Chapter 2.1-2.4

CHAPTER

2 Change and Stability in Ecosystems

Getting Started

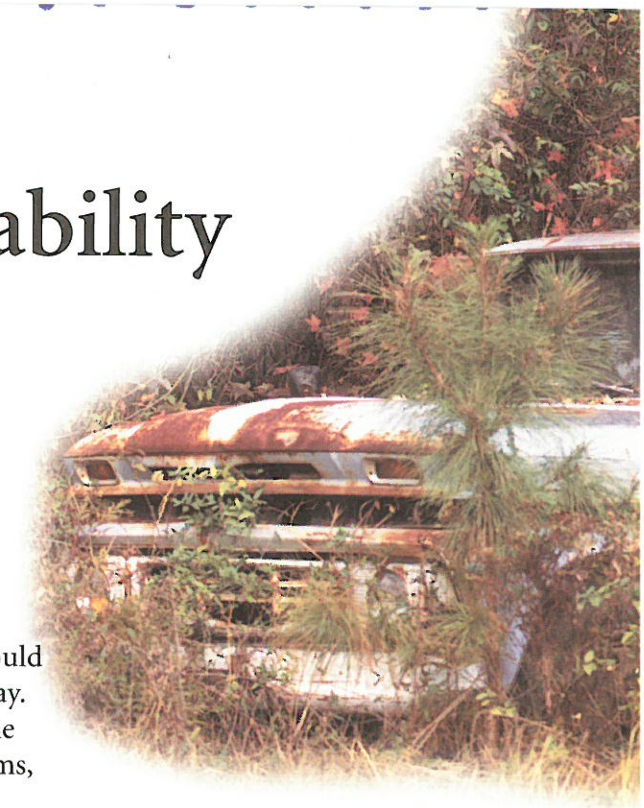


Figure 1
If left here, this truck will slowly disappear, leaving no trace.

WHY DO ECOSYSTEMS APPEAR TO BE SO STABLE?
If you could find an area of Ontario that hadn't been logged, and could take a ride in a time machine back to 1700, you would find that the forest then looked much like the forest does today.

From your own experience, you would probably say that the lakes and rivers you know change little. Even artificial ecosystems, such as lawns, appear stable.

However, that impression of a lack of change is anything but true. In a forest ecosystem, trees continuously die and are replaced by new trees. Lakes change greatly in temperature, oxygen levels, and kinds of organisms that live in them throughout the year. Ecosystems undergo continuous renewal to remain in that "unchanging" state we observe. By changing constantly, they remain the same — in a state we call equilibrium (balance).

However, sometimes ecosystems cannot maintain their equilibrium. Large changes in abiotic or biotic factors, such as those linked with humans, may cause a shift in the balance of the ecosystem. The diversion of a stream to create a freeway or the flooding of a valley after the construction of a dam are two examples of permanent changes caused by humans. In addition, ecosystems can change quickly if a new organism is introduced. The balances between predators and prey and those between living things that compete for space, food, or other resources within an ecosystem are in constant tension. Change a single factor and a new balance must be re-established.

Human interference in ecosystems is often described as harmful. For example, pollutants from industrial processes kill or injure some organisms. This in turn alters food webs and changes relationships within ecosystems. The harmful impacts of humans on an ecosystem dominate discussion so much that often we forget that we are part of the ecosystem — not merely agents of change. Things that change ecosystems also affect humans.

Change and Recovery

Ecosystems can recover, even after major human intervention, but it takes many years or even centuries. The rusting truck in **Figure 1** reminds us that ecosystems respond to change. Plants will cover the body of the car. In time, the small weeds growing around the car will be replaced by shrubs, which in turn will be replaced by mature trees. Pieces of the truck will fall off and be buried under detritus. Eventually, even the iron atoms in the frame of the truck will return to the soil. A hiker returning to the forest in 200 years would see no sign that a vehicle had ever been there.

It would be hard to find a better example of the resilience of large ecosystems than the Great Lakes. During the 1950s and 1960s, some ecologists predicted the complete collapse of food webs in Lake Erie and Lake Ontario, the most polluted of the lakes. Toxic wastes, raw sewage, and acid rain mixed into the lakes to create a poisonous soup. Dying fish floated to the surface, desperately struggling for oxygen. The carcasses of birds dotted the shoreline. One river feeding Lake Erie was so polluted with oil that it actually burst into flames. Today, ecologists have gathered evidence that the Great Lakes are recovering. Pollutants are being drawn from the water and soil by microorganisms and by burial in sediment. As long as the pollutants remain buried, they are out of the food chain and no longer pose a danger. But if the sediments are stirred up by ship or wave action, pollutants again become a hazard to the ecosystem.

Reflect on your Learning

1. One throw-away car in a forest probably won't do much damage. As you have seen, the ecosystem will adjust and regain its original balance. But humans produce far more than one waste car every few centuries. Speculate about how large amounts of waste might affect an ecosystem.
2. Europeans, and their descendants in North America, often describe humans as being at the centre of change. Not only do humans cause environmental changes, but they are also responsible for those changes. In this worldview, the ideal human acts as a steward or protector for an ecosystem. In contrast, First Nations peoples often describe humans as belonging to an ecosystem. In this worldview, the ideal human lives in harmony with the ecosystem. How would the two worldviews differ in describing what has happened to the Great Lakes and the forest ecosystems of Ontario over the last century?

Throughout this chapter, note any changes in your ideas as you learn new concepts and develop your skills.

Try This Activity 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 within the class can study a different set of variables.

Materials: apron, milk containers (cut in half), various kinds of vegetable or flower seeds, potting soil, water

Always wash your hands after handling soil.

- As a class, decide how you will control the mix of seeds in each container. (K4)
- Fill milk containers with moist potting soil.
- Plant seeds from various species according to the instructions on the packets (**Figure 2**). Water each of the milk cartons with the same amount of water every second day. Record the amount of water used.
- Once seeds start to germinate, store each of the milk cartons in a different environment. You might want to use temperature, amount of light, or amount of water as variables.
- Measure the growth of each of the plants daily.

(a) Does one type of plant begin to dominate the community? Is it the same type of plant in all containers?

(b) Speculate about why one plant might be better adapted for a specific environment than another.

