wolf, also a heterotroph, is a member of the third trophic level.

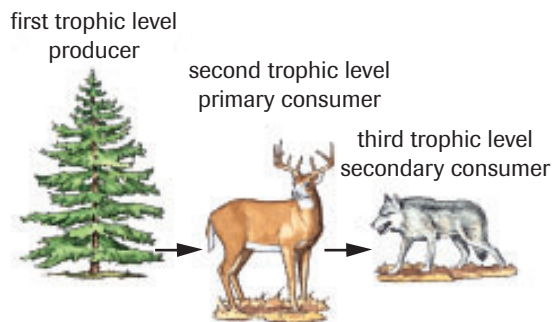


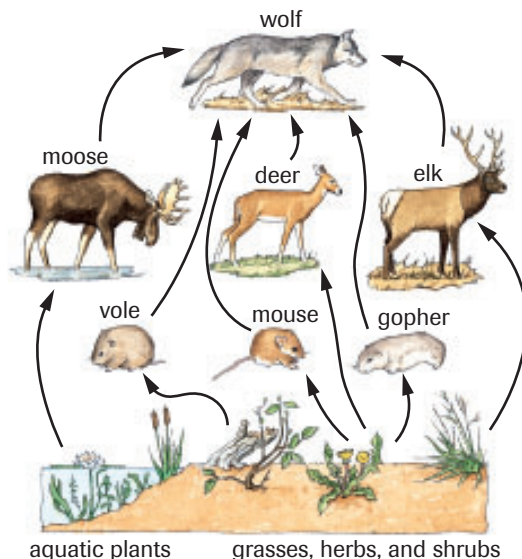
Figure 2

In this food chain, energy flows from a producer (the spruce tree), to a primary consumer (the deer), to a secondary consumer (the wolf).

Consumers are placed in categories based on their trophic level in a food chain. A carnivore directly feeding on a primary consumer is a secondary consumer. However, if the carnivore eats a secondary consumer (another carnivore), it is now a tertiary consumer—it is at the fourth trophic level. The final carnivore in any food chain is called a top carnivore. Top carnivores are not eaten by other animals (at least, while they are alive). In the example above, the wolf is both a secondary consumer and a top carnivore, since it obtains its energy from the deer and no other animal eats the wolf.

Food Webs

The food chain shown in **Figure 2** would be highly unlikely to include all the organisms in a natural ecosystem. In reality, deer also eat buds, stems, bark, and grasses. The wolf includes in its diet many different animals, such as rabbits, ground-nesting birds and their eggs, beavers, and muskrats. Each individual organism in an ecosystem is involved in many food chains. The chains all interlock with each other to form a feeding relationship called a **food web** (**Figure 3**).



+ EXTENSION



Decomposers

Decomposers do not always fit neatly into one position in food webs or trophic levels. Listen to this Audio Clip to learn more about the role of decomposers in ecosystems.

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food web a representation of the feeding relationships among organisms in an ecosystem

Figure 3

A simplified food web shows the wolf as the top carnivore and plants as producers. Notice that both the vole and the deer belong in the second trophic level of this web. Of course, in a real ecosystem, the food web would be much more complicated. It would include most of the organisms in the ecosystem.



CHEMISTRY CONNECTION

Chemical Bonds

Your Chemistry textbook has more information on the nature of chemical bonds, and energy changes during bond-making and bond-breaking.

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photosynthesis the process by which green plants and some other organisms use solar energy, carbon dioxide, and water to produce carbohydrates

cellular respiration the process by which cells break down glucose into carbon dioxide and water, releasing energy

chemosynthesis the process by which non-photosynthetic organisms convert inorganic chemicals to organic compounds without solar energy

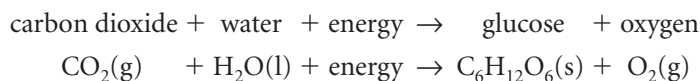
chemoautotroph an organism that can synthesize organic compounds from inorganic chemicals without using solar energy

The most stable ecosystems, those with the greatest biodiversity, have such complex and well-developed food webs that the reduction in numbers or even the complete removal of one type of organism may have only a small effect on the overall web. Predict what would happen to the organisms in **Figure 2**, on the previous page, if deer depended exclusively on the buds of spruce trees for food, and spruce budworm were introduced. Spruce budworms also eat the buds of spruce trees. What would happen to the deer and the wolves if spruce budworms ate most of the spruce buds? If this food chain showed all the organisms in the ecosystem, you would predict that the deer and wolves would be deprived of food and would die. In fact, if spruce budworms eat most of the spruce buds, deer may switch to another tree or grass, and wolves may not be much affected.

However, where abiotic factors limit the number of organisms, the webs begin to look more like food chains. This is particularly true in the Arctic, where the number of producers is small. Because there is less energy available from the Sun and temperatures are often low, producers in the Arctic cannot photosynthesize as rapidly as they do in the south. Less energy is available, so fewer organisms can live in that ecosystem. The limited number of organisms means that their relationships with each other are more direct. In these situations, the loss of any one member will have a profound effect on all the remaining organisms. The lower the biodiversity of an ecosystem, the simpler the food web, and the more vulnerable each organism is to changes in the ecosystem.

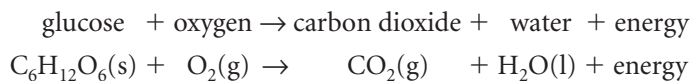
Photosynthesis and Respiration

Food webs always begin with autotrophs, such as plants. All living things use some form of chemical energy for food. Green plants make their own food by using carbon dioxide (CO_2) and water (H_2O), plus energy from sunlight, to make molecules of a sugar, glucose ($\text{C}_6\text{H}_{12}\text{O}_6$). This process, called **photosynthesis**, captures solar energy and stores it in the chemical bonds of glucose. You can read more about photosynthesis in Chapter 6. The reaction below summarizes photosynthesis.



Since photosynthetic organisms are at the first trophic level, photosynthesis ultimately provides the energy required by the entire ecosystem. Photosynthesis absorbs energy from an abiotic component of an ecosystem (sunlight) and moves it into biotic components (green plants). As one moves up through the trophic levels of an ecosystem, this energy is then transferred to different organisms through the food they eat.

All organisms, including plants, undergo **cellular respiration** in order to use the energy in their food. Cellular respiration breaks down glucose, releasing the energy stored in its bonds. Some of this energy is used to fuel cell processes, and some is released in the form of thermal energy. You can read more about cellular respiration in Chapter 7. The reaction below summarizes cellular respiration.



If you look at the two reaction equations, you will see that they are the reverse of one another. The processes of photosynthesis and cellular respiration are therefore said to be complementary. Since these two processes are complementary, a balance of oxygen and carbon dioxide is maintained within any ecosystem. The plants produce oxygen and glucose during photosynthesis, while all organisms produce carbon dioxide and water

during cellular respiration (Figure 4). Since plants carry out both photosynthesis and respiration, you might think that plants could maintain the balance between oxygen and carbon dioxide themselves. However, plants produce about nine times the amount of oxygen by photosynthesis that they use up in cellular respiration.

Chemosynthesis

Not all food webs begin with photosynthetic organisms. In a few ecosystems, such as in caves or the deep oceans, producers convert simple molecules into more complex compounds without solar energy, by a process called **chemosynthesis**. These bacteria are **chemoautotrophs**, which are organisms that require only carbon dioxide, water, and an energy source (other than solar energy) to make nutrients. Chemical energy is extracted from inorganic chemicals such as hydrogen sulfide (H_2S), ammonia (NH_3), ferrous ions (Fe^{2+}), or sulfur (S_8).

In sulfur hot springs, such as those in Banff National Park, thermal energy generated within Earth's crust heats underground water, which is then released through vents in the rock. Some bacteria use the thermal energy to convert dissolved hydrogen sulfide and carbon dioxide into organic compounds. These bacteria, as producers, become a food source for tiny consumers in this ecosystem. Figure 5 shows a food chain that depends on chemosynthesis.

Limits on Energy Transfer

Every time energy is transferred between the components of an ecosystem, the amount of energy available to the next trophic level is reduced. Why? One reason is that whenever energy is transferred, some of the energy is transformed to a different form. Some energy is released as thermal energy during cellular respiration. Some of it is converted to other chemical energy in molecules other than glucose. The organisms at the next trophic level may not be able to use all these molecules as a source of energy. Let's return to the simple spruce → deer → wolf food chain.

- Through photosynthesis, producers such as the spruce tree use solar energy to make molecules of glucose. The plant then uses most of that energy to carry out the processes it needs to live and to manufacture the chemicals it needs to grow. Therefore, not all of the chemical energy captured during photosynthesis is available to an animal that eats the spruce tree.
- Primary consumers, such as the deer, rely on the chemical energy produced by plants to sustain their lives. A deer does not digest all of a meal of spruce buds. Some is eliminated in the deer's feces (wastes). Some of the remaining energy is lost as thermal energy during the chemical transformations of digestion. Some of the remainder is used to fuel the deer's cells through cellular respiration, which also releases thermal energy. Some of that thermal energy is used to maintain the deer's body temperature, but eventually all of the thermal energy released is lost to the surrounding air. Only about 10 % of the energy in the spruce buds is transferred to the deer. It uses this energy to move its limbs, pump its blood, and manufacture the molecules it needs to carry out its life processes and grow.
- Like the deer, the wolf loses some of the energy in its meal during digestion and body maintenance. Therefore, only about 10 % of the energy in the wolf's meal is transferred to the wolf.

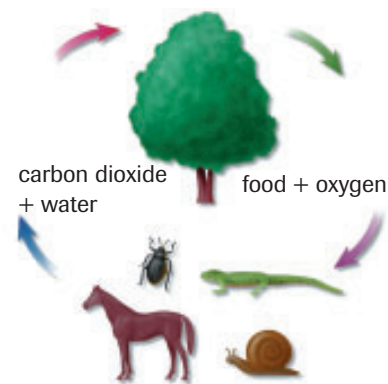


Figure 4

The byproducts that plants release in photosynthesis support animals. The waste products that both animals and plants produce in cellular respiration support plants.

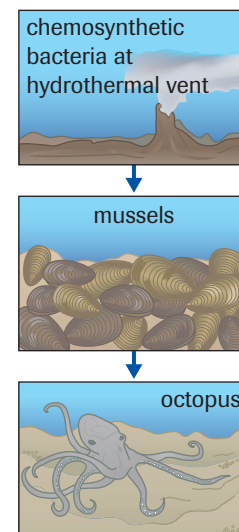


Figure 5

In this food chain, bacteria use the thermal energy from hydrothermal vents on the ocean floor to make nutrients.

+ EXTENSION

Chemosynthetic Food Chains

Listen to a discussion of energy sources that may be used by chemoautotrophs.

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In all food chains, whether the producers are photosynthetic organisms or chemoautotrophs, the farther up the chain you travel, the less energy is available (**Figure 6**). In every ecosystem, less energy is available to secondary consumers than to primary consumers. In general, the overall loss of energy at each step limits the number of trophic levels in a food chain to about five. This is supported by the laws of thermodynamics.

Laws of Thermodynamics

thermodynamics a scientific study of energy transformations, described by laws

Thermodynamics is the study of energy transformations. The energy flowing from the Sun through ecosystems illustrates the laws of thermodynamics.

- The *first law of thermodynamics* states that although energy can be transformed (changed) from one form to another, it cannot be created or destroyed.
- The *second law of thermodynamics* states that during any energy transformation, some of the energy is converted into an unusable form, mostly thermal energy, which cannot be passed on. Each time energy is transformed, some energy is lost from the system. As a result, the amount of energy available in each step of a chain of transformations is always less than the amount of energy available at the previous step. This applies to all systems, including food chains (**Figure 7**).

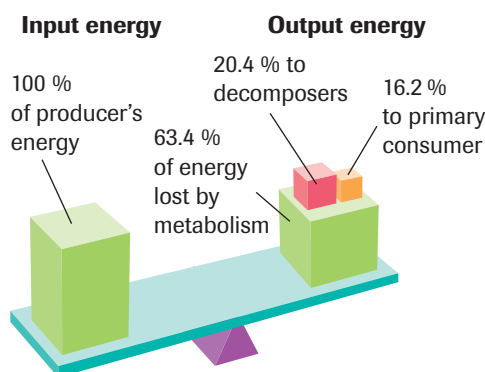


Figure 6

Most of the energy transformed from solar energy to chemical energy by a plant is used to maintain the plant and to grow. Every time the plant uses some of its energy store, it also loses energy as thermal energy. As a result, when the plant is eaten, only a small amount of energy is available for the primary consumer and decomposers.

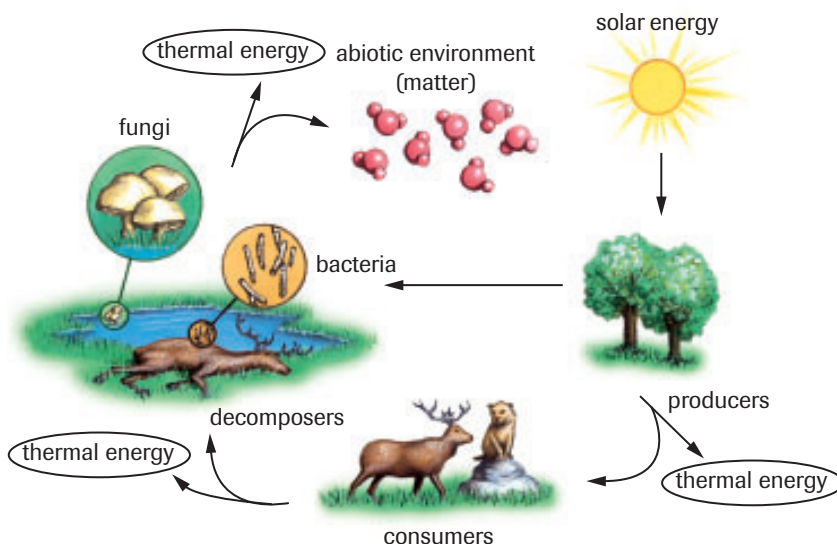


Figure 7

According to the second law of thermodynamics, energy is lost each time energy is transferred from one organism to another, and inside each organism as it uses the energy to survive.

INVESTIGATION 2.1 Introduction

Constructing Food Webs

In Part 1 of this Investigation, you will research an Antarctic ecosystem and connect the organisms in a food web. In Part 2, you will construct a food web of organisms found in your community.

Report Checklist

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| <input type="radio"/> Purpose | <input checked="" type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input type="radio"/> Problem | <input checked="" type="radio"/> Materials | <input type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input checked="" type="radio"/> Procedure | <input type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

To perform this investigation, turn to page 35.



Web Quest—Designing Food Webs

There are many different food webs in our world, some containing familiar organisms, others filled with exotic species. Drawing food webs by hand and analysing them can be difficult. In this Web Quest, you will use the computer to build a food web. You can then easily study the interactions by adding and removing organisms and seeing the result.

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SUMMARY *Energy Transfer and Food Webs*

- Food chains describe relationships between lower and higher trophic levels and describe the flow of energy within an ecosystem.
- Energy is transferred to organisms at the next trophic level in a food chain or food web. At each transfer, some energy is transformed into thermal energy and is no longer available.
- During photosynthesis, plants use solar energy to combine carbon dioxide and water. Photosynthesis can be summarized by the equation:

$$\text{carbon dioxide} + \text{water} + \text{energy} \rightarrow \text{glucose} + \text{oxygen}$$
- The energy required for almost all living organisms originates with solar radiation, which is converted to chemical energy during photosynthesis and stored in the chemical bonds of sugars such as glucose. In the cells, cellular respiration breaks down the chemical bonds, releasing the energy to be used for growth and metabolism. Cellular respiration can be summarized by the equation:

$$\text{glucose} + \text{oxygen} \rightarrow \text{water} + \text{carbon dioxide} + \text{energy}$$
- Chemoautotrophic organisms produce chemical energy without solar energy, and provide the base of food pyramids in those rare ecosystems with little or no sunlight.

▶ Section 2.1 Questions

1. In your own words, explain what is meant by the term *trophic level*.
2. What type of food would be consumed by a secondary consumer? Explain your answer.
3. Distinguish between a food chain and a food web. Give examples of each.
4. Identify the reactants and products for the chemical reaction of photosynthesis.
5. Identify the reactants and products for the chemical reaction of cellular respiration.
6. What source of energy is used by chemosynthetic bacteria to make organic compounds?
7. In your own words, explain the first and second laws of thermodynamics.
8. Explain why only about 10 % of the energy available in a plant is transferred to the primary consumer.

2.2 Scientific Models

DID YOU KNOW?

Speed and the Dinosaur

From fossil evidence, some scientists suggested that *Tyrannosaurus rex* was capable of speeds in excess of 70 km/h. However, by using mathematical models, other scientists have calculated that *T. rex* would be killed if it ever tripped. The tiny forelimbs were much too small to offer protection to such a heavy animal at such speeds. They calculated that *T. rex* would skid for more than 40 metres after tripping if it ran at such speeds. Falling would create a force on the chest equivalent to a 36 tonne mass (352 800 N), easily crushing the dinosaur's ribs. Even greater damage would occur to the head. A fall would apply a force equivalent to a 13.6 tonne mass (133 820 N), enough to snap its neck. These new calculations have caused scientists to estimate that *T. rex* likely didn't run any faster than 15 km/h.

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ecological pyramid a representation of energy flow in food chains and webs

Scientists often construct models to help them understand how living things function. Models are theoretical descriptions or analogies that help us visualize something that has not been directly observed. For example, a scientist might reconstruct the climatic conditions of 65 million years ago to uncover what might have happened to the dinosaurs. Indirect fossil evidence is used to gather information on weather patterns and vegetation cover in an ecosystem. Plants such as ferns are unable to live in hot, arid conditions or in extreme cold. When fossils of ferns are found, scientists are able to make inferences about climate range.

The advantage of scientific models is that they provide a pathway for making predictions. Scientists often use mathematical models, which exist only as equations, to help them understand biological observations. There are three essential steps in formulating a mathematical model:

1. making an estimate and developing an equation based upon indirect data and background information;
2. computing the prediction implied by the equation; and
3. comparing the prediction with future or past events. Supporting evidence is gathered to make sure that the mathematical model does not support just one situation. If this is ever shown to be the case, then the model is rejected.

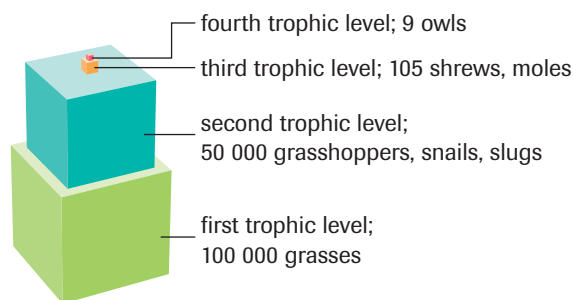
A good mathematical model can be used to test and predict the implications of many different courses of action. By being tested on past events, the model gains acceptance in predicting future events.

Ecological Pyramids

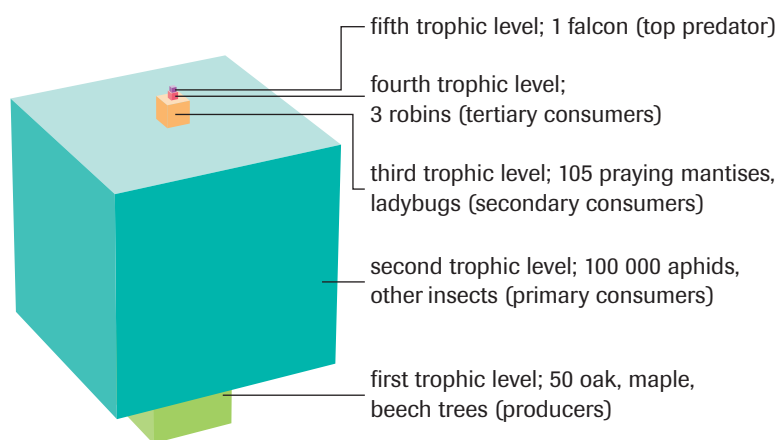
Graphs called **ecological pyramids** can be used to represent energy flow in food chains and food webs or the populations of organisms in a food chain. These graphs help the ecologist visualize more clearly the relationships in an ecosystem and compare ecosystems.

Pyramids of Numbers

A pyramid of numbers can be drawn by counting the number of organisms at each trophic level in an ecosystem. When these numbers are then represented on a vertical graph, with the volume of each level representing the number of organisms at that level, the graph sometimes takes on the general shape of a pyramid (**Figure 1**, next page). However, ecologists have found that, in some cases, the shape is not like a pyramid because of the physical size of the members of a food chain. For example, many tiny aphids (an insect that feeds by sucking sap from plants) may be found feeding off a single plant (**Figure 2**, next page).

**Figure 1**

A pyramid of numbers for a grassland ecosystem. In this ecosystem, the number of producers is greater than the number of primary consumers.

**Figure 2**

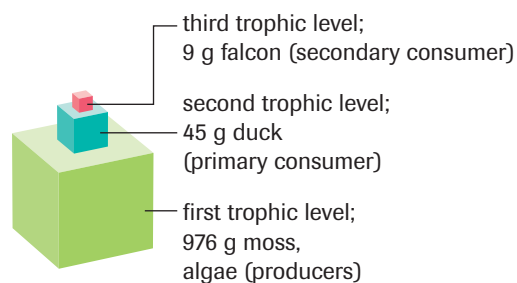
A pyramid of numbers for a deciduous forest ecosystem. Because an aphid is much smaller than a tree, a single plant may provide food for thousands of aphids.

Pyramids of Biomass

Biomass is the total dry mass of all the living material in an ecosystem. Since organisms store energy as organic molecules, biomass is a measure of stored energy content. To understand this idea, compare a rainforest ecosystem with a tundra ecosystem. Rainforest ecosystems are located in tropical areas with intense sunlight. A rainforest ecosystem would be able to store large amounts of energy from the Sun. As a result, it would contain a large amount of organic material and have a large total biomass. In contrast, tundra ecosystems are located in northern areas with less intense sunlight and long, dark winters. A tundra ecosystem would be able to store less energy, and thus would contain a smaller amount of organic material and have a lower total biomass.

A pyramid of biomass is a useful way to represent an ecosystem. To make such a pyramid, the dry mass (after water has been removed) of the tissue in the plants or animals is measured and graphed (**Figure 3**). Occasionally, a graph of biomass is not a regular pyramid. Such ecosystems, however, are rare.

biomass the total dry mass of all the living material in an ecosystem

**Figure 3**

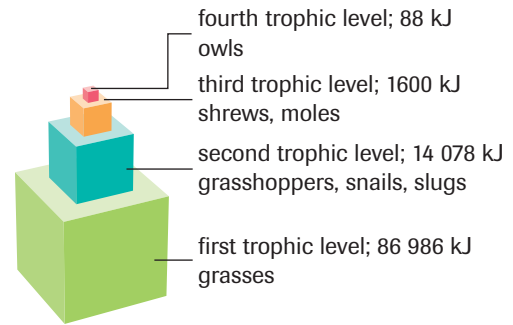
A pyramid of biomass for a Newfoundland peat bog. The numbers represent the dry mass (g) for all organisms at that trophic level found in 1 m². As you can see, there is less biomass at each trophic level.

Pyramids of Energy

It is possible to measure the amount of energy available at each trophic level. Creating a pyramid graph allows us to better understand the relationships and energy flow (**Figure 4**, next page). The comparatively larger mass of the individual tertiary consumers and the vast amount of energy that they expend while hunting limits the number of individuals that can be supported at the top position of the pyramid.

Figure 4 

A pyramid of energy for a grassland ecosystem. At each level, the energy found in the bodies of the organisms is graphed. The larger the volume of the level, the greater the energy at that level. As you can see, only about one-thousandth of the chemical energy from photosynthesis stored in the producers in this food web actually reaches the top predator (the owl) at the fourth trophic level. Energy is measured using joules (1000 joules (J) = 1 kilojoule (kJ)).



As you learned in the previous section, most of the energy at each level of a food chain is used and/or lost as heat. Only a fraction of the energy passes from one level of a food chain to the next. This fraction is often said to be about $\frac{1}{10}$, or 10 %. Although this number is just an approximation, it can be useful for making estimations. For example, if the grasses in an ecosystem produce 1×10^{10} kJ of energy per year, you can estimate that the primary consumers in that ecosystem can only obtain 1×10^9 kJ per year by eating the grasses. Secondary consumers will only obtain about 1×10^8 kJ per year. (Note that these estimations are extremely simplified. Calculations are more often done for energy per gram, or per square metre, rather than for an entire ecosystem.)

Look at the sample exercise below to learn how to create two- and three-dimensional pyramids. The second sample exercise shows how to calculate energy loss through a food chain.

SAMPLE exercise 1

Pyramids of energy are graphical representations that show energy flow in food chains and webs. As energy is lost, fewer organisms can be supported at each successive level. The base of the pyramid always indicates the total amount of energy held by producers. Use the data in **Table 1** to construct a two-dimensional energy pyramid.

Table 1 Energy Pyramid Data

Trophic level	Energy (kJ)	Area of the box (mm ²)
producers (first trophic level)	100 000	1 000
consumer (second trophic level)	15 000	
consumer (third trophic level)	1 000	

Solution

1. Establish a ratio between the area of the box and the amount of energy held by the producers. For two-dimensional pyramids, the amount of energy held by producers is displayed as a ratio of the area of the box at the base of the pyramid.

$$\begin{aligned} \text{energy} &= \text{area of the box at the base of the pyramid} \\ 100\,000 \text{ kJ} &= 1000 \text{ mm}^2 \end{aligned}$$

2. Determine length and width of the producer box.

$$\begin{aligned} 1000 \text{ mm}^2 &= \text{width} \times \text{length} \\ 1000 \text{ mm}^2 &= 20 \text{ mm} \times 50 \text{ mm} \end{aligned}$$

Draw the box with these dimensions (**Figure 5 (a)**, next page).

3. Use the ratio for producers to establish the size of the box for second-level consumers.

$$\frac{\text{area of box for producer}}{\text{energy of producer}} = \frac{\text{area of box for second-level consumer}}{\text{energy of second-level consumer}}$$

$$\frac{1000 \text{ mm}^2}{100\,000 \text{ kJ}} = \frac{x}{15\,000 \text{ kJ}}$$

$$x = \frac{1000 \text{ mm}^2 \times 15\,000 \text{ kJ}}{100\,000 \text{ kJ}}$$

$$x = 150 \text{ mm}^2$$

4. Determine the length and width of the second-level consumer box.

$$150 \text{ mm}^2 = \text{width} \times \text{length}$$

$$150 \text{ mm}^2 = 30 \text{ mm} \times 5 \text{ mm}$$

Draw the box with these dimensions on top of the producer box (**Figure 5 (b)**).

5. Repeat for the third-level consumer box.

$$\frac{\text{area of box for producer}}{\text{energy of producer}} = \frac{\text{area of box for third-level consumer}}{\text{energy of third-level consumer}}$$

$$\frac{1000 \text{ mm}^2}{100\,000 \text{ kJ}} = \frac{x}{1000 \text{ kJ}}$$

$$x = \frac{1000 \text{ mm}^2 \times 1000 \text{ kJ}}{100\,000 \text{ kJ}}$$

$$x = 10 \text{ mm}^2$$

6. Determine the length and width of the third-level consumer box.

$$10 \text{ mm}^2 = \text{width} \times \text{length}$$

$$10 \text{ mm}^2 = 5 \text{ mm} \times 2 \text{ mm}$$

Draw the box (**Figure 5 (c)**).

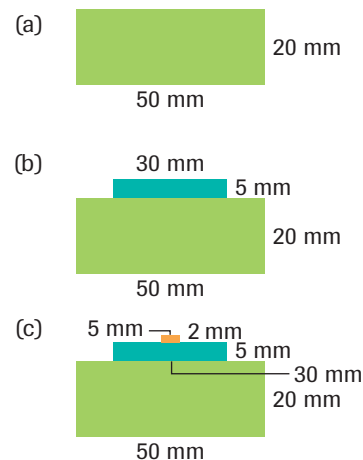


Figure 5
Constructing an energy pyramid

Practice

1. Draw two-dimensional and three-dimensional pyramids using the data in **Table 2**, of an Alberta mixed woodland ecosystem.

Table 2 Pyramid of Numbers

Trophic level	Number of organisms
producers (trees and shrubs) first trophic level	100
consumers (insects, slugs, snails) second trophic level	9800
consumers (ladybugs, praying mantises) third trophic level	500
consumers (shrews, moles, robins) fourth trophic level	10
consumers (hawks, falcons, snakes) fifth trophic level	3

▶ **SAMPLE** exercise 2

As shown below, phytoplankton are at the base of an ocean food chain.

phytoplankton → zooplankton → herring → salmon

- (a) If the phytoplankton in an ecosystem produce 20 000 000 kJ of energy per day, how much energy is available for the salmon?
- (b) Suppose each herring requires 1000 kJ of energy per day to survive. How many herring can this ecosystem support?

Solution

- (a) Assume that 10 % of the energy passes from each level of the food chain to the next. Calculate the amount of energy that reaches the top level of the food chain.
- $$20\,000\,000\text{ kJ} \times 0.10 = 2\,000\,000\text{ kJ (energy that will reach the zooplankton)}$$
- $$2\,000\,000\text{ kJ} \times 0.10 = 200\,000\text{ kJ (energy that will reach the herring)}$$
- $$200\,000\text{ kJ} \times 0.10 = 20\,000\text{ kJ (energy that will reach the salmon)}$$
- Thus, 20 000 kJ of energy is available for the salmon each day.
- (b) You know that 200 000 kJ of energy is available for the herring each day. Divide this number by the amount of energy required by each herring.
- $$200\,000\text{ kJ} \div 1000\text{ kJ/herring} = 200\text{ herring}$$
- The ecosystem can support 200 herring.

▶ **Practice**

2. Draw a two-dimensional energy pyramid for the following food chain. Use the data from the sample exercise and solution.
- phytoplankton → zooplankton → herring → salmon
3. An ecosystem contains 1000 bushes and grasses. Each produces about 10 000 kJ of energy per day.
- (a) How many rabbits can be supported by this ecosystem, if each rabbit requires 5 000 kJ of energy per day?
- (b) How many foxes can be supported by this ecosystem, if each fox requires 10 000 kJ of energy per day?
- (c) Draw a pyramid of numbers for this ecosystem.



INVESTIGATION 2.2 Introduction

Report Checklist

Light Intensity and Plant Biomass

Through photosynthesis, plants capture solar energy and use it to combine water and oxygen into glucose. Glucose is then used to fuel its cellular activities and to build other molecules required by the plant. These molecules are used in plant growth, which increases the mass and size of the plant. How does light intensity affect plant biomass? In this investigation, you will design and carry out your own experiment to address this problem.

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| <input checked="" type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

To perform this investigation, turn to page 36.

Human Use of Energy in Ecosystems

Like all other living things, humans are dependent on the energy flow through ecosystems. We are part of many food chains at different levels. For example, a person eating vegetables is a primary consumer; a person eating steak is a secondary consumer; and a person eating salmon may be a tertiary consumer, depending on the salmon's diet. Unlike most other living things, humans also use the energy in ecosystems in other ways. For example, we burn wood for fuel, obtaining the energy trapped in it by photosynthesis.

Human use of the energy in an ecosystem often changes the ecosystem itself. Most ecosystems can adapt to small changes, such as the removal of a few salmon. Large-scale changes in ecosystems, however, often permanently change the types and sizes of populations of organisms found in that ecosystem. For example, humans have permanently changed many ecosystems in order to grow and hunt food. Hunting, fishing, and extensive crop growth have impacted many large ecosystems (Figure 6).

Hunting and Fishing

The science of wildlife management involves the manipulation of populations of wild species and their habitats for the benefit of humans. In the past, over-hunting of wild species such as wolves and buffalo have led to extirpation and large changes in ecosystems. Today, however, conservation groups like the Sierra Club and the Defenders of Wildlife recognize hunting and fishing as acceptable management tools.

A confrontation between technology and nature is unfolding in Canadian coastal waters. Improved factory ships, larger nets, improved technology for fish detection, and more boats have dramatically increased the harvest of marine fish. As a result, prized fish such as cod, halibut, and salmon have been drastically reduced. The pursuit of short-term economic gain at the expense of long-term economic collapse from overfishing is an important issue that governments must address.

Monocultures

Fossil records tell us that biological diversity has increased over time. About 150 different families of animals existed at the end of the Cambrian period 500 million years ago. Since then the number has increased to nearly 800 (Figure 7). This represents over two million species. However, most biologists will argue that this number is very conservative. There may be as many as 15 million different species of organisms now living on Earth.

Historically, humans have used about 700 different species of plants. According to the noted biologist Edward Wilson, today we rely heavily on about 20 species—wheat, rice, cotton, barley, and corn being the most important. Most human agriculture has

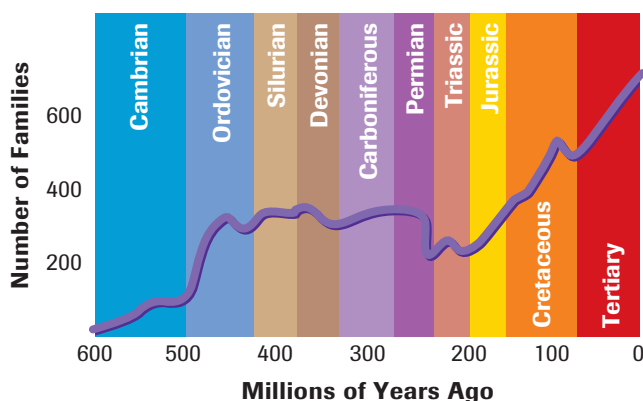


Figure 6

Cultivation of the land has disrupted many food chains. In Alberta, European settlers who selected monocultures of wheat and barley in favour of natural grasses contributed to a decline in the populations of mule deer, bison, elk, and moose, while increasing the range and number of whitetail deer.

CAREER CONNECTION



Geographer

Geographers study physical aspects of particular biological or physical regions. They often use satellite and imagery technologies to provide information on environmental issues, study the large-scale effects of human activity, or coordinate development plans with land-use planners. Learn more about geographer specializations and decide if this career direction is right for you.

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Figure 7

The graph shows a trend toward greater biodiversity.

monoculture cultivation of a single species



Figure 8
Many different species of plants can be found in a rain forest.

been directed at producing food crops. However, many wild plants are also important to humans. For example, the rosy periwinkle, a plant native to Madagascar, produces two important chemicals that are useful in treating Hodgkin's disease, a form of leukemia, or cancer of the white blood cells. Unfortunately, many wild plants have already been destroyed to grow food crops, especially in tropical rain forests.

The nutrient-poor soil of the tropical rain forests is not well suited for **monocultures** of cereal grains such as wheat and barley. These soils require the renewal of decomposed matter to maintain adequate levels of nitrogen and phosphorus. Nitrogen and phosphorus cycles should not be disrupted in the delicate rain forests (**Figure 8**). A few seasons after planting, the soil will no longer support the growth of crops. What makes the situation even more critical is that the greatest biodiversity exists in the tropical rain forests. Many species have yet to be classified, let alone investigated for possible medicines.

SUMMARY *Scientific Models*

- Mathematical models are theoretical models that exist as equations. These models are used to make non-intuitive and testable predictions that follow from simple assumptions.
- Environmental models allow scientists to study what could happen to organisms in an ecosystem if changes occurred. The models help check predictions without disrupting a large area.
- Pyramids of energy measure the amount of energy available at each trophic level.
- Pyramids of numbers can be drawn by counting the number of organisms at each trophic level in an ecosystem.
- Pyramids of biomass can be drawn by determining the dry mass of organisms.

► Section 2.2 Questions

1. What data would you need to collect to create an ecological pyramid of numbers?
2. What problem might you encounter if you tried to show energy flow through an ecosystem using a pyramid of numbers?
3. How might a pyramid of energy for a grassland community differ between summer and winter? Think about the effects the different abiotic conditions of each season might have on the ecosystem. Use your conclusions to draw a pyramid of energy for each season. Explain any differences between the two pyramids.
4. **Figure 9** shows pyramids of biomass and numbers for a deciduous forest. Explain why the two pyramids are different shapes.
5. Why do energy pyramids have their specific shape?
6. What would be the best source of energy for an omnivore: the plant or animal tissue it feeds on? Explain.
7. A field mouse eats 10 000 g of leaves each year, among other things. If each gram of leaves has absorbed 150 kJ of energy from the Sun, about how much energy is available for the mouse?
8. The producers in a closed ecosystem capture 1.5×10^9 kJ of energy from the Sun each year. The main food chain in the ecosystem has four levels.
 - (a) How much energy is available for the consumers at the top level?
 - (b) Draw a pyramid of energy for the food chain.
9. Despite warnings about future shortages and the pollutants released, we continue to burn oil and coal for energy. What evidence, if any, suggests that attitudes toward conservation are changing? Are they changing quickly enough?

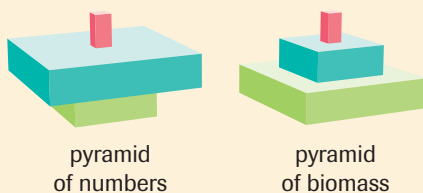


Figure 9

INVESTIGATION 2.1

Constructing Food Webs

Part 1: Antarctic Ecosystem

Research each of the organisms shown in the diagram (Figure 1) and connect them with a food web. Your teacher will provide you with an outline diagram of the organisms. Cut them out and stick them on another piece of paper. Use arrows to connect consumers with their food. Be prepared to explain how the organisms are interrelated.

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Report Checklist

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Part 2: Food Webs in Your Community

Using field guides, identify the organisms found in one of the following ecosystems within your community, and construct a food web:

- forested area
- park
- natural grassland
- lake or pond

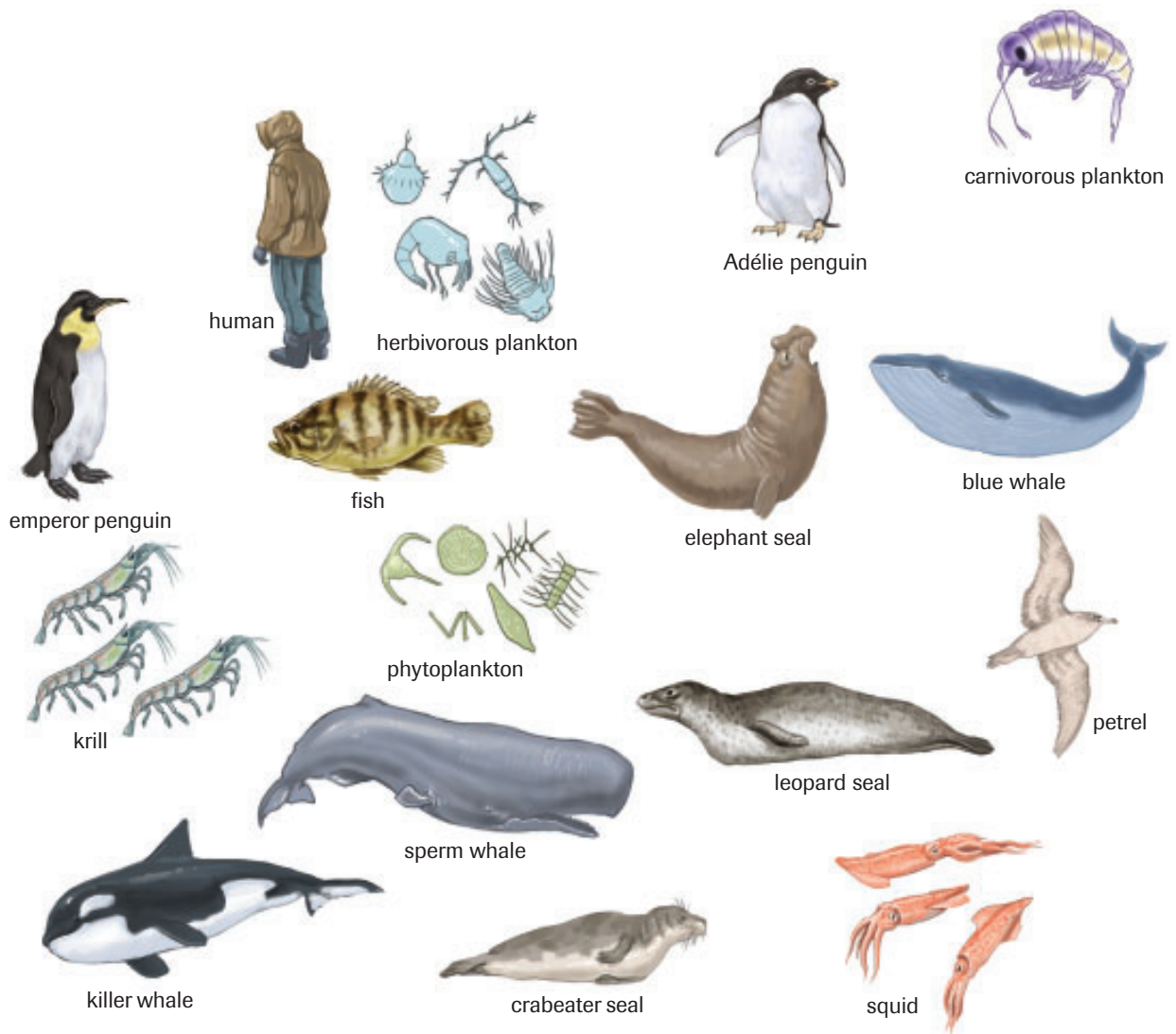


Figure 1

INVESTIGATION 2.1 *continued*

Design

- (a) What area did you choose to study?
- (b) How did you define the area of study?

Procedure

- (c) Provide your procedure.

Evidence

- (d) What organisms did you identify?

Analysis

- (e) Find out more about each organism. How does it fit into the food ecosystem? What does it eat? Which organisms prey on it?
- (f) Construct a food web.

INVESTIGATION 2.2

Light Intensity and Plant Biomass

Through photosynthesis, plants capture solar energy and use it to combine water and carbon dioxide to make glucose. Glucose is then used to fuel its cellular activities and to build other molecules required by the plant. These molecules are used in plant growth, which increases the mass and size of the plant.

Does plant biomass increase with light intensity? Make a prediction. Then, using the materials listed and the design given, write a procedure to address this problem. Make sure you include safety procedures in your design. When your teacher has approved your procedure, carry out the experiment. Ensure you collect the evidence in a clear manner that will allow you to evaluate it later. Your analysis should indicate whether your prediction was correct.

Purpose

To determine how light intensity affects plant biomass

EXTENSION

Constructing Scientifically Valid Procedures

Do you remember how to conduct investigations so that your data are reliable and valid? Listen to this audio clip for a quick review.

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Report Checklist

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| <input type="radio"/> Hypothesis | <input checked="" type="radio"/> Procedure | <input type="radio"/> Synthesis |
| <input checked="" type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

Materials

algae culture
filter paper
light source or access to sunlight
balance (mechanical or electronic)
funnel
two 250 mL beakers
light meter
plastic wrap
retort stand
clamp
graduated cylinder

Design

Plant biomass can be determined by filtering a given quantity from an algae culture and allowing the filter paper and algae to dry.

Outcomes

Knowledge

- explain, in general terms, the one-way flow of energy through the biosphere and how stored biological energy in the biosphere is eventually “lost” as thermal energy (2.1, 2.2)
- explain how biological energy in the biosphere can be perceived as a balance between both photosynthetic and chemosynthetic, and cellular respiratory activities, i.e., energy flow in photosynthetic environments and; energy flow in deep sea vents (chemosynthetic) ecosystems and other extreme environments (2.2)
- explain the structure of ecosystem trophic levels, using models such as food chains and webs (2.1, 2.2)
- explain, quantitatively, energy exchange in ecosystems, using models such as pyramids of energy, biomass, and numbers (2.2)
- explain the interrelationship of energy, matter and ecosystem productivity (biomass production) (2.2)
- explain how the equilibrium between gas exchanges in photosynthesis and cellular respiration influences atmospheric composition (2.2)

STS

- explain that scientific investigation includes analyzing evidence and providing explanations based upon scientific theories and concepts (2.1, 2.2)

Skills

- ask questions about observed relationships and plan investigations (2.1, 2.2)
- conduct investigations and use a broad range of tools and techniques by: performing an experiment to demonstrate solar energy storage by plants (2.2)
- analyze data and apply mathematical and conceptual models by: describing alternative ways of presenting energy flow data for ecosystems: pyramids of energy, biomass, or numbers (2.2)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms 

2.1

trophic level	photosynthesis
autotroph	cellular respiration
primary consumer	chemosynthesis
secondary consumer	chemoautotroph
heterotroph	thermodynamics
food web	

2.2

ecological pyramid	monoculture
--------------------	-------------

▶ **MAKE a summary**

1. Using scientific models, such as a pyramid of energy, draw a diagram that shows the one-way flow of energy through the biosphere. Briefly describe how stored energy in the biosphere is eventually lost as heat.
2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

▶ **Go To** 

The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 2
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

+ EXTENSION 



Lovin’ a Lichen

Dr. Irwin Brodo describes lichens—tiny creatures, part algae and part fungus, that are found in all parts of the globe. They are an integral part of the global food web.



Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

- Bracket fungi, mushrooms, and bread mould can be classified by ecologists as
 - producers
 - herbivores
 - carnivores
 - decomposers
- An example of an ecosystem in equilibrium would be
 - a grassland community in which the number of producers and consumers remains relatively constant over a number of years
 - a naturally occurring grassland community in which fire is prevented
 - a pond ecosystem in which the water temperature changes little throughout the year
 - a pond ecosystem in which the population of algae remains constant throughout the year
- Photosynthesis can best be explained by the following simplified equation.
 - $\text{CO}_2 + \text{H}_2\text{O} + \text{O}_2 \rightarrow \text{energy} + \text{C}_6\text{H}_{12}\text{O}_6$
 - $\text{CO}_2 + \text{H}_2\text{O} + \text{energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$
 - $\text{energy} + \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{O}_2$
 - $\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$

Part 2

- In your own words, **explain** what is meant by the term *top carnivore*. **Illustrate** your explanation by giving three examples of a top carnivore. **Identify** the ecosystem in which you would find each one.
- Sketch** a food web for a freshwater ecosystem in a dark cave.
- Using the example of a cat and a mouse, **explain** the factors that account for the loss of energy in the transfer from mouse to cat.