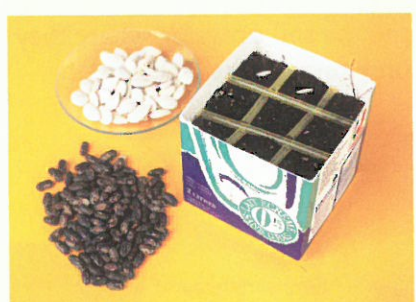


Figure 2

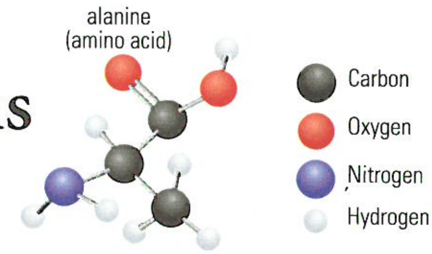
SKILLS HANDBOOK: (K4) Creating the Design

Cycling of Matter in Ecosystems

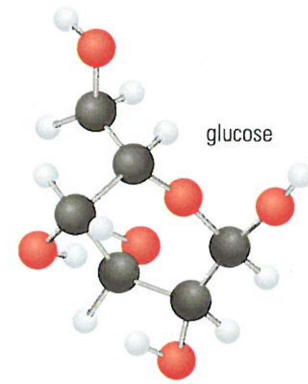
To understand how matter cycles through ecosystems, we must also understand the cycling of organic substances within living things.

Organic substances always contain atoms of carbon and hydrogen, and often contain oxygen and nitrogen atoms. Proteins, sugars, and fats, the important chemicals that make up your body, are all organic (**Figure 1**). Matter that doesn't contain a combination of carbon and hydrogen atoms is called **inorganic**. For example, carbon dioxide (CO_2), water (H_2O), and ammonia (NH_3) are considered to be inorganic.

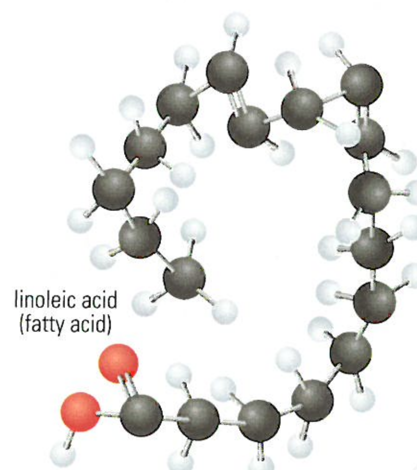
Organic chemicals undergo changes within living things and within ecosystems. Their complex structures are broken and rebuilt in a continuous cycling of matter.



(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, containing hundreds of thousands of atoms.

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.

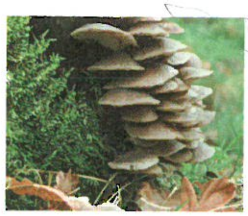
Incredible as it may sound, every carbon atom is recycled time and time again into new life forms. Because of this cycling, it is likely that somewhere in your body are atoms that once made up a *Tyrannosaurus rex*, one of the giant carnivorous dinosaurs that lived 70 million years ago. You probably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

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 complex molecules, which 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 (**Figure 2**) 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 3**).

Figure 2

(a) Bacteria
Several different types of bacteria decompose organic matter. This bacterium lives in the soil.



(b) Bracket fungi
These decomposers feed on dead and living trees, breaking down complex organic molecules into simple ones.

(c) Mould
Another form of fungi. These decomposers feed on organic matter, returning nutrients to ecosystems.

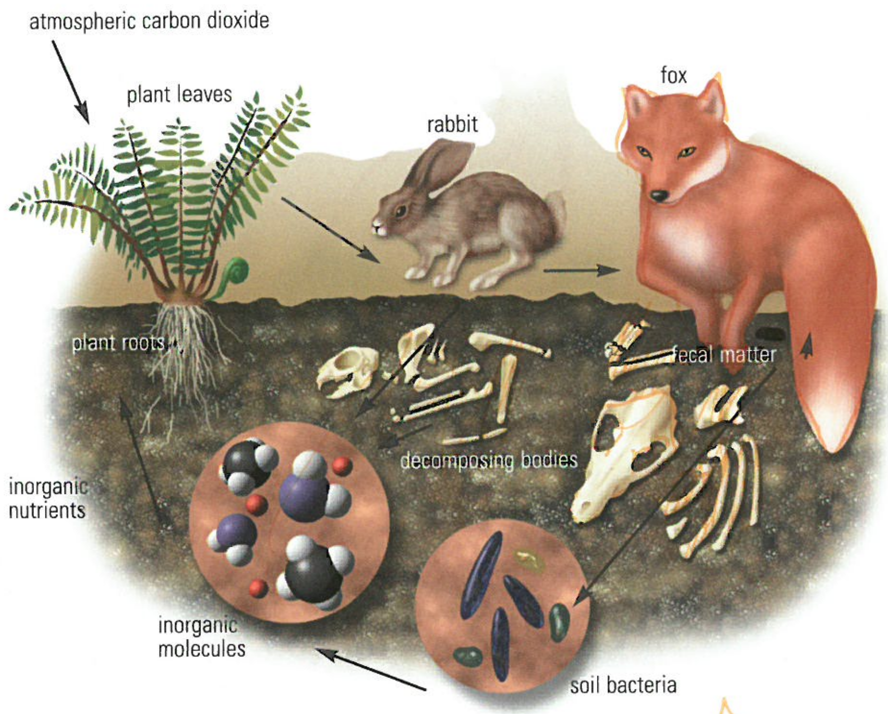


Figure 3

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.

Understanding Concepts

1. **(a)** Explain the difference between organic and inorganic chemicals.

   (b) Give some examples of each.

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 4**.

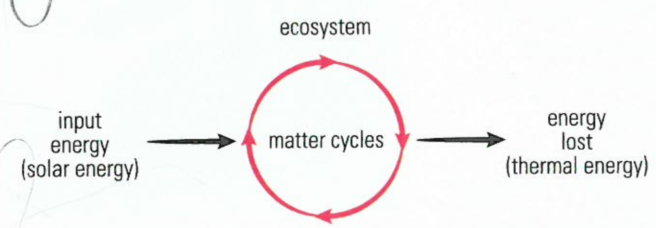


Figure 4

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 was present in these soil samples?

Making Connections

5. Predict what might happen if forest decomposers, such as soil bacteria and fungi, were destroyed by a pollutant.

6. 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? Identify both benefits and risks.

Exploring

7. Natural and genetically engineered bacteria and fungi can (I) be used to either destroy toxic chemicals or convert them to (J) 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.

Reflecting

8. Cells are very complicated. Scientists continue to struggle to explain why chemical reactions in cells don't seem to work out the way they do in test tubes. There are questions about cells that are still unanswered. What questions do you have about the ideas you have encountered in this section?