Use the following information to answer questions 7 to 9.

Figure 1 shows the flow of energy in an ecosystem.

- Illustrate** the first and second laws of thermodynamics using the components of **Figure 1**.
- Sketch** the predicted shape of an ecological pyramid of numbers using the organisms in **Figure 1**.

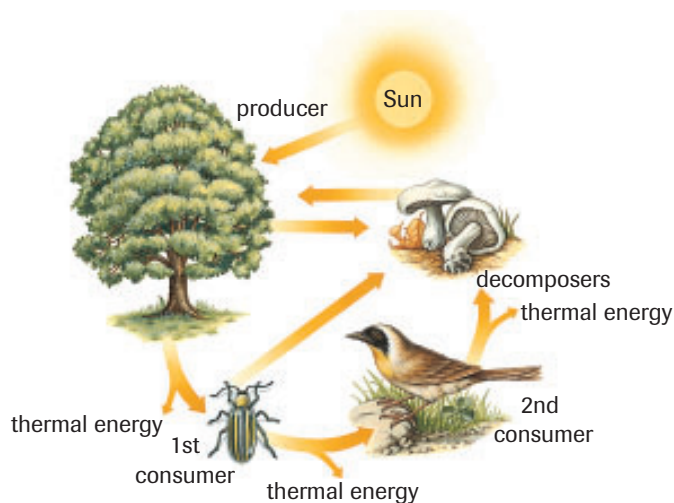


Figure 1

- Sketch** the predicted shape of an ecological pyramid of energy.

- Predict** whether each of the four ecosystems listed in **Table 1** can be sustained. A check mark indicates that the type of organism is present. Write a paragraph to **justify** each answer.

Table 1 Four Ecosystems

System	Autotrophs	Heterotrophs	Decomposers
1	✓		
2		✓	✓
3	✓		✓
4	✓	✓	

- In your own words, **explain** why photosynthesis and cellular respiration are considered to be complementary processes.
- Around the world, habitats available for wild animals have become smaller and smaller as the human population grows. Write a unified response addressing the following aspects of habitat loss.
 - Using an energy flow argument, explain why this shrinkage would affect animals in the highest trophic levels more severely than those in lower levels.
 - Describe** a way to protect wild habitat. How would your solution affect humans?
 - Identify** the type of habitat that might be at the greatest risk of collapse.
- Wolves often prey upon cattle or sheep as well as on natural species, such as deer. Earlier in the century it was considered beneficial to eliminate predators. **Describe** two harmful outcomes of this approach to managing predator populations.
- In underground caves, where there is permanent darkness, a variety of organisms exist. In terms of energy flow, **explain** how this is possible.

15. Based on what you have learned about energy pyramids, **criticize** the practice of cutting down rainforests to grow grain for cattle.
16. **Sketch** complex food webs for a tundra ecosystem and a middle-latitude woodland ecosystem. Conduct additional research to determine the members of the food web, if necessary.

www.science.nelson.com **GO**

- (a) Which ecosystem has the greatest biomass? **Explain.**
- (b) Which ecosystem has the greatest number of organisms? **Explain.**
- (c) Which ecosystem has the greatest energy requirement? **Explain.**
17. By law in Canada, the cutting of forests must be followed by replanting. **Why** do some environmentalists object to monoculture replanting programs?
18. **Illustrate** the two laws of thermodynamics with examples of some common, everyday events.
19. Of the three basic energy pyramids, which best illustrates energy transfer in a food chain? **Explain.**
20. Assuming a 90 % loss of energy across each trophic level, **determine** how much energy would remain at the fourth trophic level if photosynthesis makes available 100 000 kJ of potential energy. **Justify** your answer. **Sketch** a properly labelled pyramid to represent this situation. Could a fifth-level organism be added to the chain? **Explain.**
21. Assume that a ski resort is proposed in a valley near your favourite vacation spot. **Describe** the type of environmental assessment that should be done before the ski resort is built. In providing an answer, pick an actual location you are familiar with and give specific examples of studies that you would like to see carried out.
22. Insect-eating plants such as the sundew are commonly found in bogs across the country. Although referred to as “carnivorous” plants, they are still considered to be members of the first trophic level. Is this the proper trophic level to assign to these plants? Research carnivorous plants, then state the trophic level you think is most appropriate. **Explain** your choice.

www.science.nelson.com **GO**

23. Some ecologists have stated that, to maximize the food available for Earth’s exploding human population, we must change our trophic level position. **Describe** the probable reasoning behind this statement. **Predict** any potential biological problems that might occur if this switch were actually made.
24. The sea otter was once an extirpated species in Canada. This species was reintroduced to the west coast from 1969 to 1972. There are now well over a thousand sea otters on the west coast of Canada, but they are still listed as a threatened species. The sea otter eats sea urchins, which

in turn eat algae, such as kelp. When the sea urchin population is kept in control, kelp populations increase. This improves the health of the ecosystem. Higher kelp populations also result in a decrease of barnacles and mussels.

- (a) **Sketch** a food chain that includes the sea otter.
- (b) Sea otters are threatened by oil spills. If the population of sea otters decreases, **predict** what will happen to the population of kelp.
- (c) If the population of sea otters increases, what will happen to the populations of barnacles and mussels?
- (d) Kelp provides shelter for fish. **Predict** how higher populations of kelp might impact fish-eating birds, such as eagles and osprey.
- (e) **Sketch** a concept map showing the impact a decrease in sea otters would have on each species in this ecosystem.

25. The Banff longnose dace, *Rhinichthys cataractae smithi*, now extinct, was found only in Banff National Park, in a marsh into which the Cave and Basin Hot Springs drain. **Summarize** the factors that contributed to the extinction of this species.

www.science.nelson.com **GO**

26. **Figure 2** shows a food web.
- (a) Make a chart classifying the species shown into producers, consumers, and trophic levels.
- (b) Use the information in **Figure 2** to **sketch** a pyramid of energy that shows the level of each species. (Since you do not have energy data, just estimate the size of each level.)
- (c) **How** might an increase in the population of snowshoe hares affect the owl over a short period of time? over a long period of time? **Explain** your reasons.
- (d) **Predict** what would happen to the population of owls if hawks were introduced to the ecosystem.

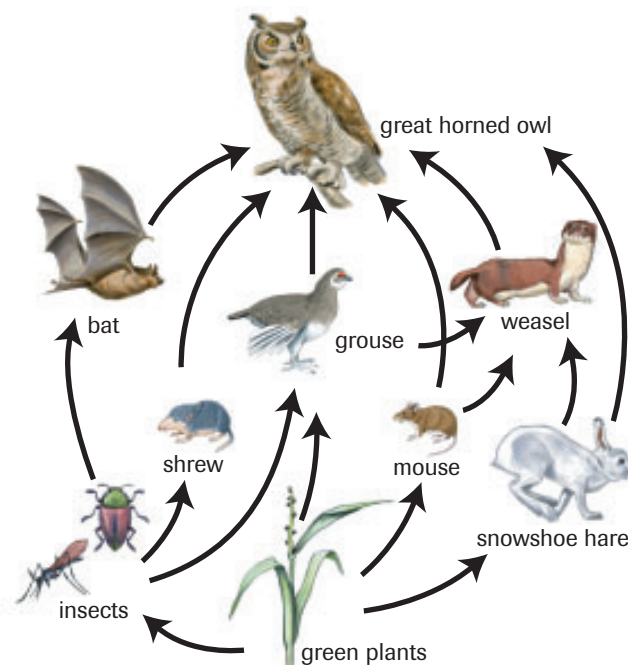















Figure 2

The Cycling of Matter in the Biosphere

In this chapter

-  Exploration: Recycling Matter
-  Investigation 3.1: Nutrient Cycling and Plant Growth
-  Mini Investigation: Measuring Water Loss from Leaves
-  Web Activity: Pesticides: Pro or Con?
-  Lab Exercise 3.A: Carbon Dioxide Production by Plants and Animals
-  Mini Investigation: Greenhouse Effect Simulation
-  Investigation 3.2: The Albedo Effect
-  Case Study: Technological Solutions for Global Warming
-  Web Activity: Biosphere 2
-  Investigation 3.3: Environmental Models
-  Mini Investigation: Effects of Nitrogen on Algal Growth
-  Investigation 3.4: Phosphate Identification
-  Web Activity: Persistent Pesticides and Matter Flow

Ecosystems are always changing. Trees in a forest die and are replaced by new trees. Lakes change greatly in temperature and oxygen levels throughout the year. Grasslands are burned by wildfires, and new plants appear. By changing constantly, ecosystems can remain stable, in a dynamic equilibrium, or balance.

The rusting truck in **Figure 1**, on the next page, reminds us of some of the ways that ecosystems respond to change. In time, the weeds growing around the truck will be replaced by shrubs, and the small trees will grow tall. Pieces of the truck will fall off and be buried under detritus. Eventually, even the iron atoms in the truck will return to the soil.

Where will the atoms and molecules of the truck go? Recall that the biosphere is a closed system. Energy can pass into and out of the biosphere but, other than small amounts in meteorites, matter neither enters nor leaves the biosphere. Instead, all the atoms that make up matter in the biosphere are transformed from one form to another through different cycles. The cycling of matter helps to maintain the environmental conditions that support the organisms in that ecosystem. Any large changes may cause an irreversible shift in the dynamic equilibrium, and a new balance must be established. If changes are too large or too fast, some species may not survive.

STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. One truck abandoned in a forest probably won't affect the ecosystem too much. However, humans produce far more than one waste truck every year. Estimate the number of trucks and cars that are abandoned each year in Canada. What problems might be caused by this volume of waste?
2. Western thought often describes humans as being at the centre of change. In this worldview, the ideal human acts as a protector for an ecosystem. By contrast, Aboriginal peoples describe humans as belonging to an ecosystem, living in harmony with it. How would a description of a grassland ecosystem written by a typical scientist differ from a description written by an Aboriginal elder?
3. Low oxygen levels in landfills limit the number of bacteria that can decompose foods.
 - (a) Explain why slow rates of decomposition are a concern.
 - (b) Why is reducing wastes so important?

 Career Connection:
Environmental Auditor



Figure 1

If left here, this truck will slowly disappear, leaving little behind.

► **Exploration**

Recycling Matter

Materials: scissors, shoe box, masking tape, soil, magnifying lens, plastic (e.g., garbage bag), spoon, rubber gloves, beaker, items for testing (newspaper, orange peel, aluminum foil, plastic bottle cap, coffee grounds, lettuce, metal tab from pop can)

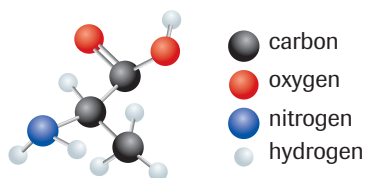
- Line a shoe box with plastic from a garbage bag. Tape the plastic along the top edge of the box.
- Place about 8 cm of soil in the shoe box and add enough water to make the soil moist. Arrange different items for testing on the surface of the soil. Cover each item with a layer of moist soil.
- Place the shoe box in a warm, sunny place for the next month. Keep the soil moist by adding water when needed.
- Examine each item once a week. Each time, put on rubber gloves and use a spoon to remove the top layer of soil. Put the soil in a beaker. Examine each sample using a hand lens. Cover the materials with the soil after you examine them.

(a) Explain why you lined the box with plastic.

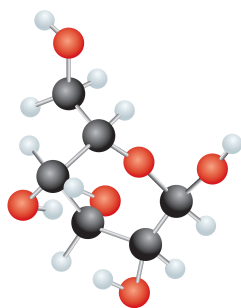
(b) Record your observations in a chart.

(c) Why should you wear rubber gloves to examine the materials?

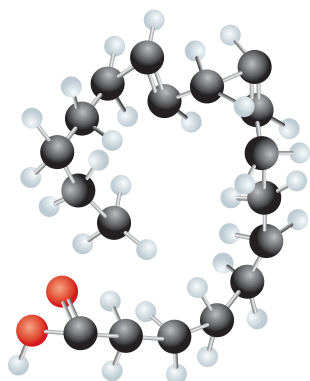
3.1 The Hydrological Cycle



(a) alanine, an amino acid. Amino acids are used to build proteins, which regulate the chemistry of the cell and make up most of its structures.



(b) glucose, a sugar. Sugars are used to store energy.



(c) linoleic acid, a fatty acid. Fatty acids are combined to form fats, which are used to store energy and to build cell membranes.

Figure 1
Three organic molecules. Note that they all contain carbon and hydrogen atoms. Some organic molecules are extremely complex. A DNA molecule, for example, contains millions of atoms.

To understand how matter cycles through ecosystems, we must also understand the cycling of organic substances within living things. Living organisms contain many organic compounds, which are substances that contain atoms of carbon and hydrogen. Proteins, sugars, and fats, the important chemicals that make up your body, are all organic (**Figure 1**). Organic compounds undergo changes within living things and within ecosystems. Their complex structures are broken and rebuilt in a continuous cycling of matter.

Cycling of Organic Matter

The materials used in building the bodies of living organisms are limited to the atoms and molecules that make up the planet. There is no alternative source of matter. Therefore, to maintain life on Earth, matter must be recycled.

Incredible as it may sound, every carbon atom is recycled time and time again into new life forms. Because of this cycling, it is possible that somewhere in your body are atoms that once made up a *Tyrannosaurus rex*, one of the giant carnivorous dinosaurs that lived 70 million years ago.

Food is organic matter. Every time you eat, organic matter that was once part of other living things passes into your body. Through the process of digestion, complex organic molecules are broken down into simpler molecules. Cells use these simple molecules to build the complex molecules that become part of your own structure.

Another process involved in the cycling of matter is decay. Organic materials are held temporarily in the bodies of living organisms, but after death, decomposer organisms make the materials available to other living things. Decomposers break down the organic matter in dead bodies and feces into small, inorganic molecules. These small molecules pass into the soil or water, where they can become part of the living world at some future time (**Figure 2**).

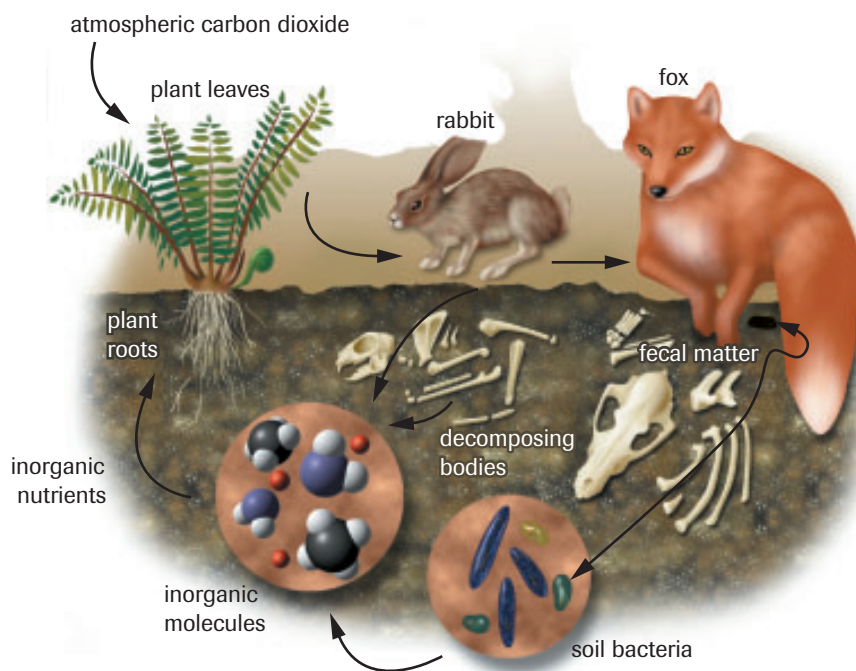


Figure 2
Decomposers break down complex organic molecules into inorganic matter, which may be used by plants. Plants reassemble these inorganic substances (also called nutrients) to make food for themselves. In turn, animals may eat the plants, continuing the cycling of matter.

INVESTIGATION 3.1 Introduction

Report Checklist

Nutrient Cycling and Plant Growth

Humans often add nutrients to soil to promote plant growth. In natural ecosystems, soil nutrients are recycled between decomposing matter and growing plants. In this investigation, you will determine which of three samples of different soil types delivers the most nutrients to plants.

<input type="radio"/> Purpose	<input checked="" type="radio"/> Design	<input checked="" type="radio"/> Analysis
<input checked="" type="radio"/> Problem	<input type="radio"/> Materials	<input checked="" type="radio"/> Evaluation
<input type="radio"/> Hypothesis	<input type="radio"/> Procedure	<input checked="" type="radio"/> Synthesis
<input type="radio"/> Prediction	<input checked="" type="radio"/> Evidence	

To perform this investigation, turn to page 67. 

Properties of Water

All living organisms need water (**Table 1**). Water is the solvent in which most metabolic reactions take place. It is the major component of a cell's cytoplasm. Many organisms live within its stable environment, while others depend on water to carry dissolved nutrients to their cells. The volume of water in the biosphere, including its solid phase (snow or ice) and gaseous phase (vapour), remains fairly constant; however, the specific amount in any one phase can vary considerably. It is continuously entering and leaving living systems.

Table 1 The Importance of Water to Organisms

- | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> Absorbs and releases thermal energy and moderates temperature fluctuations |
| <ul style="list-style-type: none"> Is the medium in which metabolic reactions take place |
| <ul style="list-style-type: none"> Is an excellent solvent |
| <ul style="list-style-type: none"> Makes up over 60 % of the cell's mass |
| <ul style="list-style-type: none"> Supplies hydrogen atoms to producers during the metabolism of key organic molecules during photosynthesis and oxygen atoms to all organisms during cellular respiration |
| <ul style="list-style-type: none"> Is a reactant in some metabolic activities and a product in others |

Water: A Polar Molecule

Water molecules are held together by covalent bonds that join one oxygen and two hydrogen atoms (**Figure 3**). The electrons are drawn toward the oxygen atom, creating a region of negative charge near the oxygen end of the molecule and a positive charge near the hydrogen end of the molecule. Although the positive and negative charges on the molecule balance each other out, the molecule has a positive pole and a negative pole. It is for this reason that water is referred to as a **polar molecule**. The negative end of a water molecule repels the negative end of another water molecule, but attracts its positive end. Attraction between opposing charges of different molecules creates a special **hydrogen bond**. Hydrogen bonds pull water molecules together (**Figure 4**).

Hydrogen bonding helps explain some of the physical properties of water. Water boils at 100 °C and freezes at 0 °C. By comparison, sulfur dioxide, a molecule of similar size, boils at 62 °C and freezes at -83 °C. The higher boiling point and melting point of water can be explained by the hydrogen bonds. Consider the boiling point of water. Before water molecules can escape into the air, hydrogen bonds must be broken. This requires additional energy. Molecules like sulfur dioxide and carbon dioxide do not have hydrogen bonds. Consequently, they require less energy to boil and have lower boiling points.

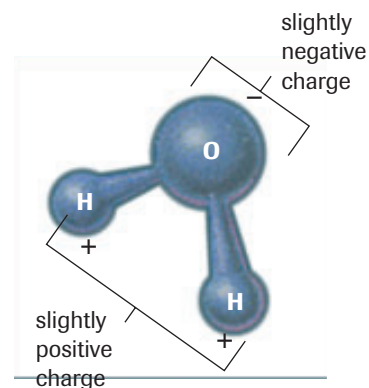


Figure 3

The electrons are pulled closer to the oxygen end of the molecule. The single proton of each hydrogen atom causes a positively charged end.

polar molecule a molecule that has a positive and a negative end

hydrogen bond the type of bond that is formed between the positive end of one water molecule and the negative end of another water molecule

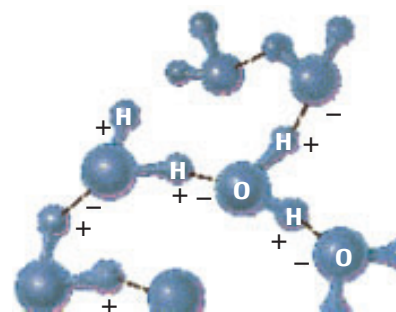


Figure 4

A hydrogen bond is formed between the oxygen end of one water molecule and the hydrogen end of another water molecule.

hydrological cycle (water cycle)
the movement of water through the environment from the atmosphere to Earth and back

+ EXTENSION

Dissociation of Water

Water exists as two atoms of hydrogen attached to an atom of oxygen. However, a small number of water molecules dissociate into two separate ions: a positive hydrogen ion and a negative hydroxide ion. Solutions in which the concentration of hydrogen ions is greater than the number of hydroxide ions are acids. Bases are formed when the concentration of hydroxide ions is greater than the concentration of hydrogen ions. Complete this Extension to review acids, bases, and the pH scale.

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The Hydrological Cycle

The movement of water through the biosphere is called the **hydrological** or **water cycle**, shown in **Figure 5**. Water reaching Earth's surface as precipitation (rain, snow, sleet, hail, or any combination of these forms) can enter a number of pathways. It may remain on the surface as standing water (lakes, swamps, sloughs) or form rivers and streams that eventually flow to the oceans, which form the bulk of the water reserves. Some of the precipitation sinks into the soil and subsurface rock, forming ground water. If the rock is permeable, some of this ground water may seep to the surface, forming springs or adding water to existing lakes and streams. The movement of water through rock is slow but measurable.

By absorbing energy from the Sun, some of the surface water evaporates and becomes water vapour. The water vapour rises upward in the atmosphere until it reaches a point where the temperature is low enough for the water vapour to condense into tiny droplets of liquid water. These droplets are so light that they remain suspended in the atmosphere as clouds, supported by rising air currents and winds. When conditions are right (e.g., the temperature drops), the droplets join together, forming larger drops or ice crystals. Once the mass of the droplet or ice crystal can no longer be supported by air currents, precipitation occurs. This cycle repeats itself endlessly.