SKILLS HANDBOOK: (I) General Research Tips (J) Internet Research

Pesticides

There is no better way to understand the flow of matter through an ecosystem than to study food webs. This is true of both natural organic matter and toxins (poisons) introduced by humans. In this case study, you will investigate the impact of pesticides on living things and ecosystems. **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.

(a) Decide under what circumstances, if any, each organism in **Figure 1** could be considered a pest.

(b) Speculate about how the removal of one of the pests might affect the food web.

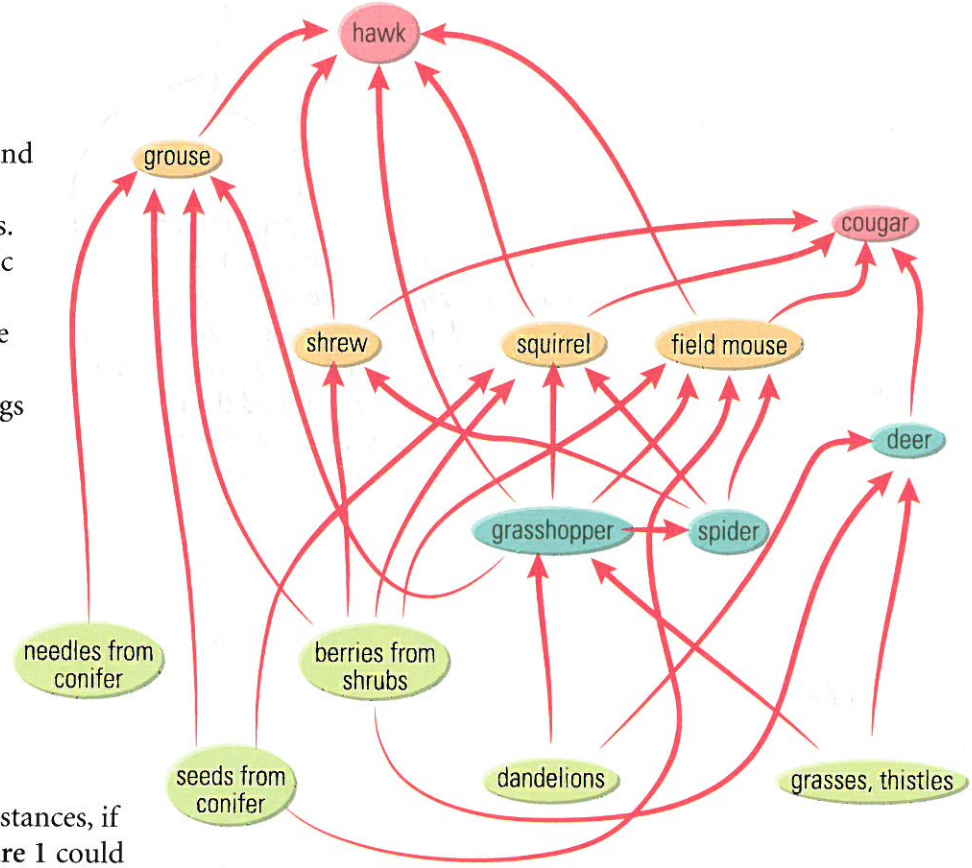


Figure 1
A food web showing relationships among organisms living at the edge of a forest ecosystem.

Why Use Pesticides?

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 (**Figure 2**), a fungus that grows inside the leaves and stems of the wheat plant, feeding on the plant's stores of food.

The anopheles mosquito, found in tropical areas, often carries a microbe that enters the circulatory system while the mosquito is sucking the victim's blood. The microbe produces malaria. Malaria causes fever and can lead to death. As late as 1955, malaria affected more than 200 million people. Today, because of pest control measures, the incidence of malaria has been drastically reduced, although it is still a major killer in some countries.

(c) List three possible short-term benefits of using pesticides.

Figure 2
Stem rust, a fungus, is a consumer. In a wheatfield it is also a pest.

Did You Know?

We associate malaria with tropical climates, but it was once a serious problem in Canada. A malaria outbreak occurred during the building of Ontario's Rideau Canal in the 1830s.

First-Generation Pesticides

Our attempts to control pests extend back to about 500 B.C., when sulfur was first used to repel insects. During the 15th century arsenic, lead, and mercury were applied to crops as insecticides. As many farmers eventually discovered, these substances were not only deadly for insects, but also highly poisonous for people. By the 1920s, farmers had become fully aware of the hazardous effects and the practice was abandoned. Unfortunately, these dangerous substances still show up in some vegetables if they are grown in soils that were treated with the metals for a great number of years.

In 1763, French gardeners began using nicotine sulfate, a chemical extracted from the tobacco plant, to kill aphids (**Figure 3**). By the mid-1800s, two more plant extracts had been developed in the battle against insects — one from the head of the chrysanthemum and the other from the roots of a tropical legume. (Legumes are plants that bear their seeds in pods, like peas, beans, and locust trees.) Many plants have developed chemical defences against animals. Insects and other animals that try to eat the leaves or seeds of the plants die or become very ill. They learn to avoid the plant in future. Borrowing those chemicals from plants seemed to make sense.

Figure 3
Aphids suck sap from the leaves and soft stems of plants.

(d) Why might chemicals taken from plants create a much lower risk for humans and ecosystems?

Second-Generation Pesticides

Second-generation pesticides are chemicals made in a laboratory. In 1939 Paul Mueller found that *d*ichloro*d*iphenyl*t*richloroethane (DDT), a chemical known since 1874, was a potent insecticide. This discovery forever changed the practice of chemical control. It sent researchers looking for more such chemicals, which were developed to protect troops fighting in the tropical jungles of Asia and the Pacific during the Second World War.

Thousands of pesticides have since been developed. More than 500 chemical pesticides are registered for use in Canada alone. Worldwide approximately 2.3 million tonnes of pesticides are used yearly, or about 0.4 kg for every person on Earth. About 75% of these chemicals are used in developed countries, and they are not used only in agriculture. Pesticides are added to shampoos, carpets, mattresses, paints, and even the wax on produce. More than 25% of pesticides are used to get rid of pests in homes, gardens, and parks.

Pesticides can be grouped into four different categories (**Table 1**). As you can see, some pesticides decompose fairly rapidly, but others stay in the ecosystem for many years.

Table 1 **Classification of Pesticides**

Type of Pesticide	Target	Examples	Persistence
insecticide	insects	DDT	high (2–15 years)
		Malathion	moderate (1–12 weeks)
herbicide	weeds	2,4-D, Silvex, Roundup	mostly low (days to weeks)
fungicide	moulds and other fungi	Captan	low (days)
bactericides	bacteria	penicillin, vancomycin	mostly low

Bioamplification

Pesticides that contain chlorine, such as DDT and Dieldrin, are soluble in fat but not in water. As a result, these toxins cannot be released in urine or sweat, so they accumulate in the fatty tissues of animals. When there is a small amount of the pesticide in the environment, it will enter the bodies of animals that are low in the food chain. That's where the problem begins, but it gets much worse as the toxin moves up a food chain into higher trophic levels.

Even though there is only a small amount of the toxin in each of the prey animals that a secondary consumer eats, the amount of the toxin in its body will be larger because each predator eats many prey. When the secondary consumer is eaten, the higher-level predator gets all of its toxins, plus those of all the other prey it eats. At each stage of the food chain the concentration becomes greater. The higher the trophic level, the greater the concentration of toxins. This process is referred to as **bioamplification** (**Figure 4**).

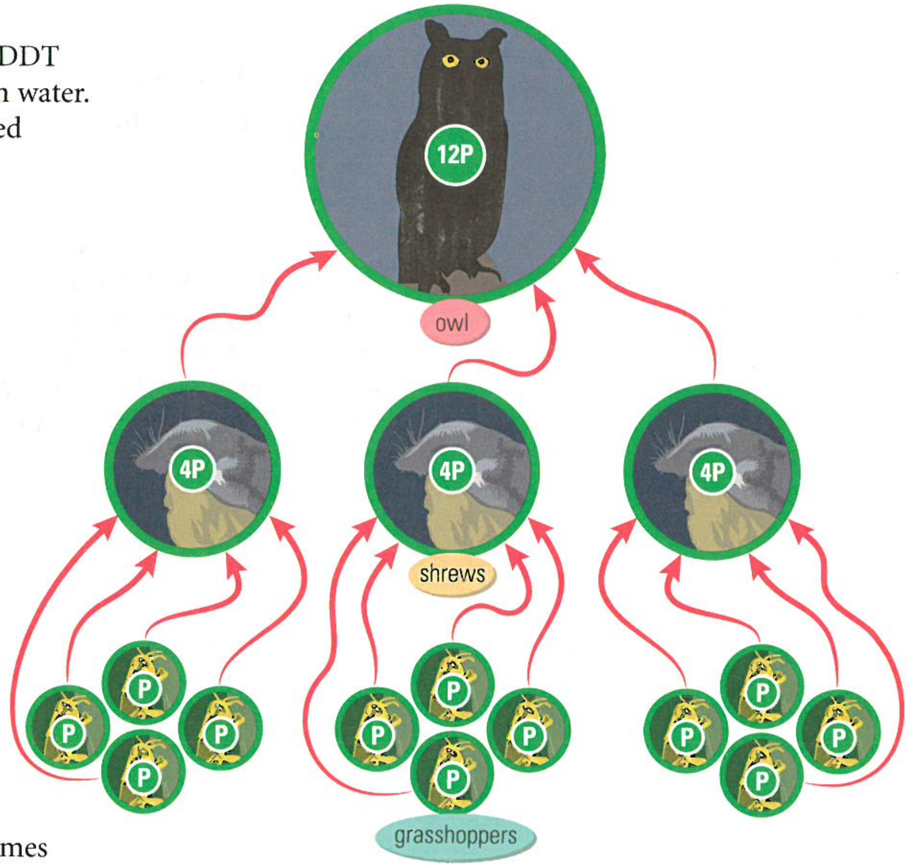


Figure 4

Bioamplification. The concentration of a fat-soluble pesticide (P) increases as you move up a food chain. The pesticide is present in only small concentrations in grasshoppers (primary consumers), higher concentrations in shrews (secondary consumers), and much higher concentration in owls (tertiary consumers). The greater the number of trophic levels, the greater the amplification in the top level.

(e) How would a chart showing the concentration of toxins differ from a biological pyramid of biomass for the same food chain?

(f) Vultures and some species of beetles feed on the dead bodies of animals from several trophic levels. Predict how these animals might be affected by bioamplification.

Effects on Humans

The irony of the insecticide is that although insecticides were developed to rid the world of harmful insects, they have had a much greater effect on humans. Like other top predators, humans are subject to bioamplification. Evidence that DDT was beginning to accumulate in humans was collected in the 1950s and 1960s.

DDT levels became especially high in humans who lived where DDT was sprayed on crops. However, anyone who ate crops from these areas or ate animals that had fed on the crops was exposed to DDT.

Concern about this growing threat was so great that use of DDT was banned in Canada in 1971 and in the United States in 1972. The ban hasn't totally eliminated the problem. Migratory birds like the mallard duck, Canada goose, and peregrine falcon winter in Central America and Mexico, where DDT is still used. Fish living in the Atlantic and Pacific oceans also migrate up and down the coasts.

(g) Why is the fact that other countries have not banned DDT of concern to Canadians?

(h) Breast milk contains fat. Speculate about how breast-feeding might affect the concentration of DDT in a mother and in her baby.

Modern Chemical Pesticides

Unlike DDT and other chlorine-based insecticides, the newer chemicals are not stored in fat tissue; they are soluble in water. Animals can remove them from their bodies by breaking them down in their livers and excreting them. They can also be broken down within the soil. These new compounds operate like nerve gases, which act by preventing electrical messages from travelling from the brain to the muscles that control breathing or the limbs. This either kills the animal directly or makes it vulnerable to predators.

Although somewhat safer than the older chemicals, the newer insecticides are not without their problems. First, they break down quickly in the soil, and so must be applied to crops more often. Second, these new chemicals are not selective. Because the nerve action of most larger animals is very similar, these insecticides are capable of killing mammals, birds, reptiles, amphibians, and fish. Unintended changes to the food web are difficult to predict. Third, animals that have died or been weakened by the toxin put any other animal that eats them at risk through bioamplification. Large dosages of the toxin can still cause death.

(i) Why are the new pesticides less harmful to ecosystems than DDT and related compounds used in the 1950 and 1960s?

The Pests Fight Back

It seems that chemical pesticides have a natural shelf life, because the pests they are supposed to kill gradually become resistant. This is particularly true of bactericides and insecticides, because of the pests' high rates of reproduction.

If the first application of a chemical kills 90% of the insects, that still leaves 10% that survive. Some of those insects have genes that helped them survive application of the pesticide (**Figure 5**). With every generation of insects, the pesticide removes those that are susceptible, and leaves those that are not. In addition, because the pesticide removes so many of the insects, the survivors have the benefit of less competition for food. After several generations of this selection process, most of the insects carry genes that will help them survive an application of the pesticide. Eventually the pesticide becomes useless, and pesticide chemists must search for a new poison.