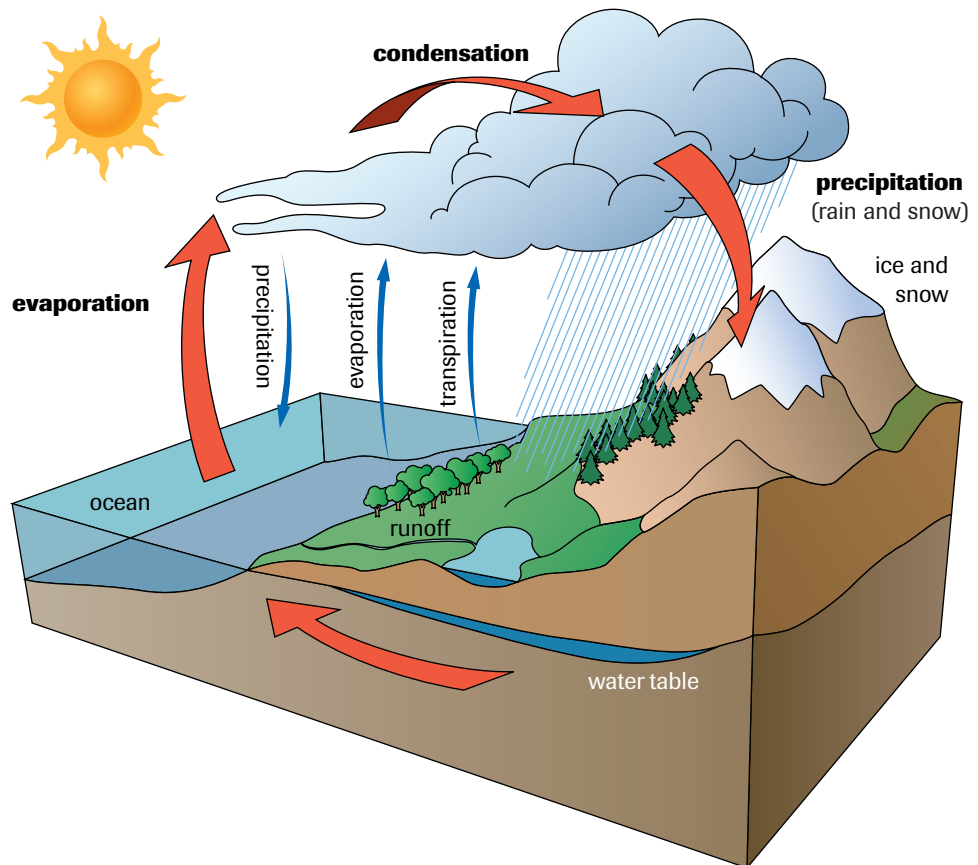



Figure 5 
The water cycle

Living organisms also play a vital role in the water cycle. Water enters all organisms and is used by them in various ways during their metabolic activities. You may think that living things tend to remove water from the environment, thus interfering with the cycle. However, through such processes as cellular respiration and the decay of dead organisms, water is released back to the land or atmosphere. Plants, particularly broad-leaf trees and shrubs, play a major role in water recycling through the process of **transpiration**. In fact, where forests have been removed by logging or burning, there is less water in the atmosphere, along with noticeable climate changes. Surface runoff patterns become disturbed and the water-holding capability of the soil may be reduced. This helps explain why the destruction of Brazilian rainforests provides only temporarily usable land for agriculture.

Water beneath the Soil

The fresh water that we use comes from two sources: ground water and surface water. Precipitation that collects above the ground, such as the water in lakes, ponds, and rivers, is called surface water. Precipitation increases surface runoff, making lakes and rivers rise. In addition, rainfall seeps into the soil. The water filters downward because of gravity. The downward pull of water is called **percolation**. The larger the soil particles are, the greater the size of the pores between the particles and the faster the percolation rate. Eventually, water fills the lower levels of soil, which are composed of sand and gravel. The **water table** forms above a layer of relatively impermeable bedrock or clay. The greater the rainfall, the higher the water table will be.

As water seeps downward, it carries dissolved organic matter and minerals to the lower layers of the soil. The process is called **leaching**. Removing these chemicals from the upper layers of the soil is a serious problem because plants require these nutrients for growth and development. In many ways, plants help correct the problem of leaching. Long branching roots extend deep into soil and help bring minerals and other chemicals from the lower levels of the soil back to the surface.

transpiration the loss of water through plant leaves

percolation the movement of a liquid through a porous material, such as soil particles

water table the top level of the region below the ground that is saturated with water

leaching the removal of soluble minerals by percolation

▶ mini Investigation

Measuring Water Loss from Leaves

Plants contribute to the water cycle by moving water from their roots to the atmosphere, through pores in their leaves. Do all plant species contribute at the same rate?

Materials: balance, small clear, plastic bags with twist-ties, access to coniferous and deciduous trees and other living plants

- Find the mass of two small plastic bags. Place one bag around a leaf of a growing deciduous tree and another around a small branch from a coniferous tree (**Figure 6**).

- Gently tie off the bags and collect water for 24 hours.

- Find the mass of the bags.

(a) In which bag was the most water collected?

(b) Provide reasons to explain the difference.

(c) Design an activity to measure water consumption and loss in animals.

(i) Identify the responding and manipulated variables.

(ii) What variables must be controlled?

(iii) Write a possible laboratory procedure.



Figure 6



CAREER CONNECTION

Environmental Auditor

Environmental auditors work to make sure that industries and corporations are meeting environmental standards and regulations. They help to detect potential environmental concerns and to monitor business activities that might have environmental impacts. These specialists also oversee remediation activities and make recommendations to environmental organizations.

Find out more about this important and meaningful career, including the educational requirements.

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Acid Deposition and the Water Cycle

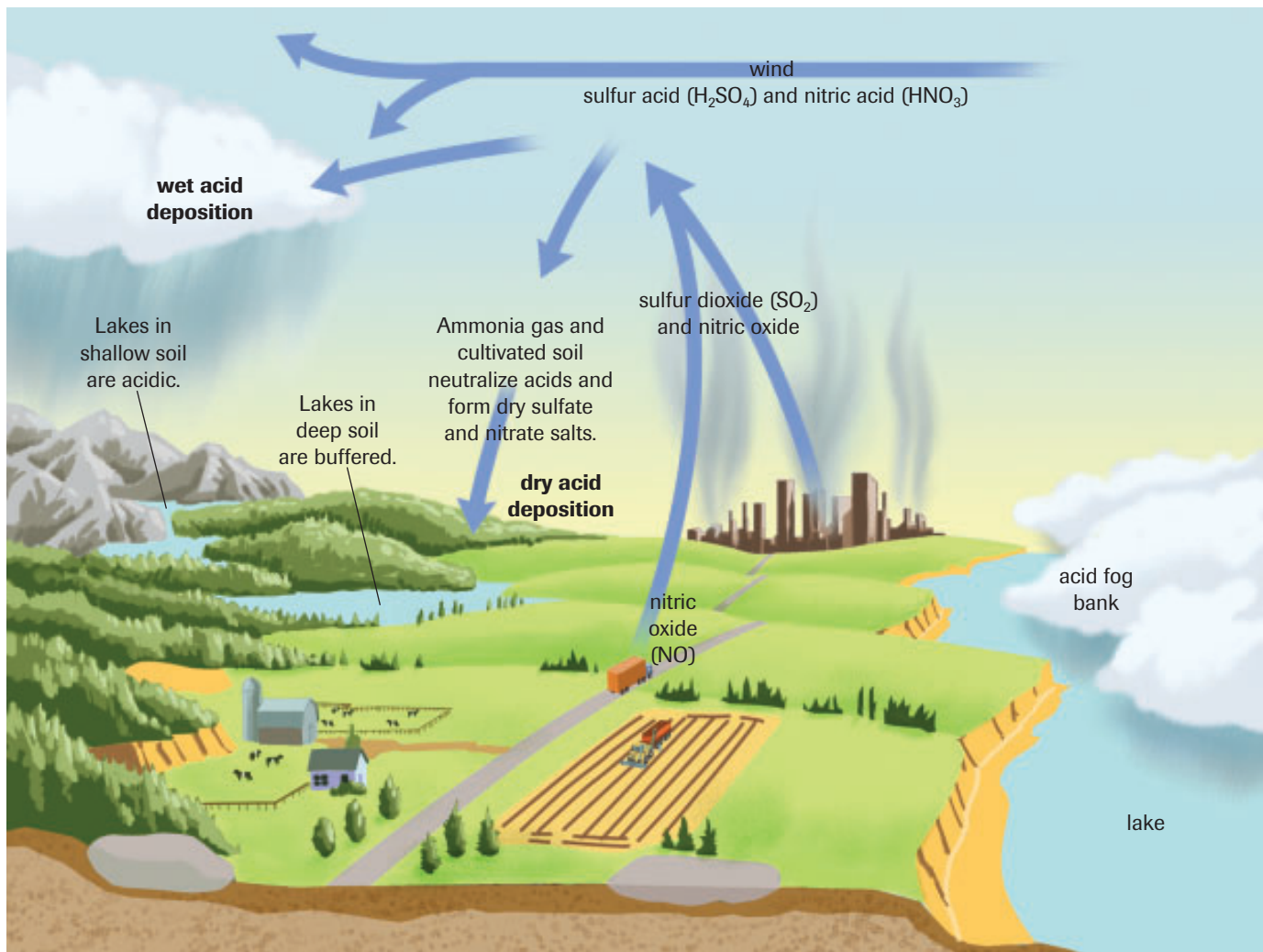
Although society obtains many benefits from technology, there is almost always an environmental price to pay. Nowhere is this more evident than with the technologies that contribute to acid deposition. Smokestacks of coal-burning generating stations, metal smelters, and oil refineries provide energy and products for the industrial world, but at the same time produce oxides of sulfur and nitrogen, some of the most dangerous air pollutants.

When fossil fuels and metal ores containing sulfur are burned, the sulfur is released in the form of sulfur dioxide (SO_2), a poisonous gas. Combustion in automobiles and fossil fuel-burning power plants, along with the processing of nitrogen fertilizers, produce various nitrous oxides (NO_x). Sulfur dioxide and nitrous oxides enter the atmosphere and combine with water droplets to form acids. The acids return to the surface of Earth in the form of snow or rain, called “acid rain” (Figure 7).

Acid rain has been measured to be as much as 40 times more acidic than normal rain. The devastation of acid rain on ecosystems has been well documented. Acid precipitation kills fish, soil bacteria, and both aquatic and terrestrial plants, as shown in Figure 8, on the next page. It leaches nutrients from the soil by dissolving them in the ground water. The devastation is rarely uniform; some ecosystems are more sensitive than others. Alkaline soils neutralize the acids, minimizing their impact. The moun-

Figure 7

Wet and dry acid deposition



tains of British Columbia are limestone, which help to counter the effect of the acid. Thus, Alberta's rivers are not very acidic. Soils in much of southeastern Canada, however, lie over a solid granite base, which does little to balance the acid.

The sulfur and nitrous oxides released from smokestacks do not always enter the water cycle in the atmosphere. Depending on weather conditions, particles of sulfur and nitrogen compounds may remain airborne and then settle out in the dry state, or as "dry deposition." These dry pollutants, then, form acids when they combine with moisture on a surface, such as the dew on a lawn, the surface of a lake, or the water inside your respiratory tract.

Technology offers some solutions to the problems that have been caused by emitting oxides of sulfur and nitrogen. "Scrubbers" in smokestacks now remove much of the harmful emissions, and lime has been added to lakes in an attempt to neutralize acids from the atmosphere. However, both of these solutions are expensive. The prospect of improving smelters is equally difficult. Mining companies are already battling to remain operational and compete in a world market. Many developing countries are producing ores at a much lower cost because of cheaper labour and more relaxed environmental standards. Tougher legislation could result in higher levels of unemployment.

The Role of Water in Nutrient Cycling

As you have just seen, many harmful substances are transported when dissolved in water. In the next two sections, you will see that water also plays an essential role in the cycling of other substances throughout the biosphere. Since it is such an excellent solvent, water can dissolve nutrients such as nitrates and phosphates, enabling plant roots to absorb them. Because of hydrogen bonding, water can move against gravity, carrying nutrients up plant stems and trunks to cells throughout the plant. This upward motion of water is called "capillary action." Water has a role in the cycling of carbon and oxygen as well. For example, water dissolves carbon dioxide and oxygen, bringing these gases to organisms in aquatic ecosystems. Because water can dissolve carbon dioxide, the ocean stores vast amounts of carbon. Water is also an essential factor in photosynthesis and cellular respiration, two processes that form the backbone of carbon and oxygen cycling in the biosphere.



Web Quest—Pesticides: Pro or Con?

Pesticides are chemicals that protect our crops from damage by insects and disease-causing organisms. Although they were developed to improve human life, this protection also has a price. Instead of contributing to the cycling of matter, many pesticides persist in the environment for long periods. Many people now believe that pesticides cause more harm than good. In this Web Quest, you will explore the costs and benefits of pesticides, and then make a well-supported decision about where you stand on this issue.

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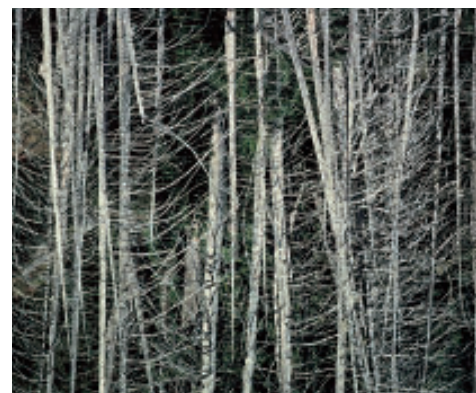


Figure 8

Devastation of forests caused by long-term exposure to acid rain. Conifers are particularly susceptible to acid, which makes them vulnerable to a variety of infections.

SUMMARY

The Hydrological Cycle

- Polar molecules, such as water, are molecules with a positive and a negative end. Hydrogen bonds are formed between the positive end of one water molecule and the negative end of another water molecule.
- The hydrological cycle or water cycle is the movement of water through the environment from the atmosphere to Earth and back.
- The hydrological cycle traces the phase changes of water in the abiotic environment and follows its role in living organisms.
- Sulfur dioxide and nitrous oxides enter the atmosphere and combine with water droplets to form acids. The acids return to the surface of Earth in the form of snow or rain, called “acid precipitation.”
- Water plays an important role in the cycling of nutrients in the biosphere.

Section 3.1 Questions

1. (a) What two types of atoms are contained in all organic compounds?
(b) Oxygen atoms are part of many organic compounds. How might these atoms enter the body of a living thing?
(c) Many organic compounds also contain nitrogen and phosphorus atoms. How might these atoms enter the body of a living thing?
(d) What are three ways that matter leaves the bodies of living things?
2. Using diagrams, show two different ways that a carbon atom that was once in a cell in a grass leaf could become part of a cell in your ear.
3. In a few paragraphs, explain the diagram in **Figure 9**.

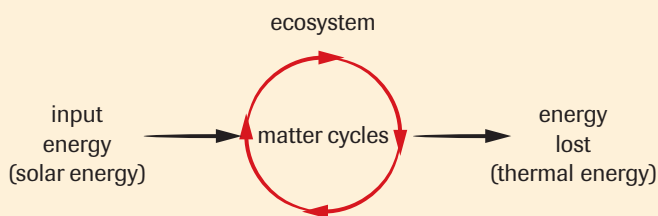


Figure 9

4. When space probes were sent to the Moon and Mars, soil samples were collected and analyzed for organic compounds. Why would scientists want to know if organic matter were present in these soil samples?
5. The following sentence is found in the opener of of this chapter: “By changing constantly, ecosystems can remain stable, in a dynamic equilibrium, or balance.” Using a grassland ecosystem as an example, explain what is meant by dynamic equilibrium.

6. Predict what would happen to a deciduous forest ecosystem if an agent were released that destroyed decomposing bacteria found in the soil.
7. Why is water important to living things?
8. Using water as an example, define polar molecules.
9. What is a water table?
10. How does the water cycle purify water samples?
11. Why do minerals leach from the soil?
12. Identify and describe two factors that would alter the amount of ground water in an area.
13. How do the roots of plants help prevent the leaching of important minerals?
14. Describe the danger of digging a hole for an outhouse at a beach cottage.
15. How could a landfill site contaminate ground water?
16. Natural and genetically engineered bacteria and fungi can be used to either destroy toxic chemicals or convert them to harmless forms. The process, referred to as bioremediation, mimics nature by using decomposers to recycle matter. Research how bioremediation is used to clean up various pollutants, and report on your findings.

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17. List abiotic characteristics of an ecosystem that make it particularly vulnerable to the effects of acid deposition. Predict the long-term effects of such deposition.

The Carbon Cycle and the Oxygen Cycle

3.2

Carbon is the key element for living things. Carbon can be found in the atmosphere and dissolved in the oceans as part of the inorganic carbon dioxide (CO_2) molecule. Each year, 50 to 70 billion tonnes of carbon from inorganic carbon dioxide are cycled into more complex organic substances. This is done through photosynthesis (see Chapter 2). Some of the organic carbon is released back to the atmosphere through cellular respiration as carbon dioxide.

Because photosynthesis and cellular respiration are complementary processes, and because the carbon that they use is repeatedly cycled through both processes, this relationship is often called the **carbon cycle**. This cycle is actually much more complex than a simple exchange of carbon-as-carbon-dioxide and carbon-as-glucose (**Figure 1**). Most of the carbon in living organisms is returned to the atmosphere or water as carbon dioxide from body wastes and decaying organisms. However, under certain conditions the decay process is delayed and the organic matter may be converted into rock or fossil fuels such as coal, petroleum, and natural gas. This carbon is then unavailable to the cycle until it is released by processes such as uplifting and weathering, or by burning as fuels. The burning process (**combustion**) releases carbon dioxide into the atmosphere.

Reservoirs for Inorganic Carbon

When it is not in organic form, carbon can be found in three main reservoirs (storage areas): the atmosphere, the oceans, and Earth's crust. The smallest of these reservoirs is the atmosphere. Carbon dioxide makes up a very small percentage (about 0.03 %) of the gases that we breathe in. However, there is plenty of atmospheric carbon dioxide for land plants to use in photosynthesis.

carbon cycle the cycle of matter in which carbon atoms move from an inorganic form to an organic form and then back to an inorganic form

combustion the chemical reaction that occurs when a substance reacts very quickly with oxygen to release energy

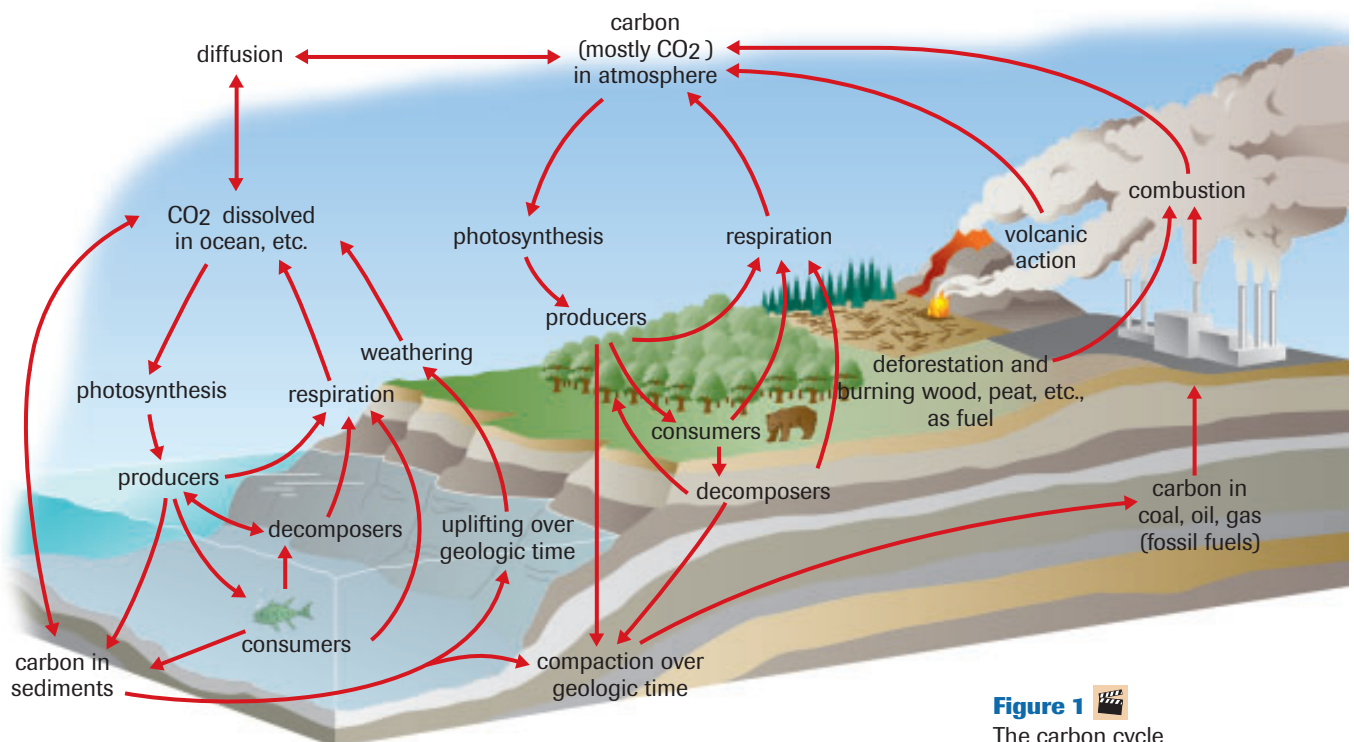


Figure 1  The carbon cycle

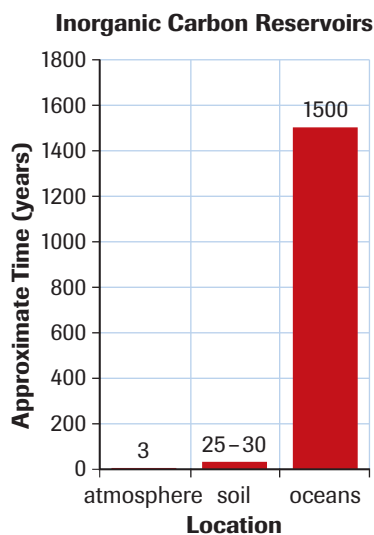


Figure 2

The average carbon atom is held in inorganic form much longer in the ocean than in the atmosphere. The time for carbon held in rocks (millions of years) would not fit well in this graph.

peat slowly decomposing plant matter produced in low-oxygen environments such as bogs

A tremendous amount of inorganic carbon is held as dissolved carbon dioxide in the oceans, where it is available to algae and other water plants for photosynthesis. However, some carbon dioxide reacts with sea water to form the inorganic carbonate ion (CO_3^{2-}) and the bicarbonate ion (HCO_3^-). Combined with calcium, these ions become calcium carbonate (CaCO_3), which is used by living things to make shells and other hard structures. The carbon in carbonates can be recycled, but in the ocean much of it ends up as sediment. As layers of sediment form, the carbonates are crushed and heated and eventually become rock. Limestone is made from the discarded shells and bones of living things. This explains why by far the largest reservoir of Earth's carbon is in sedimentary rocks. Carbon can be trapped in rock for millions of years until geological conditions bring it back to the surface. Volcanic activity can break down carbonate-containing rocks such as limestone, releasing carbon dioxide. Acid rain falling on exposed limestone will also cause the release of carbon dioxide into the atmosphere.

Figure 2 shows how long, on average, a carbon dioxide molecule will remain in each reservoir.

Reservoirs for Organic Carbon

Organic carbon is also held in reservoirs—the bodies of living things. However, all living things die, and decomposition eventually returns the carbon to the cycle in inorganic form. There is one important exception to this rule: some ecosystems, such as bogs, store huge quantities of carbon in organic form. Bogs contain very little oxygen, and under these conditions decomposition is very slow. Carbon atoms may remain locked away in dead plant matter (**peat**) for many years in a bog. Occasionally these deposits are overlaid with sediment. As more layers of sediment are piled on top, the slowly decaying organic matter can end up trapped between layers of rock. The result is the formation of a carbon-containing fossil fuel, coal (**Figure 3**).

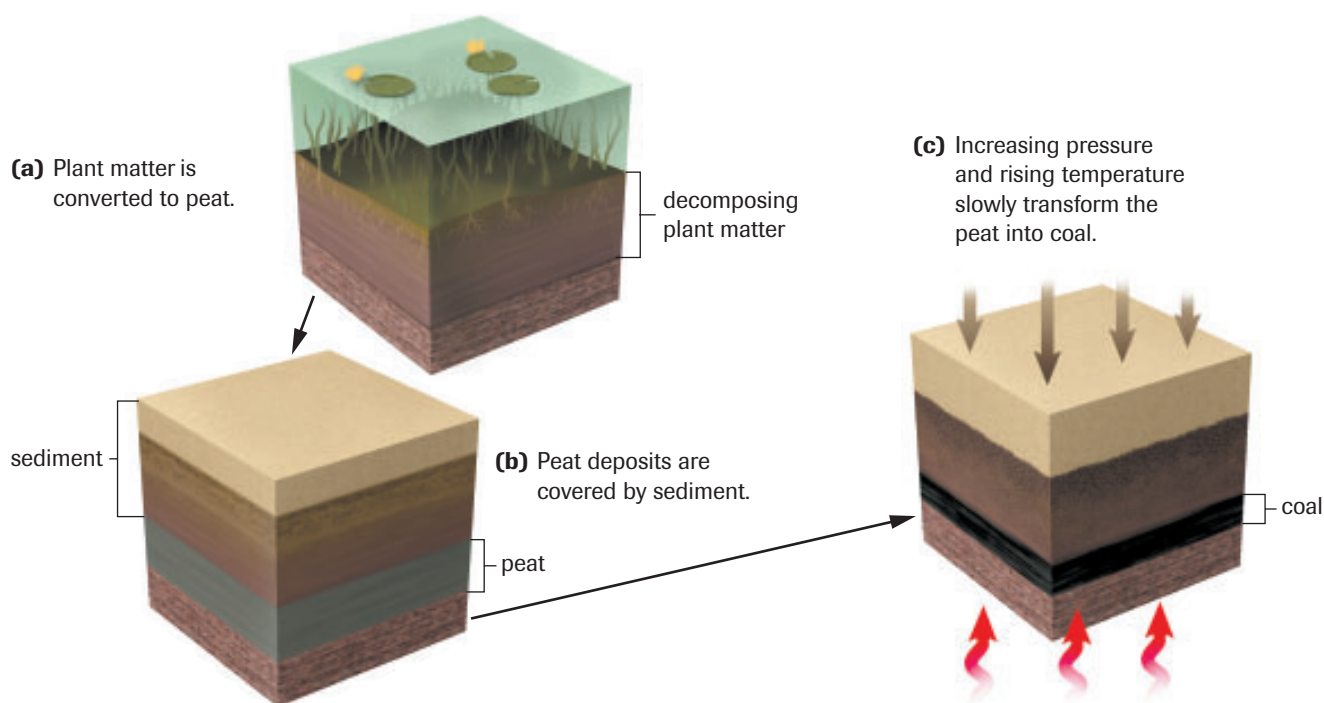


Figure 3

Coal is a reservoir of organic carbon that can be stored in Earth's crust for millions of years before cycling again into carbon dioxide.

Conditions similar to those in a bog also exist on the floors of oceans; organic carbon can also be trapped there for long periods. Oil is formed in a process similar to the formation of coal, when decaying aquatic animals and plants are trapped under sediment in a low-oxygen environment.

In the form of fossil fuels in Earth's crust, organic forms of carbon can be held out of the carbon cycle for many millions of years.



LAB EXERCISE 3.A

Carbon Dioxide Production by Plants and Animals

Through photosynthesis, plants take up carbon dioxide and release oxygen. Both plants and animals carry out cellular respiration, which uses oxygen and releases carbon. Plants and animals, therefore, could have very different effects on the cycling of carbon. Carbon dioxide produced by aquatic species dissolves in the water in which they live. Bromothymol blue is an indicator used to show the presence of carbon dioxide in solution. Low levels of carbon dioxide will result in the bromothymol blue solution remaining blue, while higher levels of carbon dioxide will cause the dye to change to yellow. In this lab exercise, you will use the given list of materials to design an investigation to compare the carbon dioxide production of plants and animals.

Purpose

To compare carbon dioxide production of plants and animals

Problem

Do plants and animals contribute similar amounts of carbon dioxide to the carbon cycle?

Report Checklist

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| <input type="radio"/> Problem | <input type="radio"/> Materials | <input type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input type="radio"/> Evidence | |

Materials

8 test tubes
water
4 aquatic snails
8 stoppers
bromothymol blue solution
4 stalks of *Elodea*
light source
timer

Design

Design an experiment to address the Problem. Ensure you include the manipulated variable and controlled variables in your design.

The Oxygen Cycle

Since oxygen is an integral part of both photosynthesis and cellular respiration, the cycling of oxygen in the biosphere is closely linked to the cycling of carbon. In general, the oxygen cycle on Earth consists of the movement of oxygen gas, O_2 , from living things into the atmosphere through photosynthesis, and then back into living things through cellular respiration. However, this description of the oxygen cycle is very simplified. Oxygen atoms cycle in the atmosphere between oxygen gas and ozone, O_3 . Oxygen atoms are also present in carbon dioxide, water, glucose, and many other important substances. In addition, oxygen gas plays a part in many reactions. As a result, the oxygen cycle is extremely complex. Oxygen can be found in living things, in the atmosphere, in water, and in many types of rock. In fact, most of Earth's oxygen is stored in the rock of the lithosphere. Oxygen is needed by most living things for cellular respiration, and as part of the decomposition process.

+ EXTENSION

Interpreting Changes in the Ozone Layer from Satellite Images

Human industry has also affected the amount of ozone in our atmosphere. In this Extension, you will investigate the ozone layer and its changes over time.

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Figure 4
The burning of the rain forest disrupts the balance between photosynthesis and cellular respiration. Many human activities affect the carbon cycle.

Human Impact on the Carbon Cycle

Over the past century, humans have mined fossil fuels trapped in Earth's crust and burned them. This has modified the global carbon cycle by releasing carbon from organic reservoirs faster than would normally occur.

Humans are also increasing the amount of carbon dioxide in the inorganic reservoir of the atmosphere by clearing away vegetation in order to build or farm. The destruction of vegetation reduces the amount of photosynthesis, and so reduces the amount of carbon dioxide removed from the atmosphere (**Figure 4**). Most carbon dioxide released into the air eventually becomes dissolved in the oceans, but the oceans can hold only so much. The amount of carbon dioxide in the atmosphere is rising.

The Greenhouse Effect

Have you ever noticed how hot it can get in a car on a sunny day? Every year, dogs and cats are killed when their owners leave them in closed cars. The heating is caused by the greenhouse effect. The shorter wavelengths of sunlight (primarily infrared) enter the car (acting just like a greenhouse) through the glass. These are absorbed and re-radiated as longer wavelengths. The reflected light is prevented from escaping by the glass. The car (or greenhouse) heats up.

Many of the atmospheric gases that surround Earth, such as CO_2 and CH_4 , act like the glass of the greenhouse shown in **Figure 5**. The gases trap the heat from the Sun and warm Earth's surface. A certain amount of "greenhouse gas" is essential for the survival of life on Earth. Without greenhouse gases, the average temperature of the planet would fall from 15°C to -18°C .

Global Warming

The increased energy demands of an industrialized world have brought about more factories that produce smoke and more automobiles that release exhaust. Carbon dioxide is released during combustion. Scientists estimate that the burning of wood and fossil fuels (coal, oil, and gas) has caused carbon dioxide levels to triple over the past 40 years. Global temperatures have increased by 1°C over that same time. The rising levels of carbon dioxide, one of the main greenhouse gases, have changed the balance between photosynthesis and cellular respiration (**Figure 7**, next page).

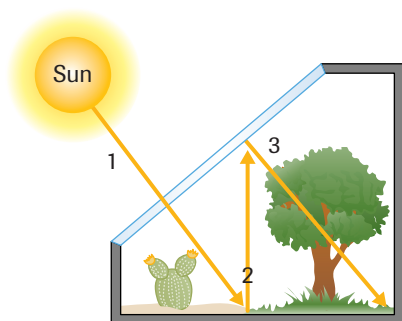


Figure 5
The greenhouse effect: 1. Shorter wavelengths of sunlight enter the greenhouse. 2. Light is reflected and wavelengths become longer. 3. The longer wavelengths are trapped by the glass.

▶ mini Investigation

Greenhouse Effect Simulation

The greenhouse effect can be simulated by the following experiment.

Materials: ice cubes, 2 plastic bags, 2 small thermometers, 1 large glass jar, clock or timer, 100 mL graduated cylinder

- Put the same mass of ice cubes in two separate plastic bags.
- Place a small thermometer inside each bag to record the air temperature.
- Place one of the bags inside a large glass jar and allow it to sit in sunlight. Put the second bag beside the first, but not enclosed in glass (**Figure 6**).

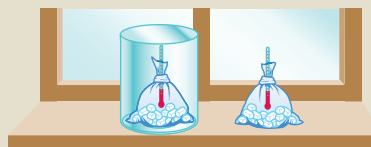


Figure 6

- After 10 min, remove the first bag from the glass jar. Record the air temperatures inside both bags.
- Use a graduated cylinder to measure the amount of melting that has occurred.
 - (a) Present your data.
 - (b) State your conclusions.

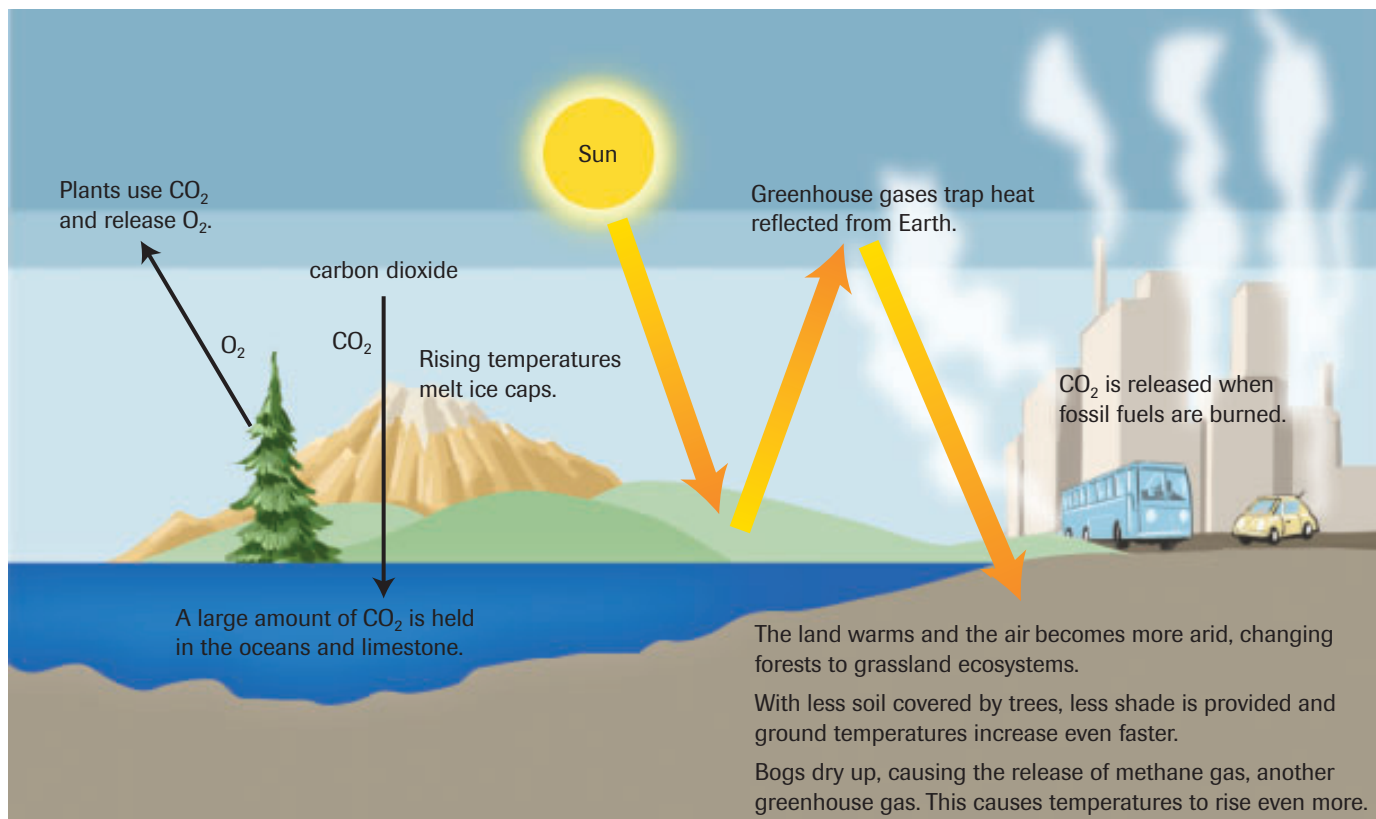


Figure 7
Effects of increases in carbon dioxide levels in the atmosphere

A Warmer Climate

The prospect of increased temperatures may seem appealing to most Canadians. However, increased temperatures can bring several ecological problems. In Canada's high Arctic, the layer of ground that remains permanently frozen would thaw, causing the collapse of many roads and buildings that rely on frozen ground for support. Snowcaps would melt and rivers would overflow, causing flooding in many of our cities. The melting snow and glaciers would also raise the level of the world's oceans, causing drastic changes in coastal areas.

Port cities like Halifax and Vancouver would find much of their waterfront real estate under water. Cities that border large lakes or have rivers would experience greater fluctuations in water levels. The city of Winnipeg has many neighbourhoods that are regularly affected by flood waters from the Red and Assiniboine Rivers (**Figure 8**). This flooding could become worse.



Figure 8
Because so many Canadians live close to large bodies of water, scientists believe that global warming could cause enormous property damage.

The Albedo Effect

If global warming continues to increase, scientists fear that much of the world's permanent ice and snow cover will melt. As mentioned earlier, the melting of polar ice caps will increase the level of Earth's oceans. What other effects could the loss of ice and snow have on the biosphere?

As radiation from the Sun reaches Earth, it is reflected back by Earth's surface. Some surfaces reflect radiation more than others. The term **albedo** is used to describe the extent to which a surface can reflect radiation. The higher the albedo, the greater the ability to reflect radiation. This principle can be applied to the solar radiation striking Earth's surface. The higher the albedo of the surface, the less energy will be absorbed.

Snow and ice have a valuable role in maintaining temperatures on Earth. The albedo of snow and ice cover is extremely high. During winter, the Sun's energy reflects off snow, keeping temperatures low. Snow is part of a cycle known as snow-temperature feedback (**Figure 9**). To picture this cycle, think of an area that is covered in snow. If that area warms up, the snow will melt. Less of the sun's radiation will be reflected, so more radiation will be absorbed. The temperature in the area will increase even more.

Some parts of Earth are permanently covered in snow or ice. If Earth's overall snow and ice cover decreases due to global warming, Earth's surface could absorb more heat, and warm up even more. The snow-temperature feedback cycle works the opposite way, as well. For example, if Earth's temperature were to drop during an ice age, more snow would cover Earth's surface, reflecting more of the Sun's radiation. The temperature would continue to drop.

albedo a term used to describe the extent to which a surface can reflect light that strikes it. An albedo of 0.08 means that 8 % of the light is reflected.

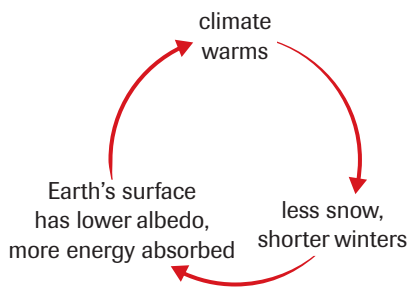


Figure 9

The snow-temperature feedback cycle

INVESTIGATION 3.2 Introduction

The Albedo Effect

The albedo of a surface is affected by various factors, including colour and surface conditions. In this investigation, you will measure the amount of light reflected when the colour and texture of a surface is varied.

Report Checklist

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To perform this investigation, turn to page 68. 

Equilibrium and Earth's Atmosphere

The levels of carbon dioxide and oxygen change little from year to year. However, when these levels are examined over the life of the planet, dramatic changes in the carbon cycle show how living things, Earth's crust, and the atmosphere interact to alter the biosphere. Initially, Earth contained exceedingly high concentrations of CO₂, causing the planet to warm. About 3.5 billion years ago, microscopic marine life began consuming CO₂ and releasing methane. Fossils of these bacteria can be found in rocks called **stromatolites**. Stromatolites are banded limestone structures that contain colonies of marine bacteria.

stromatolite a banded limestone structure containing fossilized bacteria

Many researchers believe that the methane-producing bacteria poured about 600 times the amount of methane into the skies as is found today. That amount of methane, another greenhouse gas, would have increased the temperature of the planet even more. According to this theory, the warmer conditions of the planet in turn increased the population of methane-producing bacteria, causing more methane to be produced and the temperature to rise even more, in a positive feedback loop (Figure 10).

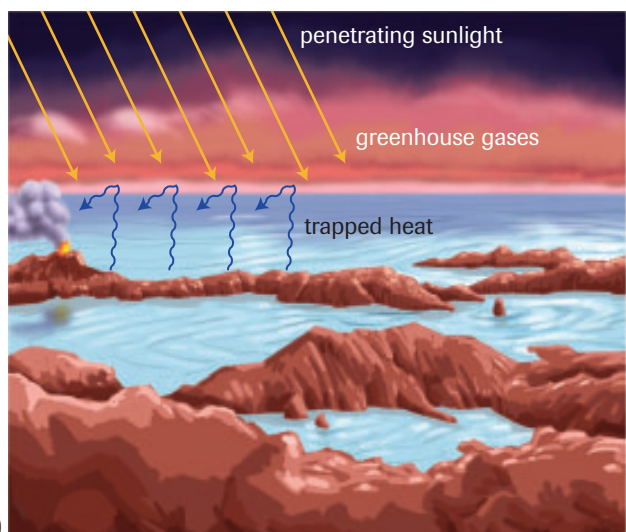
Warmer conditions intensified the water cycle and accelerated the weathering of rocks, a process that pulls CO_2 from the atmosphere. The CO_2 concentrations began to fall and methane production continued to rise. Eventually, the methane gas formed a haze over the planet, deflecting incoming sunlight, and causing temperatures to drop. This made conditions less favourable for the methane-producing bacteria.

DID YOU KNOW?

The Kyoto Accord

The Kyoto Accord is an international agreement to reduce greenhouse gas emissions. It calls for Canada to reduce emissions to 6% below 1990 levels over a period of 10 years. Why does the government of Alberta oppose Kyoto's targets? What is your own opinion? Visit the Nelson Web site to learn more about Alberta's response to the Kyoto Accord.

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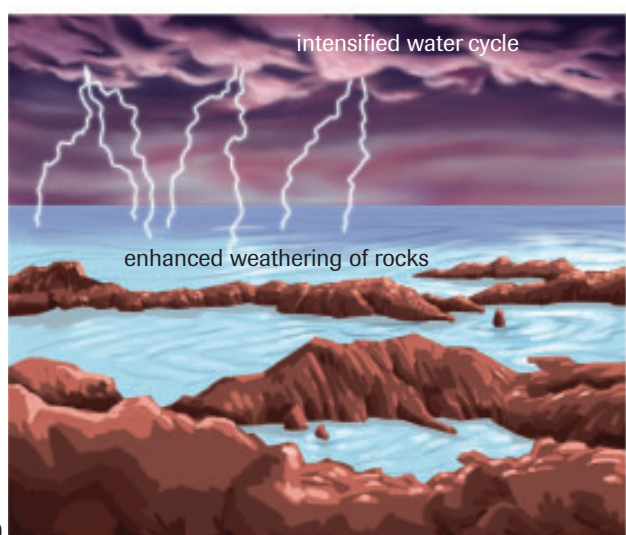


(a)

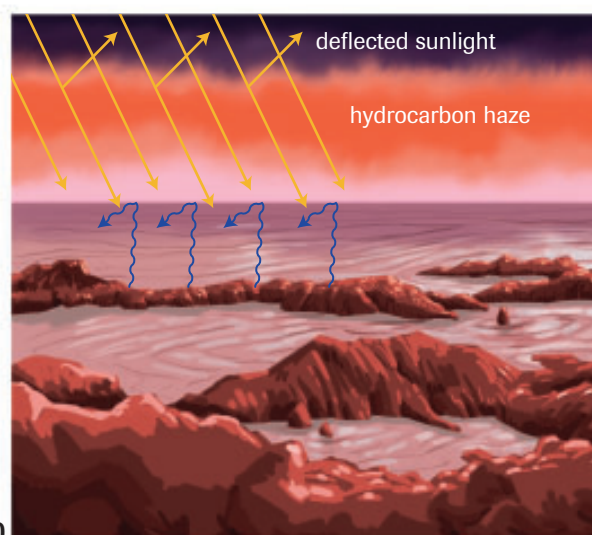
Figure 10

Earth's early atmosphere.

- (a) The greenhouse gases carbon dioxide (from volcanoes) and methane (from bacteria) trapped heat while allowing sunlight to penetrate.
- (b) Warmer temperatures accelerated the water cycle and increased the weathering of rocks. The process caused CO_2 to be absorbed from the atmosphere. CO_2 levels dropped and methane increased.
- (c) A methane haze blocked sunlight and lowered temperatures. Lower temperatures made conditions less favourable to methane-producing bacteria.



(b)



(c)

+ EXTENSION

Causes of the Greenhouse Effect

This Audio Clip provides some deeper information about the causes and global impacts of the greenhouse effect.

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The decline in methane-producing bacteria, approximately 2.3 billion years ago, was accompanied by the appearance of another life form capable of withstanding the cooler temperatures. These photosynthetic bacteria released oxygen. Eventually, the hardier oxygen-producing bacteria overtook the methane-producing bacteria. As oxygen levels began to increase, more complicated life forms could be supported.

Deforestation and the Atmosphere

In the distant past, changes in the populations of living things resulted in changes to Earth's atmosphere. Large-scale changes are happening to populations of trees and other plants at the present time. How will these changes affect the atmosphere?

Human activities are reducing the number of organisms on Earth that carry out photosynthesis. For example, logging reduces the amount of forested area, and land development decreases the space available for plants to grow. Photosynthesis is the source of oxygen in our atmosphere, and also removes carbon dioxide gas from the atmosphere. With less photosynthesis happening on Earth, oxygen levels will decrease, and carbon dioxide levels will increase even more. Protecting forests on Earth is, therefore, essential to preserving our atmosphere.

INVESTIGATION 3.3 Introduction

Report Checklist

Environmental Models

Environmental models allow scientists to study what could happen to the plants and animals in an ecosystem if changes occur. Models help check predictions without disrupting a large area.

In this investigation, you will build an ecocolumn to research an environmental problem. An ecocolumn is an ecological model that is especially designed to cycle nutrients. You must investigate

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one of three different environmental problems in the ecocolumn. You must design your own procedure, collect your own data, and draw your own conclusions.

To perform this investigation, turn to page 69. 

Case Study

Technological Solutions for Global Warming

More than 200 years ago, Earth's atmosphere contained about 280 parts per million (ppm) of carbon dioxide. By 1993, the burning of fossil fuels had raised the level of carbon dioxide to 355 ppm. At our present rate, the projected concentration of carbon dioxide could be 700 ppm by 2050.