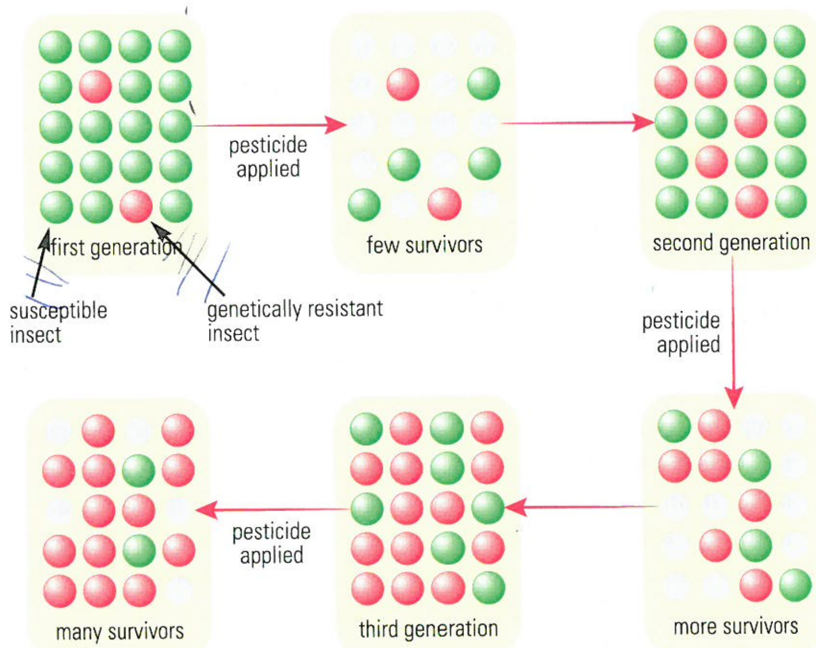


Figure 5
Continued applications of the same pesticide allow insects to gradually become resistant. Each application kills most of the susceptible insects, but not those that have genes that protect them from the insecticide.

(j) Speculate about how less competition for food helps increase the reproductive success of the remaining insects after a pesticide is applied.

(k) According to **Figure 6**, in which decade was there the greatest increase in the number of species that became resistant to pesticides? What might account for the dramatic increase?

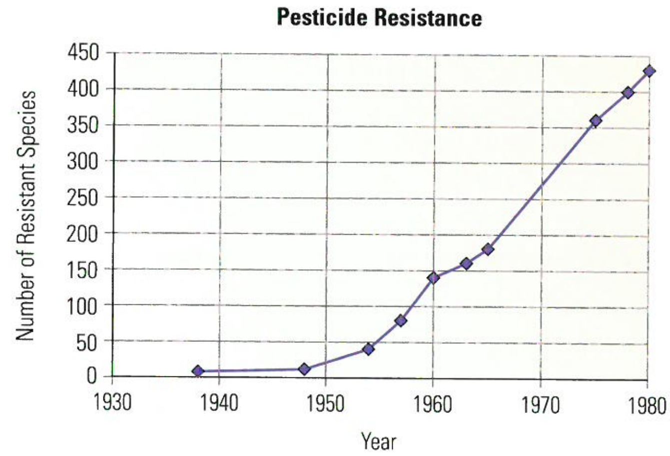


Figure 6

The number of insects resistant to at least one pesticide has increased rapidly.

Atlantic Canada and the Spruce Budworm

Throughout Canada chemical pesticides are used to control pests that threaten agriculture, forestry, and the home or garden, but due to the economic importance of spruce in pulp and paper and construction, few pests have created as much concern as the spruce budworm (**Figure 7**). Adult moths emerge in late June or July and lay eggs on spruce or fir tree. Within 10 days the eggs hatch and the larvae move into the interior of the tree. Here each worm-shaped larva spins a web and enters a dormant phase for the winter. The larvae awaken in May and begin feeding on the old needles, unopened buds and the male flowers of the trees. Eventually, the voracious larvae work their way out on the branches to the new shoots.

Often during periods of high population, the larvae eat all the new shoots early in the season, reducing growth of the trees. The removal of needles weakens the trees, making them more susceptible to infections and other insects. Successive infestations year after year could kill the tree.

The efforts to control this pest with insecticide show up in the statistics for insecticide use in Atlantic Canada (**Figure 8**).

Figure 7

The spruce budworm is a wasteful eater. It rarely eats a whole needle, rather it just bites them off at the base. Masses of dried, red-brown needles are left hanging from the ends of branches.

New Brunswick and the Budworm

From 1986 to 1990 New Brunswick dispensed about 170 000 kg of chemicals over 443 000 ha each year as it attempted to maintain control over the spruce budworm. The longest-running pesticide program in the world has protected New Brunswick forests for nearly 40 years, but it hasn't eliminated the pest. The objective of the program is to maintain acceptably low levels of the pest. Eliminating the program would likely cause the population of spruce budworms to explode, resulting in the devastation of a valuable industry.

(l) Speculate about why the spruce budworm hasn't been eliminated after 40 years of spraying.

(m) Why wouldn't biologists just use extremely high concentrations of insecticides to kill all of the spruce budworms?

(n) Identify groups who have benefited from the New Brunswick spraying program.

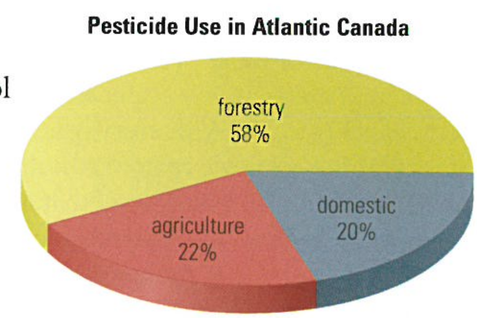


Figure 8

The influence of the spruce budworm spraying campaign is shown in the amount of pesticides used in forestry.

Cape Breton and the Budworm

On Cape Breton Island, authorities allowed the spruce budworm infestation to run its course. By the time the budworm population had stopped increasing, approximately 50% of the island's softwoods (spruce, fir, and pine) were lost. When assessing the economics of this decision, the cost of losing the valuable trees must be balanced against the fact that spraying is not needed to control the spruce budworm in Cape Breton.

(o) Identify groups of people who might have suffered as a result of the decision not to spray.
(p) What are the benefits of not spraying?