The vast majority of scientists believe that this increase in atmospheric carbon dioxide is increasing the greenhouse effect and contributing to global warming. However, indirect

evidence suggests that global fluctuations in temperature and carbon dioxide levels occurred even before humans appeared on the planet. About 135 million years ago, the levels exceeded 1000 ppm, considerably higher than current levels.

As the effects of global warming become more apparent, scientists have developed several potential solutions, using mini-ecosystems and computer models to test various hypotheses. This Case Study presents several suggested solutions. However, no plan is without problems. Think about each technological fix below, and consider its consequences.

Using “Sun Block”

The eruption of Mount Pinatubo in 1991 shot a plume of ash and debris 20 km into the atmosphere. Within three years, even the smallest particles had returned to Earth. Climatologists estimate that this ash blanket cooled global temperatures by about 0.7 °C, at least in tropical areas.

Putting more particles into the atmosphere was suggested by Dr. S.S. Penner, a retired professor from the University of California at San Diego, as a way to cool the planet. Running jet engines on a richer mixture of fuels would add particles to the atmosphere (Figure 11). Burning coal also adds soot to the air. This partial screen would be inexpensive. Eventually, the particles would fall to Earth so the air would not remain polluted.

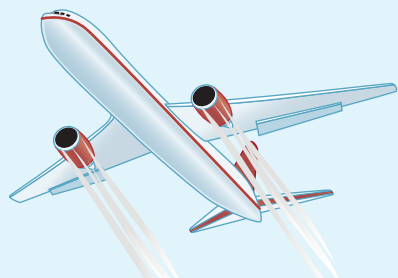


Figure 11

Adding Iron to Sea Water

For many years, naturalists have observed that certain areas of the open ocean are rich in life, while other areas appear barren. After a 7 km² patch of ocean off the coast of South America was sprayed with half a tonne of iron, it soon turned green with phytoplankton (Figure 12). The experiment, conducted in 1995, caused a bloom of marine plants that perform photosynthesis. Adding iron to seawater could increase photosynthesis and use up some of the CO₂ in the atmosphere.

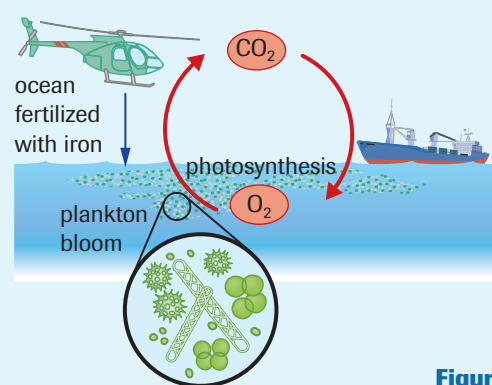


Figure 12

Creating a Deep-Water “Grave” for Carbon Dioxide

An oil company in Norway came up with a revolutionary method to reduce CO₂ levels. Normally, the CO₂ that escapes during the processing of natural gas is released into the air. In

1991, a new carbon tax made this very expensive in Norway. Norwegian companies had to find alternatives.

Natural gas is pumped into a tall tower where the carbon dioxide is removed (Figure 13). Almost 1 km below the seafloor, a pipe carries the CO₂ to a layer of shale. The CO₂ displaces seawater from the porous shale, forming a gas bubble in the rock. The CO₂ takes several hundred years to move through the shale to the seafloor.

Scientists point out that most of the floor of the North Sea is sandstone, capped with a layer of shale. This is ideal for the storage of excess carbon dioxide. On a large scale, it could soak up all of the excess CO₂ produced by countries of the European Union. One of the main dangers is that the CO₂ will combine with water to form a weak acid around the pipe.

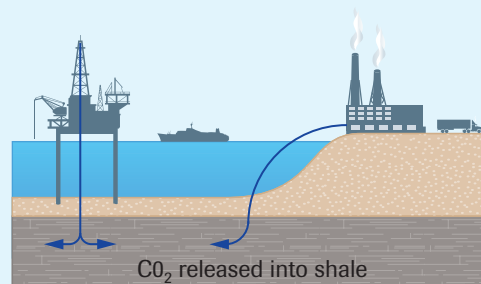


Figure 13

The shale acts as a sink for carbon dioxide gas.

Case Study Questions

1. What groups in Canada might not favour reducing carbon emissions? Provide at least one concern that might be voiced.
2. Why would ash and other particles in the atmosphere cool temperatures?
3. What are some of the possible problems with adding ash and other particles to Earth's atmosphere?
4. How could more algae in Earth's oceans lower global temperatures?
5. What negative effects could increasing the ocean's algae population have on the ecosystem?
6. Why would the formation of weak acids around pipes used to carry carbon dioxide beneath the ocean floor be dangerous?
7. Passing a bylaw saying that people must car pool or take public transportation could reduce fossil fuel usage. Make a list of benefits and problems if this law were instituted.
8. What are the major sources of carbon dioxide in Canada? And what are Canadians doing about the problem of carbon dioxide production? Do research, and then write a short paragraph answering these questions.

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Case Study—Biosphere 2

+ EXTENSION



CBC **radiONE**

QUIRKS & QUARKS

A Carbon Sinking Feeling

Dr. Werner Kurz (team leader at Essa Technologies and an adjunct professor at the University of British Columbia and Simon Fraser University) discusses the idea that carbon can be absorbed by forests and natural ecosystems.

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On September 26, 1991, four men and four women entered a gigantic dome near Tucson, Arizona, that contained 3800 species of plants and animals. The dome was sealed after they entered. They were to live there for one year. Nothing was to be brought in and nothing, and no one, would be allowed out. All raw materials and waste products were to be recycled by humans, animals, and plants living together. Named Biosphere 2, the dome was the largest and most expensive artificial ecosystem ever created.

Unfortunately, the experiment demonstrated in a fairly short time that we do not know everything we need to know about Earth's ecosystems to fulfill this goal. Despite careful planning to ensure the right numbers of plants and animals, and the use of computer simulations and electronic monitoring devices, the amount of carbon dioxide in the air inside the dome kept increasing. Scientists were not able to establish a workable balance between the number of plants and animals. On November 12, the team running the experiment gave up and pumped in purified air from the outside.

In this Web Activity, you will explore what caused the initial failure of the Biosphere 2 experiment, and find out how the facility is being used today to increase our understanding of the interactions among biotic and abiotic factors in ecosystems.

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+ EXTENSION



What's Up with the Weather?

FRONTLINE and *NOVA* take on a complex and critical phenomenon—global warming.

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SUMMARY

The Carbon Cycle and the Oxygen Cycle

- Most of the carbon in living organisms is returned to the atmosphere or water as carbon dioxide when wastes and the bodies of dead organisms decay. Carbon cycles rapidly through the atmosphere or when dissolved in water, but can be held for many years in living things such as trees.
- A tremendous amount of carbon is held in the oceans. Some of the carbon dioxide is dissolved in water, another portion reacts with seawater to form carbonate ions (CO_3^{2-}) and bicarbonate ions (HCO_3^-), and yet another portion is used by algae and plants that perform photosynthesis.
- The largest reservoir for Earth's carbon is in sedimentary rocks, such as limestone (CaCO_3), found on the ocean floor and continents.
- Oxygen cycles between living things and the atmosphere via photosynthesis and cellular respiration. Oxygen is stored in the atmosphere, in water, and in rock.
- Humans have modified the global carbon cycle through the increasing use of fossil fuels and by the burning of forests. These cause the release of carbon dioxide at a rate well above natural cycling. In addition, the destruction of vegetation reduces the amount of photosynthesis and thus the volume of carbon dioxide removed from the atmosphere.
- The term albedo is used to describe the extent to which a surface can reflect light that strikes it. The albedo of ice and snow is extremely high, so ice and snow reflect considerable amounts of radiation from the Sun. Changes in Earth's snow and ice cover may affect equilibrium in the biosphere.

Section 3.2 Questions

- Explain the importance of decomposers in the carbon cycle.
- The oceans are often described as a carbon reservoir. In what ways is carbon held within the oceans?
- Explain how the burning of fossil fuels by humans affects the carbon cycle.
- Carbon cycles more quickly through some ecosystems than others.
 - Explain why carbon is cycled more slowly in northern ecosystems than in the tropics.
 - Explain why carbon is cycled more rapidly in grassland communities than in peat bogs and swamps.
- Study **Table 1**.

Table 1 Carbon Cycle

Carbon movement	Mass of carbon per year (10^{13} kg)
from atmosphere to plants	120
from atmosphere to oceans	107
to atmosphere from oceans	105
to atmosphere from soil	60
to atmosphere from plants	60
to atmosphere from burning of fossil fuels	5
to atmosphere from net burning of plants	2
to oceans from runoff	0.4

- Calculate the amount of carbon entering the atmosphere as carbon dioxide every year and the amount of carbon leaving the atmosphere. Is atmospheric carbon dioxide increasing or decreasing?
 - Draw a bar graph showing factors that increase and decrease atmospheric carbon dioxide levels.
 - The burning of forests contributes 2×10^{13} kg of carbon yearly, but its impact on creating a carbon imbalance is even greater than the carbon dioxide released from the burning plants. What other factor would be affected by burning forests?
 - Provide a list of suggestions that would reduce the flow of carbon dioxide into the atmosphere. How would the suggestions affect your life? Which of your suggestions do you think you could help with?
- Scientists have expressed concerns about the burning of the rainforests to clear land for farming.
 - Explain how the burning of the forests could change oxygen levels in the atmosphere.
 - What impact would the change in oxygen levels have on living things?
 - In 1998, the federal government of Canada proposed a “carbon tax” on gasoline.
 - Would a carbon tax reduce the amount of carbon dioxide entering the atmosphere? Give reasons for your answer.
 - What businesses would be affected by the tax? Explain how they would be affected.
 - What other groups or individuals would be affected by the tax? Would it apply equally and fairly to everyone?
 - Based on your analysis, who would you expect to oppose the tax? Who would you expect to support the tax?
 - What are emission credits and how do these affect the amount of CO_2 produced globally? Do research to find out.

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- A number of different factors affect the balance of oxygen and carbon dioxide on the planet. Some of these are listed below. Research a factor and draw a poster. Use text to help explain the poster.

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- Deforestation means less oxygen is available.
 - Tropical rain forests are being cleared and burned for farming and ranching.
 - Temperate rain forests are being cut for lumber.
 - Agricultural land is being used for housing developments, new factories, and landfill sites. An overall decrease in plant life will lower oxygen levels.
 - Increased combustion in factories is increasing the amount of CO_2 in the atmosphere. The increased level of CO_2 elevates temperatures, which;
 - causes the ice caps and glaciers to melt;
 - expands the size of deserts; and
 - changes the types of crops and food supply.
- As ice and snow cover on Earth decreases, what effect do you think this may have on the equilibrium of Earth's atmosphere?

3.3 The Nitrogen Cycle and the Phosphorus Cycle

nitrogen cycle a cycle of matter in which nitrogen atoms move from nitrogen gas in the atmosphere, to inorganic forms in the soil, to organic forms in living things, and then back to inorganic forms in the soil and nitrogen gas in the atmosphere

nitrogen fixation two processes in which atmospheric or dissolved nitrogen is converted into nitrate ions

Life depends on the cycling of nitrogen. Nitrogen atoms are required so that cells can make proteins. Nitrogen is also required for the synthesis of deoxyribonucleic acid or DNA, the hereditary material found in all living things. The movement of nitrogen through ecosystems, the soil, and the atmosphere is called the **nitrogen cycle**.

When you consider that nitrogen gas (N_2) makes up nearly 79 % of Earth's atmosphere, you would expect nitrogen to be easy for organisms to access. Unfortunately, this is not the case. Nitrogen gas is a very stable molecule, and reacts only under limited conditions. To be useful to plants, nitrogen must be supplied in another form, the nitrate ion (NO_3^-). The nitrogen cycle is exceptionally complex. A simplified description is shown in **Figure 1**.

Nitrogen Fixation

There are two ways in which atmospheric nitrogen can be converted into nitrates, in a process called **nitrogen fixation**. The first method is through lightning, and the second is through bacteria in the soil.

A small amount of nitrogen is fixed into nitrates by lightning. The energy from the lightning causes nitrogen gas to react with oxygen in the air, producing nitrates. The nitrates

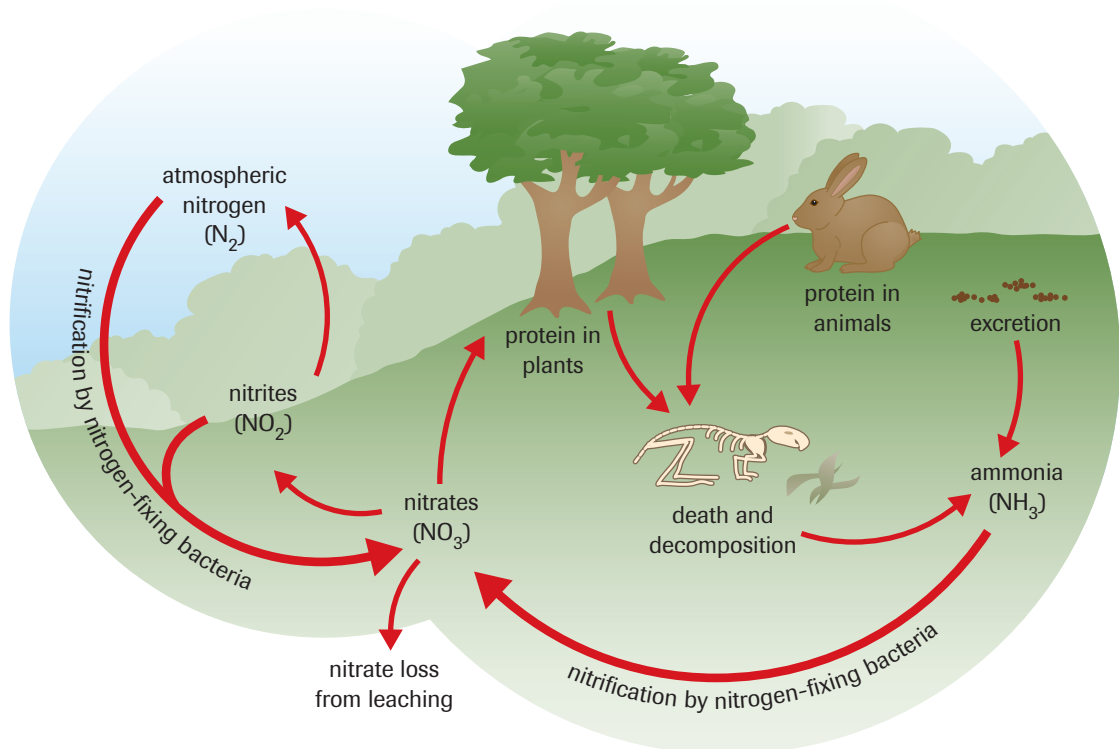


Figure 1 

Like carbon, nitrogen moves in a cycle through ecosystems, passing through food chains and from living things to their environment and back again.

dissolve in rain or surface water, enter the soil, and then move into plants through their roots. Plant cells can use nitrates to make DNA, and convert nitrates into amino acids, which they then string together to make proteins. When a plant is consumed by an animal, the animal breaks down the plant proteins into amino acids and then can use the amino acids to make the proteins it needs.

Some bacteria are capable of fixing nitrogen. These bacteria provide the vast majority of nitrates found in ecosystems. They are found mostly in soil. Nitrogen-fixing bacteria can also be found in small lumps called nodules on the roots of legumes such as clover, soybeans, peas, and alfalfa (**Figure 2**). The bacteria provide the plant with a built-in supply of usable nitrogen, while the plant supplies the nitrogen-fixing bacteria with the sugar (energy) they need to make the nitrates. This plant–bacteria combination usually makes much more nitrate than the plant or bacteria need. The excess moves into the soil, providing a source of nitrogen for other plants.

Traditional agricultural practices of including legumes in crop rotation and mixed planting, capitalize on bacterial nitrogen fixation. For example, the Iroquois traditionally planted corn, beans, and squash together. Known as the “Three Sisters,” these crops help each other and protect the soil. Corn provides scaffolding for the other plants, while beans add nitrate to the soil. Squash prevents water evaporation and erosion, and helps control the growth of weeds.

Nitrogen and Decomposers

All organisms produce wastes and eventually die. When they do, a series of decomposers break down the nitrogen-containing chemicals in the waste or body into simpler chemicals such as ammonia (NH_3). Other bacteria convert ammonia into nitrites, and still others convert the nitrites into nitrates. These bacteria all require oxygen to function. The nitrates, then, continue the cycle when they are absorbed by plant roots and converted into cell proteins and DNA.

Farmers and gardeners who use manure and other decaying matter as fertilizer take advantage of the nitrogen cycle. Soil bacteria convert the decomposing protein in the manure into nitrates. Eventually, the nitrates are absorbed by plants.

Denitrification

At various stages in the decay process, bacteria can break down nitrates into nitrites, and then nitrites into nitrogen gas. Eventually, the nitrogen gas is released back into the atmosphere. This process, called **denitrification**, is carried out by bacteria that do not require oxygen. Denitrification acts to balance nitrates, nitrites, and atmospheric nitrogen in the soil, and completes the nitrogen cycle.

Older lawns often have many denitrifying bacteria. The fact that denitrifying bacteria grow best where there is no oxygen may help to explain why gardeners often aerate their lawns in early spring. Exposing the denitrifying bacteria to oxygen reduces the breakdown of nitrates into nitrogen gas. Nitrates will then remain in the soil, where they can be drawn in by grass roots and used to make proteins.

This information may also help you understand why the leaves of some plants may not be a rich green colour. Chlorophyll is a protein, and plants require nitrates to make it. The colour of a plant’s leaves may tell you the nitrate content of the soil (**Figure 3**).

The denitrification process speeds up when the soil is acidic or water-logged (oxygen content is low). Bogs, for example, are well known for their lack of useful nitrogen. They can support only a few types of plants—those able to live with low levels of nitrogen. Insect-eating plants, such as sundews and pitcher plants (**Figure 4**), are commonly found in bogs. In an interesting reversal of roles, these plants obtain their nitrogen by digesting trapped insects.



Figure 2

A clover root: the swollen nodules contain nitrogen-fixing bacteria



Figure 3

Plants that grow in nitrogen-poor soils can form only a limited amount of chlorophyll. The yellowness of this plant’s leaves indicates that the plant is starving for nitrogen.

denitrification the process in which nitrates are converted to nitrites and then to nitrogen gas



Figure 4

Insect-eating plants like this pitcher plant can grow in nitrogen-poor soil.

fertilizer a material used to restore nutrients to plants

Agriculture and Nutrient Cycles

The seeds, leaves, flowers, and fruits of plants all contain valuable nutrients, which is why we eat them. However, as crops are harvested, much of the valuable nitrogen and phosphorus in these plants is removed and does not return to the field or orchard. This diversion of nitrates and phosphate from the local cycles would soon deplete the soil unless the farmer replaced the missing nutrients. **Fertilizers** are materials used to restore nutrients and increase production from land. Some estimates suggest that fertilizers containing nitrogen and phosphates can double yields of cereal crops such as wheat and barley. However, fertilizers must be used responsibly. More is not necessarily better.

Soil bacteria convert the nitrogen content of fertilizers into nitrates, but the presence of high levels of nitrates may result in an increase in the amount of nitric acids in the soil. Changes in the levels of acidity can affect all organisms living in the soil, including decomposer bacteria.

Depending on the soil and the other chemicals in the fertilizer, a typical annual application of between 6 and 9 kg/ha of nitrogen fertilizer can, in 10 years, produce a soil that is 10 times more acidic. This can have devastating effects on food production. Most grassland soils in Canada's prairies have a pH near 7 (neutral). If the soil becomes more acidic, some sensitive crops like alfalfa and barley will not grow as well. Acid rain and snow only add to the problem.

Fertilizer and Ecosystems

The accumulation of nitrogen and phosphate fertilizers produces an environmental problem. As spring runoff carries decaying plant matter and fertilizer-rich soil to streams and then lakes, the nutrients allow algae in the water to grow more rapidly (**Figure 5**) in what is called an algal bloom. When the algae die, bacteria use oxygen from the water to decompose them. Because decomposers flourish in an environment with such an abundant food source, oxygen levels in lakes drop quickly, so fish and other animals may begin to die. Dying animals only make the problem worse, as decomposers begin to recycle the matter from the dead fish, allowing the populations of bacteria to grow even larger, and use still more oxygen.

Nitrates present another problem. As you have seen, there are bacteria that convert nitrates into nitrites (NO_2^-). But nitrites are dangerous to animals that have hemoglobin in their blood, such as humans and other mammals, fish, reptiles, and amphibians. Nitrites can attach to the hemoglobin in blood, reducing its ability to carry oxygen to tissues.

The problem of nitrates in drinking water is especially serious for young animals, including human infants. Humans and other animals usually have bacteria that convert nitrates into nitrites in their large intestines. For adults, the presence of these bacteria in the digestive system is not harmful, because the stomach of an adult is so acidic that the bacteria cannot survive. But the stomach of an infant is much less acidic, so the bacteria can move up into the stomach, where they will convert nitrates into nitrites. The nitrites can then pass into the blood of the infant.

The question of how much nitrate should be allowed in drinking water and food is important, but we also need to know more about the nitrogen cycle in order to properly evaluate the environmental impact of nitrates.



Figure 5
Spring runoff of nitrogen and phosphorus fertilizers promotes the growth of algae.

▶ mini Investigation

Effects of Nitrogen on Algal Growth

Spring runoff of nitrogen fertilizers causes algae to grow rapidly in neighbouring lakes. In some lakes, a film of algae coats the entire surface of the water. This makes the lake a lot less appealing to swim in. More importantly, the resulting lack of oxygen places other organisms in the ecosystem in peril.

By passing pond water through a filter and then allowing the filter and algae to dry, you can measure the mass of algae collected.

- Using this technique, design a controlled investigation to measure how a fertilizer affects growth of algae.
 - Have your design, safety precautions, materials, and written procedure approved by your teacher before beginning the procedure. Conduct your investigation and collect your results.
- Report on the results of your investigation. Include an evaluation of your design, as well as suggestions for improvement.