Did You Know?

The biggest users of insecticides in Atlantic Canada are the provincial governments of New Brunswick, Nova Scotia, and Newfoundland, which spray them from aircraft to combat the spruce budworm and the hemlock looper.

Pesticides and the Great Lakes

When ice and snow melt in spring, pesticides from the land are often carried into streams and lakes. Once in the aquatic ecosystems, the pesticides are absorbed into the tissues of aquatic insects and the small fish that eat these insects. At each step of the food chain, the level of toxins can become magnified.

(q) Explain why insecticides such as DDT would pose a greater threat to freshwater ecosystems than the newer, water-soluble pesticides.

The Bald Eagle

One of the animals most affected is the bald eagle (**Figure 9**), which eats mostly fish — both live fish that it catches and dead fish that it finds. Prey include large predatory fish such as trout, salmon, and pike; smaller fish; amphibians; small mammals; and birds. Once common throughout North America, the eagle began to disappear as European settlers arrived. The destruction of the large trees the eagle used for nesting, combined with human hunting of a bird that could kill young livestock, began to take its toll. However, the greatest threat to the bald eagle population was industrialization and the subsequent release of toxins into the ecosystem. Like most top carnivores, the bald eagle accumulates fat-soluble toxins from the entire food chain. Because eagles can live for as long as 25 years, they can accumulate a tremendous amount of toxins. Once in the eagles' bodies, the fat-soluble toxins are not released except through the laying of eggs.

Figure 9
Because of restoration efforts by conservationists, the bald eagle is slowly returning to the shores of Lake Erie.

(r) Why would female eagles have slightly lower levels of toxins than male eagles? Compare egg-laying in eagles with breast-feeding in humans.
(s) Draw a food web, showing the movement of pesticides in a lake from aquatic insects to the bald eagle.

Understanding Concepts

1. In your own words, define the terms "pesticide" and "pest."
2. Using your own diagram, explain bioamplification.
3. It is often said that technology can work as a double-edged sword, creating a new problem as it solves an old one. The new problem often arises because the solution to the original problem was flawed.
   - **(a)** During the 15th century, arsenic, lead, and mercury were applied to crops as insecticides. What was wrong with this technological solution?
   - **(b)** In 1939, Paul Mueller found that DDT was a potent insecticide and could be used to kill pests such as mosquitoes. What was wrong with this technological solution?
   - **(c)** Modern insecticides are easily broken down in the body and the soil and do not accumulate in fat tissues; however, these new chemicals do not provide a perfect solution. What dangers were created by this most recent technological solution?
4. List at least two advantages and two disadvantages of a pesticide that is low in toxicity and breaks downs quickly.
5. Explain why farmers might wish to use pesticides that are soluble in water and remain active for an extended time. Why do those properties also make the pesticide dangerous?
6. Explain why humans can't adapt to toxic pesticides as quickly as insects.
7. A 1991 report by Environment Canada showed some contamination by DDT and other pesticides in shellfish, crustaceans, and fish on the Atlantic coast. Chemical pesticides have also been found in shore birds and marine mammals, particularly along the Bay of Fundy and the coast of Newfoundland. The report indicated that although the levels of pesticides are declining in most marine animals, there was still cause for concern. The porpoises in the lower Bay of Fundy still had unacceptably high levels of DDT, at 500 ppm.
   - **(a)** Explain how DDT could enter a marine ecosystem.
   - **(b)** DDT has been banned in Canada for decades. Explain why animals still carry this toxin in their bodies.
   - **(c)** Speculate about why the levels of DDT fall more slowly in porpoises than in other animals in the ecosystem.

Making Connections

8. In Atlantic Canada, synthetic pesticides called pyrethroids were used to control two pests in apple orchards — the winter moth and leaf miners. Unfortunately, the chemicals killed more insects than intended, including those that preyed on red mites and apple mites. After spraying, the mite population rose quickly, causing damage to the trees and reducing the yield of apples. What recommendations would you make to anyone considering using a new pesticide?
9. The ideal pesticide has four characteristics. Explain why each of the characteristics is important and what the consequences are when the pesticide fails to meet each test. The pesticide should:
   - kill only the intended pest;
   - disappear into something harmless after it works on the pest;
   - not create a stock of resistant pests;
   - be cheap to produce and use.

Reflecting

10. During the 1950s and 1960s, DDT and similar chemicals were inexpensive and easy to apply. However, the environmental problems they caused created a backlash. Pesticide use is now more strictly regulated. In some countries malaria has increased once again. Have we gone too far in reducing the use of pesticides? Are there other explanations for the increase? What information would you need to collect to answer these questions?

Challenge

1 Golfers do not like mosquitoes, but some of the most challenging golf courses border bodies of still water—the favourite breeding ground of mosquitoes. How can you provide a golf course with water hazards, control mosquitoes, and yet minimize disturbance to the environment?

2 Pesticides are carried into rivers with rain and melting snow. Herbicides can kill aquatic plants. Insecticides can kill or weaken small aquatic organisms. How will pesticides affect water quality in your area?

3 How will you include the uses and effects of pesticides in your game?

2.3 Career Profile

Mary Bishop

Planner

Mary Bishop has alphabet soup after her name: an honours B.Sc. degree from Dalhousie, and a Master's degree in urban and regional planning. Academic training in land use, communications, ecology, statistics, and chemistry can be added to Mary's work experience in municipal planning, environmental assessment, and socio-economic development research. She has worked with the governments in both Newfoundland and Nova Scotia. But she is not unusual in a profession that combines aspects of engineering, law, architecture, public health, and the social sciences as well as ecology and biology. Planners, she says, are the ultimate multitaskers.

Mary has been involved in research, policy planning and decision making in several key areas of Newfoundland's economic development since 1985. The project she finds most representative of her work in the field is the consultation she did with the city of Gander. Gander has a stewardship agreement with the provincial government of Newfoundland and Labrador to protect its waterfowl habitat, and Mary was called in to reconcile Gander's growing human population with the needs of the protected waterfowl. During her evaluation, she consulted all levels of government, concerned citizens' associations, local businesses, environmental activists, and a whole lot of numbers.

Understanding numbers, especially population statistics, is absolutely key to doing her job as a planner, Mary says. Statistical analysis allows the planner to balance the requirements of the individuals and the immediate community with the needs of the greater population.

Of course, adds Mary, you also need an interest in geography and the environment, as well as good teamwork skills (planners rarely work alone, but in a group of other planners, architects, engineers, and politicians) and a flair for presenting projects or proposals. After all, a planner's audience can include everyone from a schoolchild to a federal politician, and every person needs to be able to understand what is said.