The Phosphorus Cycle

Phosphorus is a key element in cell membranes, in molecules that help release chemical energy, in the making of DNA, and in the calcium phosphate of bones. The **phosphorus cycle** has two parts: a long-term cycle involving the rocks of Earth's crust, and a short-term cycle involving living organisms (Figure 6).

phosphorus cycle the cycling of phosphorus between the biotic and abiotic components of the environment; consists of a biological and geochemical cycle

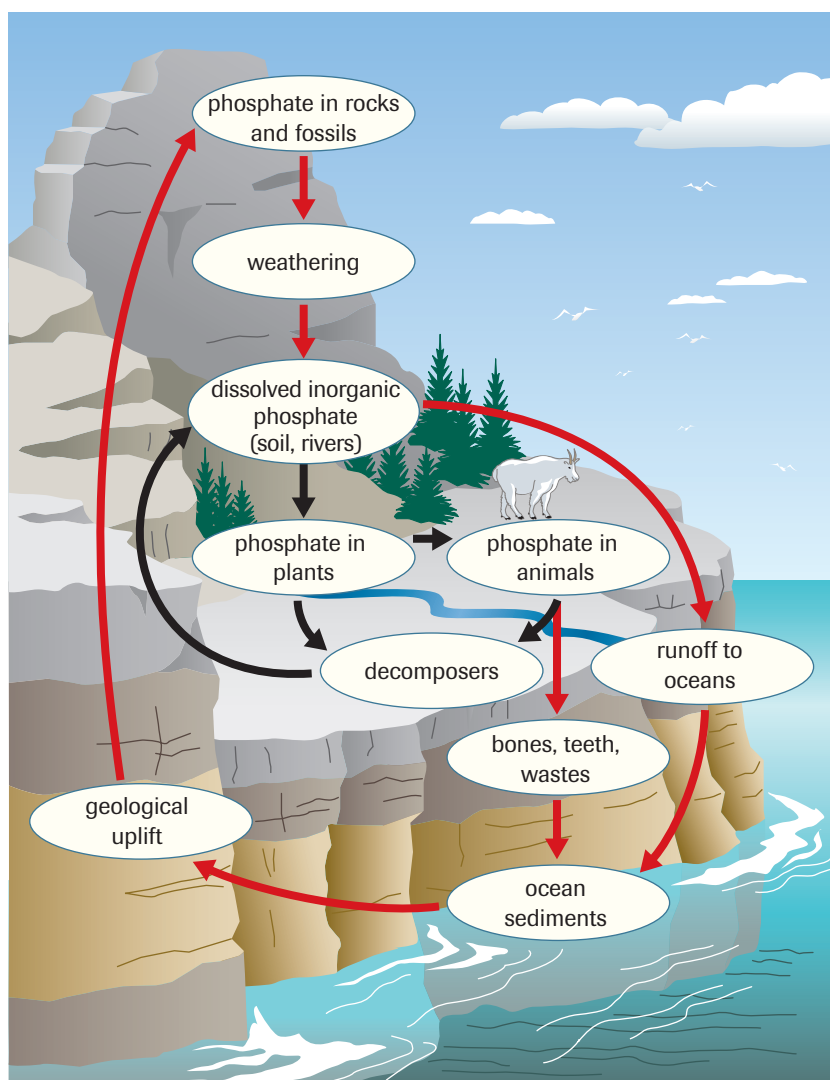



Figure 6  Phosphates cycle in both long (red arrows) and short (black arrows) cycles.

DID YOU KNOW?

Matter Cycling in a Closed System

In the International Space Station, carbon dioxide, oxygen, water, and other materials must be recycled. How does matter cycling work in a closed system? Research the life support systems of the ISS to answer this question.

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nutrient a chemical that is essential to living things

Living things divert phosphates from the normal (long) rock cycle. Phosphorus is found in bedrock in the form of phosphate ions (PO_4^{3-}), combined with a variety of elements. Phosphates are soluble in water and so can be dissolved out of rock. While dissolved, phosphates can be absorbed by photosynthetic organisms and so pass into food chains.

Phosphates eroded from rock are also carried by water from the land to rivers, and then to the oceans. In the ocean, phosphates are absorbed by algae and other plants, where they can enter food chains. Marine animals use phosphates to make bones and shells. When they die, these hard remains form deposits on the ocean floor. Covered with sediment, the deposits eventually become rock, ready to be brought to the surface again. The long cycle can take millions of years to complete.

In the short cycle, wastes from living things are recycled by decomposers, which break down wastes and dead tissue and release the phosphates. The short cycle is much more rapid.

Variations in Nutrient Cycling

Nitrates and phosphates are both nutrients. **Nutrients** are chemicals that are essential to living things. Potassium, calcium, and magnesium are other examples of nutrients. The rate at which nutrients cycle through an ecosystem is linked to the rate of decomposition. Organic matter decomposes relatively quickly in the tropical rain forests. Warmth, moist soil, and the vast number of diverse and specialized decomposers permit a cycle to be complete in as little as a few months. Cycling in cooler forests takes an average of between four and six years. In the even cooler tundra, nutrient cycling takes up to 50 years. In the oxygen-poor environment of most lakes, cycling may take even longer. Temperature and oxygen levels are the two most important abiotic factors regulating decomposition. Other factors, such as soil chemistry and the frequency of fire, also affect decomposition and cycling.



INVESTIGATION 3.4 Introduction

Phosphate Identification

Phosphate is a common pollutant that may arise from human activity. The presence of phosphates in water can be detected by adding magnesium sulfate. In this investigation, you will use this salt to test various water samples for the presence of this pollutant.

Report Checklist

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| <input type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input checked="" type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

To perform this investigation, turn to page 71.



Case Study—Persistent Pesticides and Matter Flow

Pesticides are chemicals designed to kill pests. A pest is an organism that people consider harmful or inconvenient, such as weeds, insects, fungi, and rodents. In many situations, pesticides are used to protect species that are beneficial to humans from a competitor or predator that is less useful. One estimate suggests that as much as 30 % of the annual crop in Canada is lost to pests such as weeds, rusts and moulds (both forms of fungi), insects, birds, and small mammals. The cost to consumers can be staggering. For example, in 1954 three million tonnes of wheat from the Prairies was destroyed by stem rust, a fungus that grows inside the leaves and stems of the wheat and other plants, feeding on the plant's stores of food.

In 1998, a total of 9 300 497 kg of pesticides were sold in, or shipped into, Alberta. By far the greatest amount, approximately 96 %, can be linked to agriculture. Persistent pesticides are those that break down very slowly, and so affect the environment for a long period. This activity is a case study of the use of persistent pesticides in Alberta and other regions.

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SUMMARY

The Nitrogen Cycle and the Phosphorus Cycle

- Life depends on the cycling of nitrogen, which is required for the synthesis of proteins and DNA. The movement of nitrogen through ecosystems, the soil, and the atmosphere is called the nitrogen cycle.
 - Atmospheric nitrogen is converted into nitrates by nitrogen fixation, either by lightning or by bacteria in the roots of legumes.
 - Decomposers break down nitrogen compounds in wastes or dead bodies into simpler compounds such as ammonia (NH₃). Other bacteria convert ammonia into nitrites, and still others convert the nitrites back into nitrates.
 - Denitrifying bacteria break down nitrates into nitrites, and then nitrites into nitrogen gas, which is released back into the atmosphere.
- Phosphorus is found in cell membranes, in energy-containing molecules, in DNA, and in bones.
- Phosphorus cycles in two ways: a long-term cycle involving the rocks of Earth's crust, and a short-term cycle involving living organisms.
- The rate of cycling of nutrients is linked to the rate of decomposition.

Section 3.3 Questions

- Why do the levels of nitrogen and phosphorus in fields decline when crops are harvested?
- Explain how excess fertilizers might affect decomposing organisms.
- (a) Why do algal blooms usually occur in spring?
(b) Explain how algal blooms affect other organisms in freshwater ecosystems.
- What dangers do high levels of nitrates in the drinking water present for infants?
- If a farmer does not plant a crop in one field, and then plows the field in the fall, how would this help restore nitrogen and phosphorus levels in the soil?
- Explain why nitrogen is important to organisms.
- If nearly 79 % of the atmosphere is nitrogen, how could there be a shortage of nitrogen in some soils?
- How do animals obtain usable nitrogen?
- Nitrogen-fixing bacteria are found in the roots of bean plants. Explain how the bacteria benefit the plant and how the plant benefits the bacteria.
- Draw a diagram of the nitrogen cycle for a farm or garden where manure is used.
- Explain why it is a good practice to aerate lawns.
- Explain why phosphorus is important to living things.
- Some farmers alternate crops that require rich supplies of nitrogen, such as corn, with alfalfa. Alfalfa is usually less valuable in the marketplace than corn. Why would farmers plant a crop that provides less economic value?
- Explain why bogs and swamps are usually low in nitrogen.
- Speculate about why clover would begin to grow in an older lawn. How would the presence of clover benefit the lawn?
- Nitrate levels were analyzed from living material and soil samples in three different ecosystems (grassland, temperate rain forest, and tropical rain forest) in the same month. To determine the mass of nitrates in living things, all living plant matter was collected in a study area and the levels of nitrates were determined. The same analysis was conducted for the top layer of soil. The results are listed in **Table 1**, where each ecosystem is identified by a number.
 - In which community does nitrogen cycle most rapidly? Explain your conclusion.
 - Which ecosystem (grassland, temperate rain forest, and tropical rain forest) is study area 1, 2, and 3? Give reasons for your answers.
 - Speculate about the data that might be collected from a tundra ecosystem. Explain your prediction.
- The phosphorus cycle has been described as having two components—a long cycle and a short cycle. The carbon cycle can be described the same way. Draw a diagram that splits the carbon cycle into “short” and “long” components.
- Human waste contains nitrates and nitrites. Before the arrival of municipal sewers, the backyard outhouse was standard for collection of human waste. Outhouses can still be found at some cottages. Outhouses consist of a small building over a hole in the ground. Explain why outhouses pose a risk to neighbouring lakes, using information that you have gained about the nitrogen cycle.
- How is the water cycle important in the cycling of nitrogen and phosphorus?
- The use of nitrogen-rich fertilizers has allowed farmers to abandon crop rotation.
 - What advantages are gained from planting wheat year after year?
 - New strains of crops have been especially bred to take up high levels of nitrogen. These strains produce more grain. Speculate about some possible long-term disadvantages that these crops might present for ecosystems.
- People have used fertilizers for a long time. Explain why we must begin changing our views on the use of fertilizers so the ecosystems we live in will be sustainable. Why is it so difficult to change practices?
- Crop rotation is an effective way of restoring nitrogen to the soil; however, the planting of legumes is not always popular with farmers. Legume crops may provide less income, because they are more costly to plant, difficult to tend and harvest, and worth less in the marketplace. Farmers must continually balance short-term gains and long-term results in this way. Provide some examples of how you balance short-term gains with long-term results in decisions that you make.

Table 1 Nitrate Content of Three Ecosystems

Study area	Soil nitrates (kg/ha)	Biomass nitrates (kg/ha)	Soil temperature (°C)
1	30	90	25
2	10	175	19
3	2	270	30
tundra	?	?	?

INVESTIGATION 3.1

Nutrient Cycling and Plant Growth

In a natural setting, plants grow without benefit of artificial fertilizers. The continuous recycling of nutrients between decomposing matter and growing plants, together with changes in the species of plants growing in the soil, ensures that the soil remains productive. However, not all soils are equal. In this investigation, you will determine whether nutrients leached from different soils can promote plant growth. Since many of these nutrients are water-soluble, they are carried downward to the lower levels of the soil by percolation.

Design

This is a controlled experiment to determine which of three soil samples yields the most dissolved nutrients. Seeds are planted in standard potting soil and watered using leachate from three soil samples.

- (a) Identify the dependent and independent variables in this experiment.
- (b) What control is used in the experiment? Explain your answer.

Materials

- safety goggles
- apron
- 250 mL clay soil (sample A)
- 250 mL silt soil (sample B)
- 250 mL sandy soil (sample C)
- soil-less potting mixture such as vermiculite
- food colander
- cheesecloth
- distilled water
- 250 mL beaker
- bucket or other large container
- 3 plastic storage bottles
- marking pen
- pots or other containers
- pea, corn, or bean seeds (presoaked for 24 h)
- 100 mL graduated cylinder



CAUTION: Always wash your hands thoroughly after handling soil.

Report Checklist

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| <input checked="" type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input checked="" type="radio"/> Synthesis |
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Procedure

1. Line a colander with cheesecloth. Place 250 mL of soil sample A in the colander. Position a large container under the colander and pour 250 mL of distilled water over the soil (**Figure 1**). Allow the water to collect in the container.



Figure 1

2. Repeat step 1 twice, reusing the water in the container. After the final filtering, pour the filtered water into a plastic storage bottle and label it “leachate from soil sample A.”
3. Repeat steps 1 and 2 for soil samples B and C, using clean cheesecloth and fresh water .
4. Pour a 20-cm depth of soil-less potting mixture into each of four plant pots. Label the pots A, B, C, and control.
5. Plant five seeds in each pot.
6. Using a 100 mL graduated cylinder, add 50 mL of leachate from soil sample A to the pot labelled A, from soil sample B to pot B, and from soil sample C to pot C.
7. Add 50 mL of distilled water to the seeds in the pot labelled “control.”
8. Put the pots in a warm, well-lit location.
9. Each day, check the pots for moisture (they should be moist, but not wet). If water must be added, add the same amount of water to each pot from its leachate bottle.

INVESTIGATION 3.1 *continued*

Evidence

- (c) Record the height of each plant every day. Make notes on the colour, health, and appearance of each of the plants.

Analysis and Evaluation

- (d) Calculate the mean height for the control and experimental plants each day. (If one seed in a group fails to germinate and grow, do not count it when you calculate the mean).
- (e) Why is it useful to report the mean height for all five plants, rather than the height of each individual plant?
- (f) Plot a line graph of the mean height over time for the control and experimental groups.

- (g) Read the comments you kept about the plants as they grew and review your growth data. Does the evidence that you collected in this experiment support or contradict your prediction? Explain your answer.

Synthesis

- (h) Grain farmers may burn the stubble (the stalks of the grain plants) after harvest. List the advantages and disadvantages of burning stubble for
- (i) the farmer
 - (ii) soil organisms
 - (iii) neighbours
- (i) Suggest gardening techniques that could help reduce the amount of artificial fertilizer used in a garden.

INVESTIGATION 3.2

The Albedo Effect

Purpose

To examine the ability of selected colours and surface conditions to reflect light

Materials

desk lamp	dissecting pan
ring stand	sand
extension clamp	gravel
light sensor	soil
coloured card stock	water
(including black and white)	snow and/or ice

Procedure

1. Aim the desk lamp at the bench surface.
2. Attach the light sensor to the ring stand so that it is higher than the light source. Its active surface must face down and have a clear path to the surface of the bench. (Figure 1).
3. Place the sheet of white card stock directly under the lamp.

Report Checklist

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Figure 1
The experimental setup

INVESTIGATION 3.2 *continued*

Evidence

4. Turn on the lamp and record the reading from the light sensor.
5. Repeat the experiment, using the other coloured sheets. Remember to control all your variables.
6. Set the dissecting pan directly under the lamp.
7. Record the reflective value of the pan when empty. Repeat, using a sand surface, a gravel surface, soil, water, and snow and ice.

Analysis and Evaluation

- (a) Why is it necessary to keep the light sensor out of the direct line of light?
- (b) What variable must be controlled?
- (c) Why are black and white card stock colours used in this experiment?

- (d) List the coloured surfaces in order from least to greatest reflected light.
- (e) Use your data to make comments on the albedo effect of the materials used.
- (f) What variable were you unable to control in Step 7 of the laboratory procedure? How could you redesign these steps to account for the variable?
- (g) Design an experiment to measure the effect of colour or surface conditions on the absorption of heat. State your hypothesis and the predictions resulting from it.
- (h) Perform the investigation you designed (approval of instructor required) and draw conclusions based on the collected data.

Synthesis

- (i) In order to melt a pile of snow more quickly, a researcher sprayed dye-coloured water on it. Which colour was probably selected and why?

INVESTIGATION 3.3

Environmental Models

Environmental models allow scientists to study what could happen in an ecosystem if changes occurred. Models help check predictions without disrupting a large area. In this investigation, you will build an ecocolumn, an ecological model that is especially designed to cycle nutrients. You will then design and carry out an experiment to investigate one of three environmental problems.

Problem

- (a) Choose from one of the three ecological problems below:
 - A. How would an oil spill affect an aquatic ecosystem? (You will be allowed to use motor oil to test the environmental impact.)
 - B. How would acid rain affect an ecosystem? (You will be allowed to use household vinegar only.)
 - C. How would rapid changes in climate affect an ecosystem?

Report Checklist

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| <input checked="" type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
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- (b) Research the problem and provide at least one page explaining the environmental problem.

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Prediction

- (c) Make a prediction.

Design

- (d) Based on the materials and instructions below for building an ecocolumn, design your experiment. Include materials, a procedure, and any needed safety precautions. Present your design for approval before beginning.

INVESTIGATION 3.3 *continued*

Materials

2 or more 2 L plastic pop bottles with caps (remove labels)
pond water, soil compost
representative organisms (moss, flies, spiders, snails, etc.)
scissors
duct tape or binding tape (wide width) or silicone sealant

Instructions for Building the Ecocolumn

1. Using scissors, remove the top and bottom of a 2-L plastic bottle, as shown in **Figure 1**.
2. Cut a second bottle just before the point at which the bottle narrows (**Figure 2**).

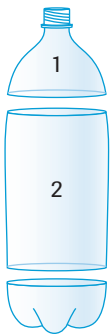


Figure 1

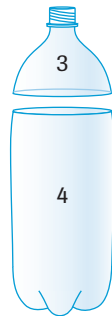


Figure 2

3. Slide part 1 into part 2, as shown in **Figure 3**. Seal the two together with silicone or tape. Next stack the structure on top of part 4.
4. A example of a more complex ecocolumn is shown in **Figure 4**. You decide on the design.



Figure 3

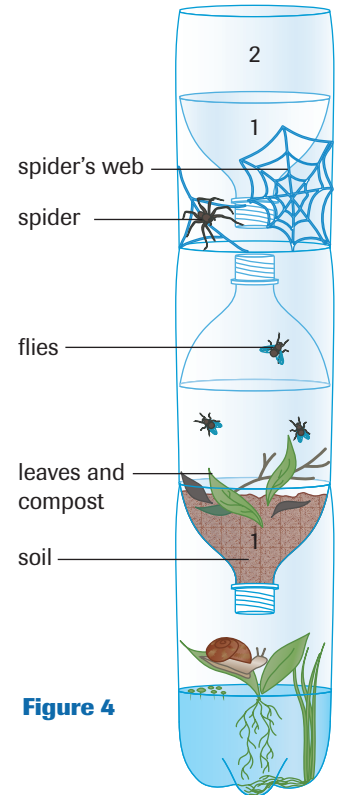


Figure 4

INVESTIGATION 3.4

Phosphate Identification

Algae populations increase rapidly in response to phosphate pollution. There is a quick, simple test for detecting this form of pollution. The presence of phosphates in a water sample can be detected by adding the salt magnesium sulfate. The magnesium in the compound combines with phosphates in the water to form the insoluble salt magnesium phosphate. As crystals of magnesium phosphate form, they turn the clear solution in the test tube cloudy.



Wear gloves throughout the procedure, and wash your hands thoroughly.

Materials

goggles
safety gloves
apron
4 large test tubes
test-tube rack
waterproof marker
distilled water (A)
water samples from your local area (B, C, and D)
10 mL graduated cylinder
medicine dropper
dilute ammonium hydroxide solution
magnesium sulfate solution
watch glass
hand lens
pH paper, pH probe, or pH meter

Procedure

1. Obtain four large test tubes and label them A, B, C, and D. Place the tubes in a test-tube rack. Using a graduated cylinder, pour 10 mL of distilled water into tube A. Pour 10 mL each of samples B, C, and D into the test tube with the corresponding letter label. Rinse and dry the cylinder after each sample.

Report Checklist

- | | | |
|----------------------------------|-------------------------------------------|---------------------------------------------|
| <input type="radio"/> Purpose | <input type="radio"/> Design | <input checked="" type="radio"/> Analysis |
| <input type="radio"/> Problem | <input type="radio"/> Materials | <input checked="" type="radio"/> Evaluation |
| <input type="radio"/> Hypothesis | <input type="radio"/> Procedure | <input checked="" type="radio"/> Synthesis |
| <input type="radio"/> Prediction | <input checked="" type="radio"/> Evidence | |

2. Measure and record the pH of each sample.
3. Using a medicine dropper, add 25 drops of dilute ammonium hydroxide to each sample. This will ensure that the samples will be basic (have a pH greater than 7).
4. Using the graduated cylinder, add 2 mL of magnesium sulfate solution to each of the samples in the test tubes. Let the test tubes stand for 5 min. Record your observations over the 5 min.
5. Pour a small sample of the solution from test tube A into a clean watch glass. Using a hand lens, examine the sample for crystals. Record your observations. Repeat this step for each of the other samples.
6. Wash your hands, first with your gloves on and then without.

Analysis and Evaluation

- (a) Based on your results, which of the samples contained phosphates?
- (b) Speculate about the source of phosphates in each of the samples that tested positive. What is the most likely source? Make a plan to determine the source of the phosphates.
- (c) Was pH related to the amount of phosphate in the samples? Explain.

Synthesis

- (d) The pH of lakes and streams can change as a result of acid rain. Predict how acidification of a lake would affect its phosphate levels.
- (e) Predict how lake acidification would affect the biomass of a lake ecosystem. Explain your reasoning, using a food chain or food web.

Outcomes

Knowledge

- explain and summarize the cycling of carbon, oxygen, nitrogen, and phosphorus, and relate to reuse of all matter in the biosphere (3.2, 3.3)
- explain water's role in the matter cycles, using its chemical and physical properties (3.1)
- explain how the equilibrium between gas exchanges in photosynthesis and cellular respiration influences atmospheric composition (3.2)
- describe the geological evidence (stromatolites) and scientific explanations for change in atmospheric composition, with respect to O₂ and CO₂, and the significance to current biosphere equilibrium (3.2)

STS

- explain that science and technology are developed to meet societal needs and expand human capabilities (all)
- explain that science and technology have both intended and unintended consequences for humans and the environment (all)

Skills

- ask questions and plan investigations by: designing an experiment to compare the carbon dioxide production of plants with that of animals (3.2); hypothesizing how alterations in the carbon cycle as a result of the burning of fossil fuels might interact with other cycling phenomena (3.2); predicting disruptions in the nitrogen and phosphorus cycles that are caused by human activities (3.1, 3.3); and predicting the effects of changes in carbon dioxide and oxygen concentration due to factors such as a significant reduction of photosynthetic organisms, combustion of fossil fuels, agricultural practices (3.2)
- conduct investigations and gather and record data and information by measuring and recording the pH and the amount of nitrates, phosphates, iron or sulfites in water samples within the local area (3.3)
- analyze data and apply mathematical and conceptual models by: analyzing data collected on water consumption and loss in plants and animals (3.1); and designing and evaluating a model of a closed biological system in equilibrium with respect to carbon dioxide, water, and oxygen exchange (3.2)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms

3.1

polar molecule	transpiration
hydrogen bond	percolation
hydrological cycle (water cycle)	water table
	leaching

3.2

carbon cycle	albedo
combustion	stromatolite
peat	

3.3

nitrogen cycle	fertilizer
nitrogen fixation	phosphorus cycle
denitrification	nutrient

▶ MAKE a summary

1. Draw a diagram of a terrestrial or an aquatic ecosystem that shows how matter is cycled. Pay particular attention to the carbon and nitrogen cycles.
2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

▶ Go To

www.science.nelson.com 

The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 3
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

▶ UNIT 20 A PERFORMANCE TASK

Environmental Effects of Human Communities

In this Performance Task, you will use the knowledge and skills you gained in this Unit to study the impact of humans on natural ecosystems. You will choose one of the following tasks: (1) design a golf course; (2) assess community water quality; or (3) design a game that teaches about the effects of human activities on the environment. Go to the Unit 20 A Performance Task link on the Nelson Web site to complete the task.

www.science.nelson.com 

Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

- Which statements accurately describe photosynthesis and cellular respiration?
 - Photosynthesis is carried out by plants and animals and uses glucose as the energy source. Cellular respiration is carried out by plants only and uses solar energy as the energy source.
 - Photosynthesis is carried out by plants only and uses glucose as the energy source. Cellular respiration is carried out by plants and animals and uses solar energy as the energy source.
 - Photosynthesis is carried out by plants only and uses solar energy as the energy source. Cellular respiration is carried out by plants and animals and uses glucose as the energy source.
 - Photosynthesis is carried out by plants and animals and uses solar energy as the energy source. Cellular respiration is carried out only by plants and uses carbon dioxide as the energy source.
- At various stages in the decay process, bacteria can break down nitrates to nitrites, and then nitrites to (1) _____. The process called (2) _____ releases nitrogen gas back into the atmosphere.
 - (1) nitrate, (2) denitrification
 - (1) nitrogen gas, (2) denitrification
 - (1) nitrate, (2) nitrogen fixation
 - (1) nitrogen gas, (2) nitrogen fixation
- The term *albedo* is used to describe the extent to which a material can reflect sunlight. Which substance has the highest albedo?
 - Dark soil: It absorbs sunlight, which warms the surface of the biosphere and stimulates plant growth.
 - Water: It holds the heat from solar energy and serves as a heat source for the land.
 - Snow: It is a contributing factor to low temperatures experienced during winter. It also delays spring, even though there is more solar radiation available per unit area.
 - Clouds: They ensure that less incoming radiant energy is reflected directly back into space. Clouds decrease solar radiation, thereby increasing the warming of the air, which in turn decreases plant growth.