Mary Bishop went into science because she was intensely curious about the world around her and how it worked. When she graduated, she decided that the world would shrink to the size of a slide on a microscope if she pursued the "traditional path" of laboratory science. "I basically fell into planning," she says gleefully, "because I wanted science to apply to the real world."

Making Connections

1. What sort of education path would you follow if you decided right now to become a planner?
2. Find out what postsecondary institutions offer a Master's degree in urban and regional planning.
3. Find five different job titles for urban and regional planners. What sort of projects might each undertake?

Work the Web

Go to a search engine and do a search with the keywords "urban," "career," and "planning." How would you refine your search to find job postings in this field?

Use your results to find a development project in your geographic area on which a planner worked. Research the issues and final outcome of the project, and give a short presentation to your class.

2.4 Case Study

The Interaction of Living Things

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 a year. Nothing was to be brought in; 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 (**Figure 1**), the dome was the largest, and most expensive, artificial ecosystem ever created. Texas billionaire Ed Bass, the architect behind the plan, had raised private funding to study a model of Earth's ecosystems. He was hoping to create an artificial ecosystem that could be used in space exploration. In taking a chance on this huge experiment, he was supporting scientific research into how living things interact with each other.

The experiment demonstrated in a fairly short time that we don't know everything we need to know about ecosystems. Despite careful advanced 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 purified air in from the outside.

(a) How would the environment of Biosphere 2 differ from that of a large apartment complex?

(b) Make a list of things that must be considered to create and maintain an artificial ecosystem.

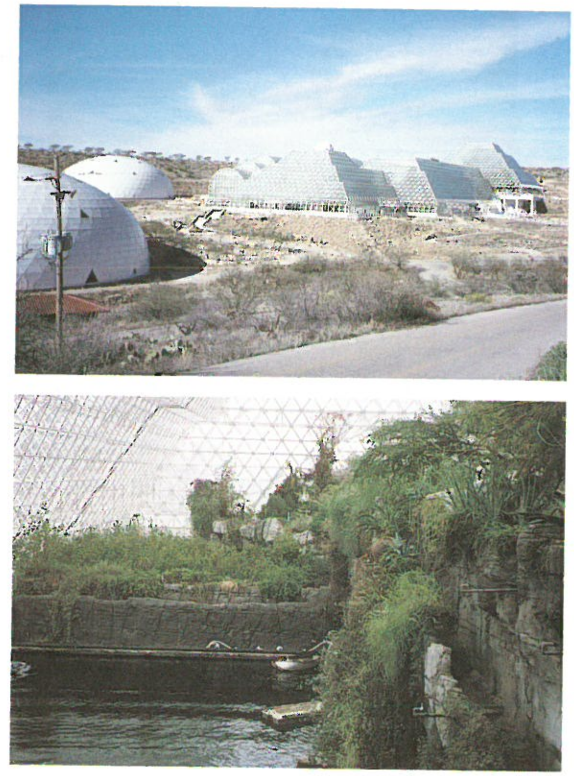


Figure 1
Biosphere 2 is still being maintained in an effort to improve our understanding of all the interactions that take place in an ecosystem.

Priestley's First Experiment

Understanding the complexity of ecosystems may be one of science's greatest challenges. The first step toward understanding was made when early scientists began to investigate the relationships between plants and animals.

Joseph Priestley, an 18th-century clergyman with a strong interest in science, performed an experiment with candles, a mint plant, and two sealed glass jars (**Figure 2**).

(c) Why do you think that the candle went out in jar A?

(d) Write a hypothesis that explains why the candle with the mint plant burned for a longer time.

(e) What gas is produced as a candle burns?

(f) Would the time of burning be changed by changing the size of the candle or the size of the plant? Give reasons for your answer.

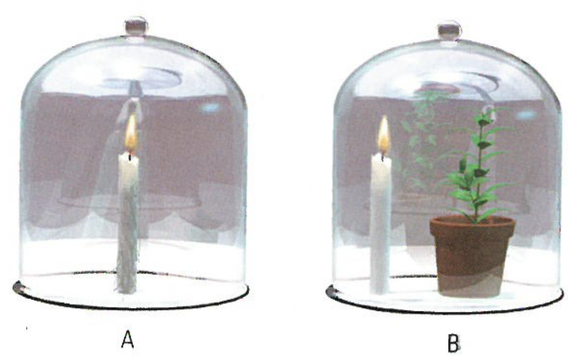


Figure 2
Priestley's first experiment. The candle in jar A burned for 3 min. The candle in jar B burned for 5 min.

Priestley's Second Experiment

Once again, Priestley used heavy glass jars to create a sealed environment (**Figure 3**) and then carefully recorded his observations.

(g) Why do you think the mouse in jar D died first?
(h) After some time the plant in jar C began to appear wilted and sickly. Provide a possible explanation for this observation. How could you test your hypothesis?
(i) The mouse in jar E lived longer and the plant appeared healthier. Provide an explanation for this observation.

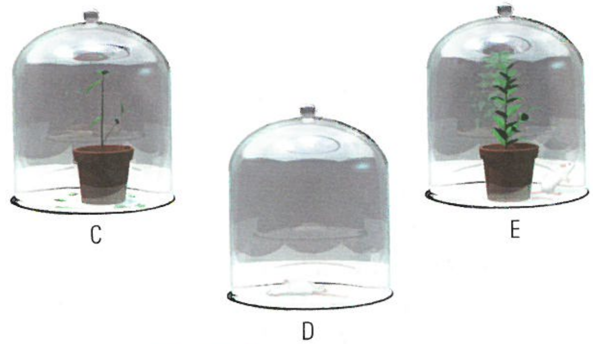


Figure 3
Priestley's second experiment. Both mice eventually died, but the mouse in jar E lived longer.

Photosynthesis and Cellular Respiration

Priestley's second experiment showed that plants and animals do help each other. Scientists later discovered that plants use carbon dioxide (a gas) and water to make sugars. Oxygen (also a gas) is released as the sugars are made. The reaction below summarizes this process, known as **photosynthesis:**

carbon dioxide + water → sugars + oxygen

Most living things, including the mice that Priestley used, use oxygen to break down sugars, their source of energy. Carbon dioxide and water are released as the sugars are broken down. The reaction below summarizes this process, known as **cellular respiration**:

sugars + oxygen → carbon dioxide + water

(j) Identify the raw materials and products of the chemical reaction of photosynthesis.
(k) Identify the raw materials and products for the chemical reaction of cellular respiration.

Respiration is not exclusive to animals. Any organism that requires energy will undergo some form of respiration. Therefore, plants also undergo respiration. This might lead you to assume that plants could maintain the balance between oxygen and carbon dioxide by themselves. However, plants produce about nine times as much oxygen by photosynthesis as they use in cellular respiration.

Maintaining a Balance

Within the biosphere a balance of oxygen and carbon dioxide is maintained because the plants provide oxygen and sugars, while animals provide carbon dioxide and water. The processes of photosynthesis and cellular respiration are said to be complementary, which means that they support one another.

Understanding Concepts

K3 **1.** Write a hypothesis for Priestley's first experiment.

2. In what ways are the candle in Priestley's first experiment and the mouse in his second experiment alike?

3. Explain why algae have been taken aboard space stations.

4. The scientists running Biosphere 2 hypothesized that if they put a certain mix of plants, animals, fungi, and bacteria in a dome, the ecosystem created would be self-sustaining indefinitely.

(a) Evaluate their hypothesis.

(b) Biosphere 2 was not a self-sustaining ecosystem, but can we call the experiment a failure? In a paragraph, comment on the outcome of the Biosphere 2 experiment.

5. Examine **Figure 2**.

(a) How would you test for the presence of oxygen in jar B?

(b) How would you test for the presence of carbon dioxide in jar A?

Making Connections

6. Both Priestley and modern scientists have used living organisms in experiments to discover how living things and their ecosystems work. Is this use of living things ethical? Is there a difference between using humans, mice, mint plants, or bacteria in this way? Write a set of rules that you would impose on scientists who wished to use living things in experiments.

SKILLS HANDBOOK: K3 Developing the Prediction and Hypothesis

2.5

The Carbon Cycle

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, about 50 to 70 billion tonnes of carbon from inorganic carbon dioxide are recycled into more complex organic substances. This is done through photosynthesis.

During photosynthesis, plants use light energy to combine carbon dioxide from the atmosphere and water from the soil. Photosynthesis actually happens in a chain of reactions, but it can be summed up in the equation below:

Reactants						*Products*		
$6CO_2$	+	$6H_2O$	+	light	→	$C_6H_{12}O_6$	+	$6O_2$
carbon dioxide	+	water	+	light energy	→	sugar (glucose)	+	oxygen

Some of the organic carbon is released back to the environment through cellular respiration as carbon dioxide. Once again, this process actually requires a long chain of reactions, but can be summed up in the simplified equation below.

Reactants				*Products*		
$C_6H_{12}O_6$	+	$6O_2$	→	$6H_2O$	+	$6CO_2$
glucose	+	oxygen	→	water	+	carbon dioxide

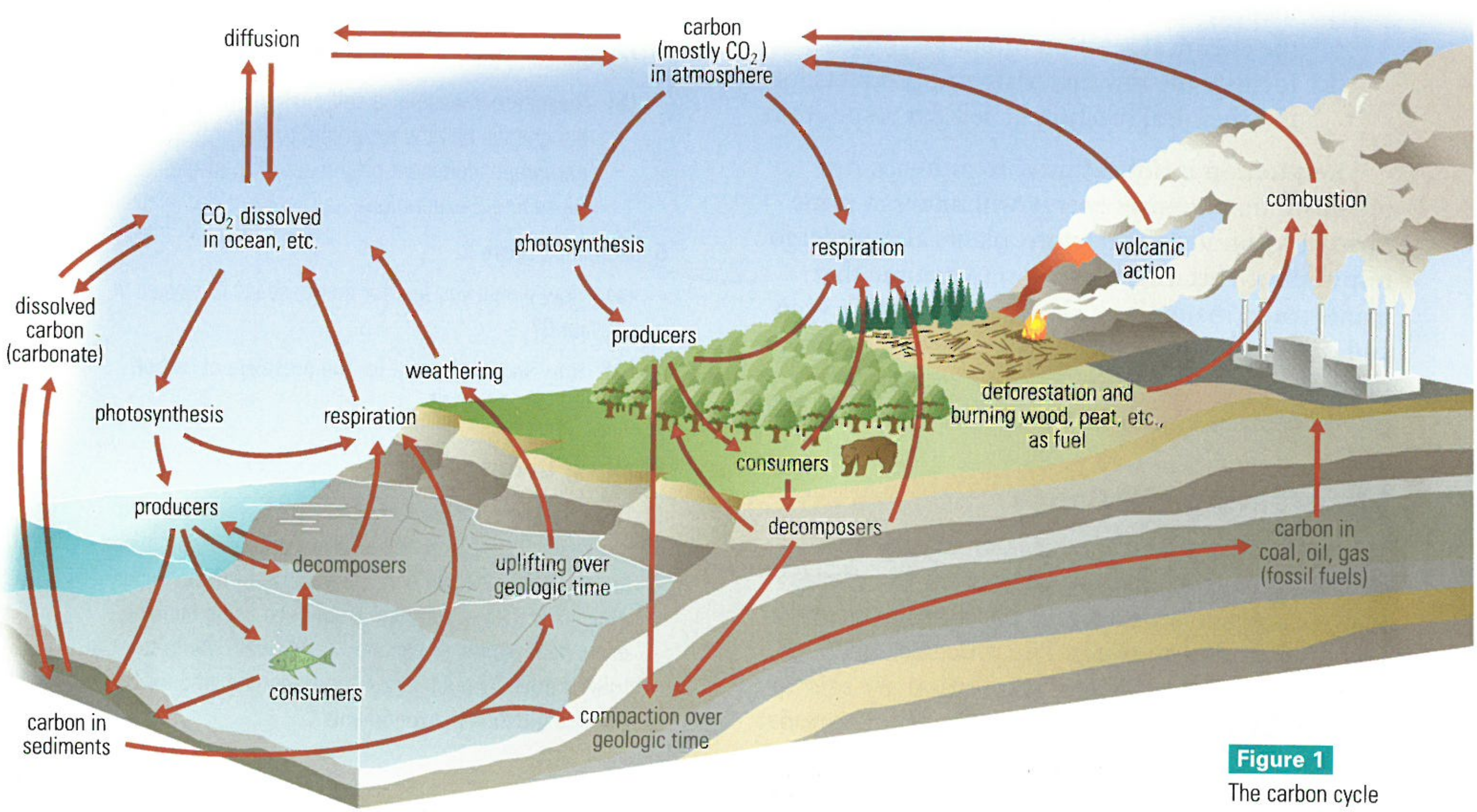


Figure 1
The carbon cycle