Use the following information to answer questions 4 and 5.

Four different soil samples with varying amounts of water were used to measure the conversion of ammonia to nitrates. The results are shown in **Figure 1**. The coloured lines show the percent of ammonia in each soil sample that was converted to nitrates. The labels for each line give the percent of water present in the sample.

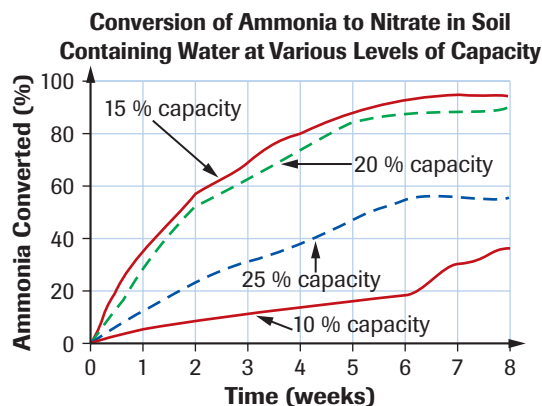


Figure 1

- According to the data presented, the amount of ammonia converted to nitrates after 4 weeks would be approximately
 - 80 % in the soil sample that contained 15 % of its water capacity.
 - 80 % in the soil sample that contained 10 % of its water capacity.
 - 20 % in the soil sample that contained 20 % of its water capacity.
 - 20 % in the soil sample that contained 25 % of its water capacity.
- According to the data presented, the best amount of water within the soils for conversion of ammonia to nitrates is
 - 10 % capacity
 - 15 % capacity
 - 20 % capacity
 - 25 % capacity

Part 2

- Describe** two ways in which the carbon cycle and oxygen cycle are connected.
- In your own words, **define** *matter cycle*.
- In your own words, **define** *biomass*.

Use the following information to answer questions 9 to 12.

Figure 2 is a diagram of an ecosystem.



Figure 2

9. Using the organisms in the ecosystem, **explain** the carbon cycle.
DE
 10. **Sketch** a flow chart that shows how nitrogen in the air reaches the caterpillar.
DE
 11. **Figure 2** doesn't show any bacteria, but they are always present in ecosystems. **Identify** the roles that bacteria have in the ecosystem.
DE
 12. **Identify** the organism that would end up with the highest concentration of the insecticide in its body, if DDT were used to control mosquitoes in the ecosystem. **Justify** your choice.
DE
-
13. (a) In your own words, **define** *nutrient*.
(b) **Why** do nutrients cycle faster in a tropical rainforest than in the tundra?
 14. In your own words, **define**
 - (a) nitrogen fixation
 - (b) denitrification
 15. Nitrogen is cycling through the ecosystems near your home and school. Choose a local natural wooded area and **sketch** a diagram to show how nitrogen cycles within this area.

Use the following information to answer questions 16 to 20.

A researcher carried out an experiment in a deciduous forest near Rocky Mountain House to determine the rate of decay of fallen leaves. At three times during a year, all the dead leaves were collected from 100 1 m² plots on the ground. The leaves were sorted by species, and the dry mass of each species' leaves was recorded. Data is provided in **Table 2**. In the table, the numbers in brackets indicate the percentage of the mass of the leaves of each species remaining.

Table 2 Leaves in a Deciduous Forest

Type of leaf	Dry mass (g) and percentage (%) of mass remaining		
	Nov.	May	Aug.
aspen poplar	4200 g (100 %)	2422 g (58 %)	1100 g (26 %)
balsam poplar	3700 g (100 %)	3110 g (89 %)	1540 g (42 %)
willow	2980 g (100 %)	1001 g (34 %)	6 g (<1 %)
birch	5700 g (100 %)	3987 g	1121 g

16. **Determine** the percentage of the dry mass remaining of the birch leaves in May and August.
DE
 17. **Identify** the species that decays fastest between November and May.
DE
 18. **Identify** the species that decays fastest between May and August.
DE
 19. **Infer** the abiotic factor(s) that could accelerate the amount of decay between November and May and between May and August.
DE
 20. **Infer** the biotic factor(s) that could accelerate the amount of decay between November and May and between May and August.
DE
-
21. **Why** do farmers add nitrogen fertilizers but not carbon fertilizers to fields?
 22. **Explain** why every ecosystem must have some continuous supply of energy to survive but can do quite well without a continuous influx of nutrients.

Use the following information to answer questions 23 to 26.

An experiment studied the effects of various factors on photosynthesis. *Elodea*, a water plant, was placed in a test tube of water. The test tube was supported upright on a stand and a light was shone at the side of the test tube. The number of oxygen bubbles produced by the plant was counted for 5 min. **Table 3** shows the collected data.

Table 3 shows the collected data.

Part 1: Distance of the light source: The light source was placed 5 cm and 20 cm away from the *Elodea*. Data was collected for two trials for each distance.

Part 2: Sodium bicarbonate added: A small amount of sodium bicarbonate (NaHCO_3) was added to the test tube. Data was collected for two trials with the lamp 5 cm from the test tube.

Table 3 Data from *Elodea* Experiment

Experimental condition	Number of oxygen bubbles produced in 5 min		
	Trial 1	Trial 2	Average
lamp 5 cm from plant	50	62	56
lamp 20 cm from plant	27	24	25.5
plant in NaHCO_3 , lamp 5 cm away	78	84	81

23. Write a hypothesis for Part 1 of the experiment.

DE

24. **Identify** the manipulated (independent) variable and responding (dependent) variable in Part 1.

DE

25. **Identify** variables that must be controlled in Part 1.

DE

26. Sodium bicarbonate undergoes the following reaction in water. **Explain** the results obtained from Part 2 of the experiment.

DE



27. A forest fire destroyed a 25 ha forest in the Swan Hills area of northwestern Alberta. Years after the fire, the forest had been regrown. A field biologist noted that pine and spruce trees in the area that had been burned appeared more lush than trees in forest areas that had not been affected by the fire. **How** is it possible that the vegetation appeared more lush in the area that had been burned?

28. Fire is a decomposer. It turns complex organic molecules into inorganic nutrients. Fire can be used to release inorganic nutrients from the stalks remaining after grain is harvested. This process is faster than normal decomposition, but much of the carbon in the stalks escapes to the air as carbon dioxide. Should fire be used to return nutrients to the soil? **Criticize** this position. Include both benefits and risks in your answer.

29. (a) **Describe** some of the ways oxygen cycles through the biosphere?

(b) **Sketch** your own diagram of the oxygen cycle.

30. **How** might changes in the carbon cycle, due to burning fossil fuels, affect the cycling of water in the biosphere?

Use the following information to answer questions 31 to 35.

Under controlled laboratory conditions, a research team from Environment Alberta monitored the solubility of oxygen and carbon dioxide in water samples taken from Lake Wabamun. Their data are shown in **Table 4**.

Table 4 Changes in Solubility of Carbon Dioxide and Oxygen with Temperature

Temp (°C)	CO ₂ solubility (ppm)	O ₂ solubility (ppm)
0	1.00	14.6
5	0.83	12.7
10	0.70	11.3
15	0.59	10.1
20	0.51	9.1
25	0.43	8.3
30	0.38	7.5

31. **Sketch** a graph of the solubility of oxygen in the water.

DE

32. **Relate** oxygen solubility in water to temperature.

DE

33. Using the data collected by the researchers, **predict** the consequences of prolonged warming of a shallow lake.

DE

34. Using the data from the table, **explain** why carbon dioxide levels can become dangerously high in an Alberta lake in winter.

DE

35. **Explain** why solubility of oxygen in water is so much greater than that for carbon dioxide at all temperatures.

DE

36. The albedo of the planet Venus is very high. At the same time, the atmosphere of the planet has an exceptionally high concentration of greenhouse gases. **How** might these two factors affect the surface temperature of Venus?

37. A plowed field is adjacent to the fairway of a golf course. During the winter, equal depths of snow cover the field and the fairway. Assuming that both fields are level and there is no disturbance to the snow pack, **explain** why the plowed field loses most of its snow before the fairway even begins to lose its cover. Is there a danger associated with the early loss of snow cover on the plowed field?

38. In this chapter, you have studied the cycling of carbon, oxygen, nitrogen, and phosphorus. In one or two paragraphs, **explain** how each cycle is part of the general reuse of all matter in the biosphere.

Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

- Place the following organisms in order as they would be in a food chain. (Record all four digits of your answer.)
 - salmon
 - shark
 - plankton
 - small herring
- Place the following levels in order, from the level with the most energy available to the level with the least energy available. (Record all four digits of your answer.)
 - tertiary consumers
 - producers
 - secondary consumers
 - primary consumers
- In a food web, organisms that break down organic matter, returning nutrients to the ecosystem for further growth, can be classified as _____.
 - herbivores
 - omnivores
 - detritus
 - decomposers
- A species that is doing well in one part of Canada but has been eliminated from another region is classified as _____, while a species that is close to extinction in all parts of Canada is classified as _____.
 - extinct, vulnerable
 - threatened, endangered
 - extirpated, endangered
 - vulnerable, extinct
- A group of organisms of the same species, located in the same area, is called a _____.
 - population
 - community
 - ecosystem
 - biome
- Decomposers break down the nitrogen-containing chemicals in the wastes or body tissues (proteins) into
 - simpler chemicals such as ammonia (NH_3), then decomposing bacteria convert ammonia into nitrites and eventually to nitrates.
 - more complex chemicals such as ammonia (NH_3), then other decomposing bacteria convert ammonia into nitrates and eventually to nitrites.
 - simpler chemicals such as nitrites, then other decomposing bacteria convert nitrites into free nitrogen.
 - more complex chemicals such as nitrates, then other decomposing bacteria convert nitrates into free nitrogen.
- In a bog you would expect
 - higher levels of usable nitrogen, since the denitrification process speeds up when the soil is acidic or becomes water-logged.
 - lower levels of usable nitrogen, since the nitrification process speeds up when the soil is acidic or becomes water-logged.
 - lower levels of methane, since methane-producing bacteria require anerobic conditions to grow, and bogs are high in oxygen.
 - low levels of carbon dioxide, since low levels of decomposing bacteria are found in bogs because of a lack of vegetation.
- Predict what will happen if fertilizers are carried from the land to an aquatic ecosystem with spring runoff.
 - Algae populations will decrease, since nitrogen and phosphorus fertilizers inhibit all plant growth, including algae.
 - Algae populations will increase, since nitrogen and phosphorus fertilizers promote all plant growth, including algae.
 - Fish populations will increase, since increased plant growth will provide more carbon dioxide for fish.
 - Fish populations will be unaffected, since fish do not use nitrates found in fertilizers.
- A step-by-step sequence showing how organisms feed on each other is referred to as
 - an ecosystem
 - a food chain
 - a population
 - an ecological pyramid
- Agriculture is affecting ecosystems in Alberta because
 - wheat fields help cycle phosphates and nitrates in the soil.
 - crops in Alberta produce carbon dioxide, which contributes to global warming.
 - taiga soil is not fertile enough for wheat crops.
 - monoculture crops are replacing the biodiversity of prairie ecosystems.
- An example of an endangered Canadian species is
 - passenger pigeon
 - whooping crane
 - elk
 - grizzly bear
- Which of the following describes an abiotic factor in an ecosystem?
 - competition between species
 - predator-prey relationships
 - amount of sunlight
 - birth rate

Use the following information to answer questions 13 to 16.

Figure 1 shows a food chain.

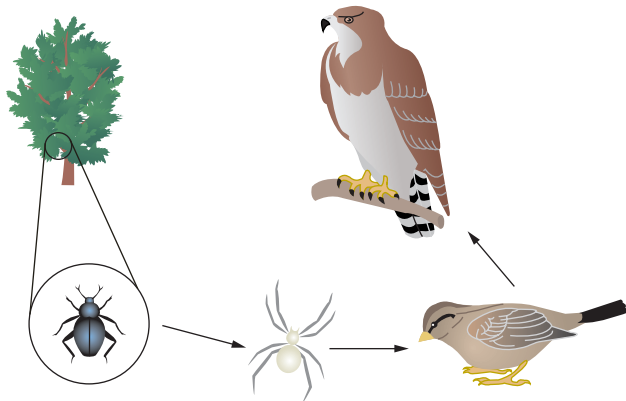


Figure 1

13. Which organism would be classified as the producer?
 - A. aspen tree
 - B. beetle
 - C. spider
 - D. sparrow
14. Which organism would be part of a population that would have the least biomass?
 - A. beetle
 - B. spider
 - C. sparrow
 - D. hawk
15. Based on your knowledge of number and biomass pyramids, which organism would you expect to have the greatest population?
 - A. aspen tree
 - B. beetle
 - C. spider
 - D. sparrow
16. Which level of organism has the least energy available to it?
 - A. beetle
 - B. spider
 - C. sparrow
 - D. hawk

Use the following information to answer questions 17 to 20.

The temperature of the air, the litter, the topsoil (10 cm below the surface), and the subsoil (30 cm below the surface) were monitored in one location in a temperate deciduous forest through the day. Use the data in **Figure 2** to answer questions 17 to 20.

Temperature Readings Taken over a 24-Hour Period in a Temperate Deciduous Forest

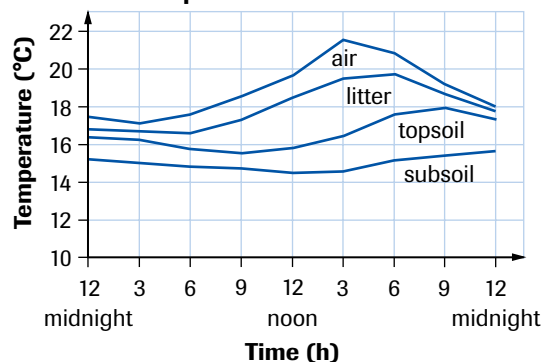


Figure 2

17. In which area of the forest did the greatest variation in temperature occur?
 - A. air
 - B. litter
 - C. topsoil
 - D. subsoil
18. Using a 24-h clock, at what time of day was the maximum ambient air temperature obtained?
 - A. 18:00
 - B. 3:00
 - C. 24:00
 - D. 15:00
19. What abiotic factor would account for the greatest difference in temperature readings in the litter?
 - A. wind
 - B. exposure to sunlight
 - C. moisture of the soil
 - D. thickness of the blanket of leaves
20. For the experiment described above, the dependent variable (responding variable) and independent variable (manipulated variable) are, respectively,
 - A. temperature and type of soil
 - B. type of soil and time
 - C. temperature and time
 - D. time and temperature

Part 2

21. Use the Great Slave Lake food web in **Figure 3** to sketch an ecological pyramid of numbers.

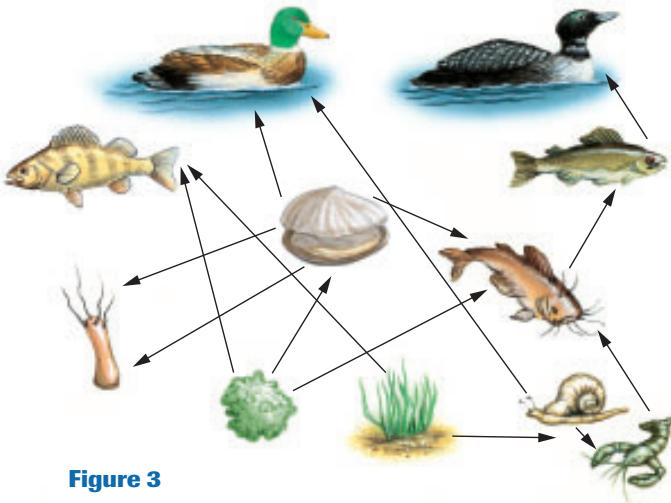


Figure 3

Use the following information to answer questions 22 to 27.

Two different experiments were carried out to determine the effects of different factors on photosynthesis. A freshwater plant, *Elodea*, was placed in a test tube of water. A light was placed at various distances from the plant for 5 min, then the number of oxygen bubbles produced by the plant were counted for 1 min. Different colours of light bulbs were used as well. The data are shown in **Table 1**.

22. **Identify** the two questions that the researcher is attempting to answer.
23. Write a hypothesis for both questions being investigated.
24. Represent the results of the experiment **graphically**.
25. **Identify** the two variables that affect the rate of photosynthesis.
26. **Why** are oxygen bubbles counted?

Table 1 Data from *Elodea* Experiment

Distance of light from test tube (cm)	Number of O ₂ bubbles produced (1 min), white light bulb	Number of O ₂ bubbles produced (1 min), red light bulb	Number of O ₂ bubbles produced (1 min), green light bulb
5	25	10	4
10	20	8	2
15	15	6	1
20	10	4	0
25	5	2	0

27. State the conclusions for the experiment.

DE

28. The removal of a predator often has consequences that extend beyond the immediate food chain. In Bangladesh, where frog populations have been decimated to supply restaurants with delicacies, the number of mosquitoes has increased. In turn, this has caused a dramatic rise in cases of malaria among humans. Write a unified response addressing the following aspects of frog and mosquito populations in Bangladesh.
- **How** has the decline in frog populations affected human health?
 - **Describe** a technological approach and an ecological approach for controlling malaria. **Describe** one advantage and one disadvantage for each approach.
29. The worldwide disappearance of frogs is a puzzle. In some areas, scientists don't really know what is causing the problem. **Illustrate** each of the following hypotheses regarding the causes of the disappearance of frogs with a supporting example. **Describe** things that the average citizen could do to remedy the problem implied by each hypothesis.
- Hypothesis: loss of habitat
 - Hypothesis: decreasing quality of air and water
 - Hypothesis: increase in ultraviolet radiation
 - Hypothesis: climate change
30. There are a number of different reasons for extinction. Use Canadian examples to **illustrate** why extinction has occurred for each of the causes described below.
- the competition between naturally occurring species and exotic species introduced into the area
 - the reduction of natural habitats
 - climate change
 - over-hunting

Use the following information to answer questions 31 to 33.

The water entering the ocean from the river in **Figure 4**, on the next page, is polluted with nitrates. A group of scientists decided to identify the sources of pollution. They chose five different testing sites to measure nitrate concentration in the water.

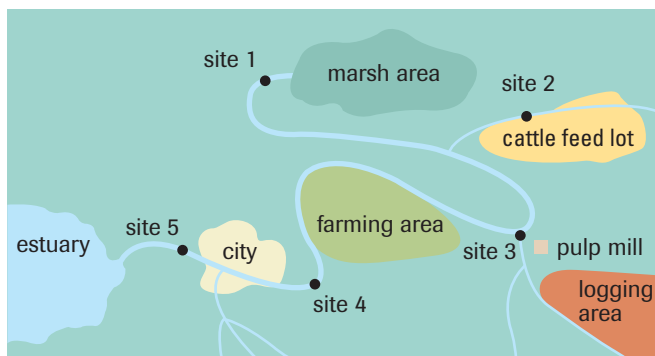


Figure 4

31. Choose two sites in **Figure 4** and **explain** why these two sites might show a local source of nitrates.
DE
32. **Describe** two effects of severe nitrate pollution.
DE
33. Choose one site in **Figure 4** and **describe** how the level of nitrates in the water could be reduced.
DE
34. As the available natural wildlife habitats are reduced worldwide, scientists have expressed concerns about animals that occupy the highest trophic levels of energy pyramids. Using energy flow as an argument, **explain** why these animals would be most severely affected.

Use the following information to answer questions 35 to 37.

In 1965, NASA scientists compared the atmosphere of Earth with those of Mars and Venus. Their data are shown in **Table 2**.

Table 2 Chemical Composition of Venus, Earth, and Mars

Chemical composition	Venus	Earth	Mars
carbon dioxide	95 %	0.03 %	95 %
nitrogen	2 %	77 %	3 %
oxygen	none	21 %	none
chemical equilibrium	yes	no	yes

35. There are very high levels of carbon dioxide in the atmospheres of Mars and Venus. **How** might this affect the temperature of these planets?
DE
36. Of these three planets, oxygen is only found in Earth's atmosphere. **Why** is this an important fact?
DE
37. Suggest some reasons **why** Earth's atmosphere is not in equilibrium.
DE

Use the following information to answer questions 38 to 42.

Figure 5 shows an apparatus that was used to measure water consumption by a plant.

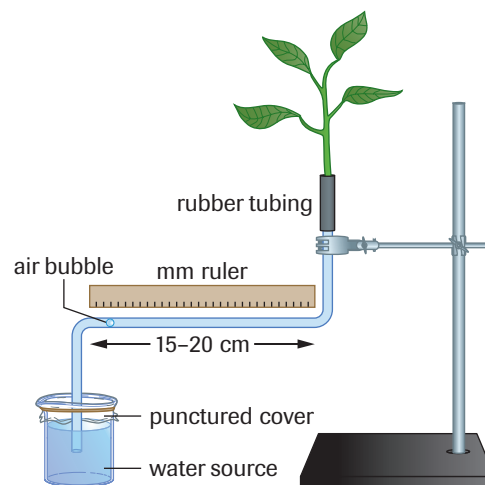


Figure 5

38. **Identify** the problem being investigated by this experiment.
DE
39. **Identify** two variables that would affect water loss by transpiration.
DE
40. **Sketch** a graph of the data provided in **Table 3**.
DE
41. **Predict** how placing a plastic bag over the leaves would affect transpiration.
DE
42. **Identify** two adaptations of the plant that reduce water loss by transpiration.
DE

Table 3 Change in Mass of Plant Over Time

Time (min)	Mass of potometer + plant (g)	Change in mass of potometer + plant (g)
0	150.2	0
10	143.6	6.6
20	137.2	13.0
30	131.4	18.8
40	125.4	24.8

43. Review the focusing questions on page 2. Using the knowledge you have gained from this unit, briefly **outline** a response to each of these questions.