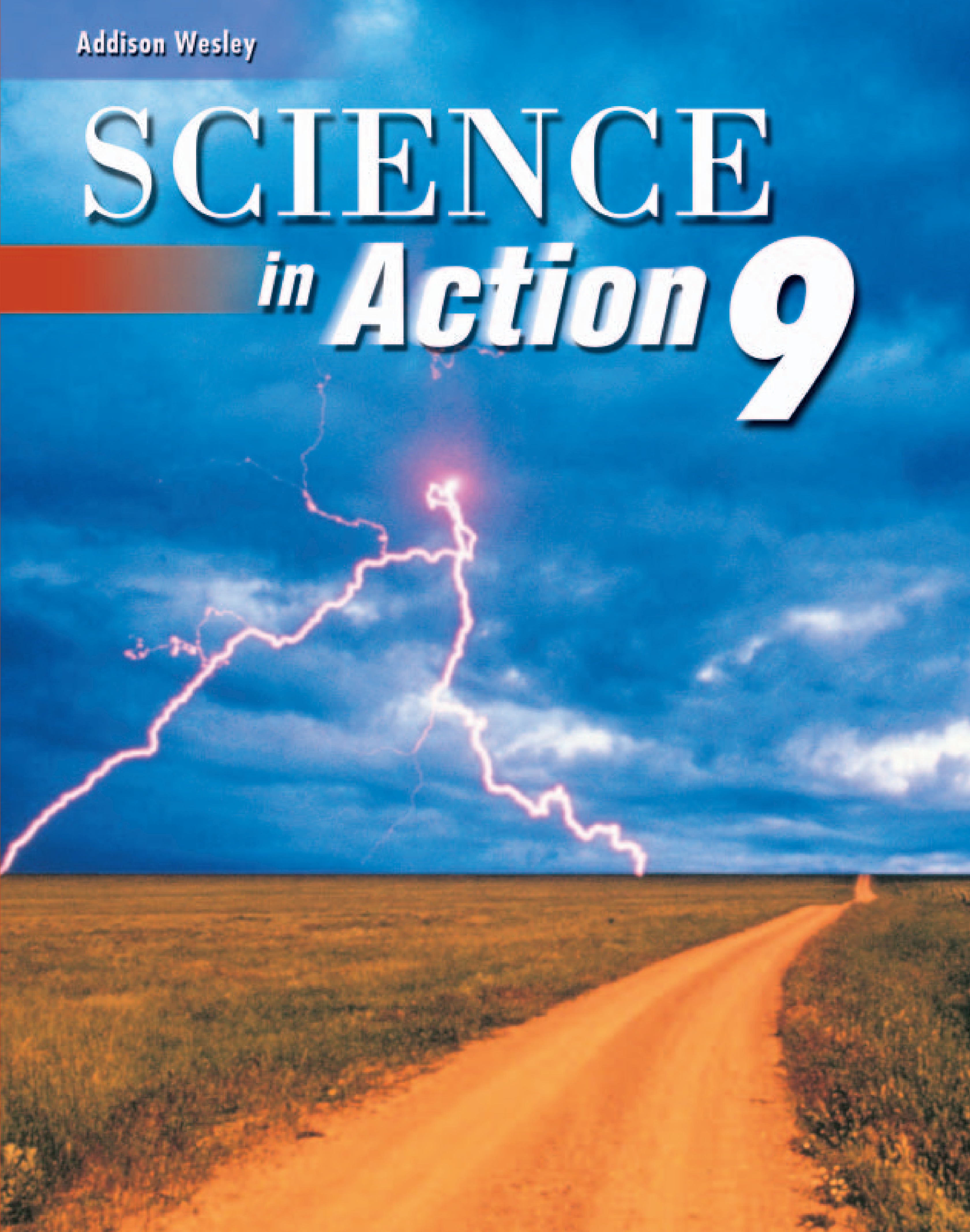
Addison Wesley

SCIENCE in Action 9



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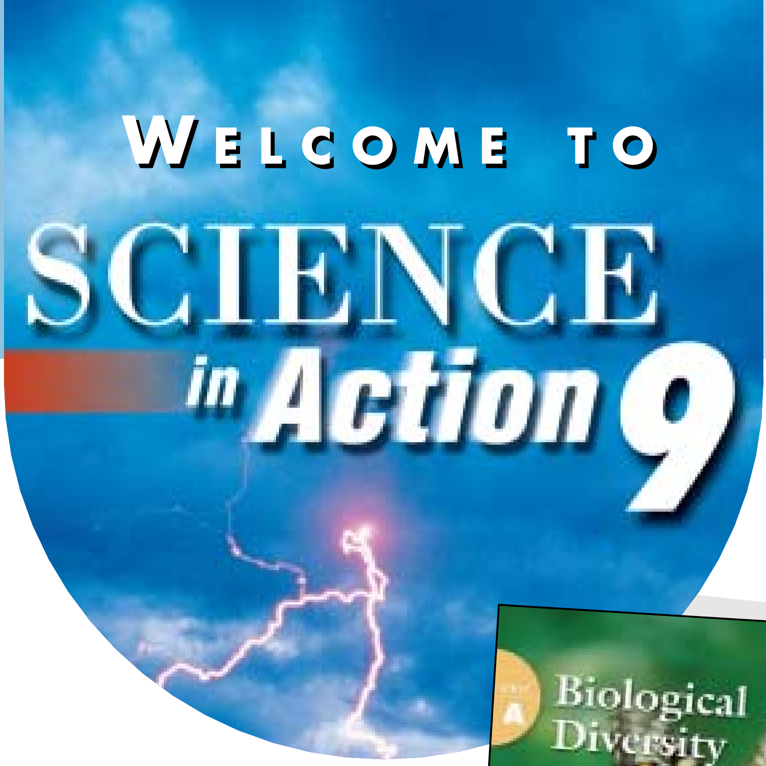
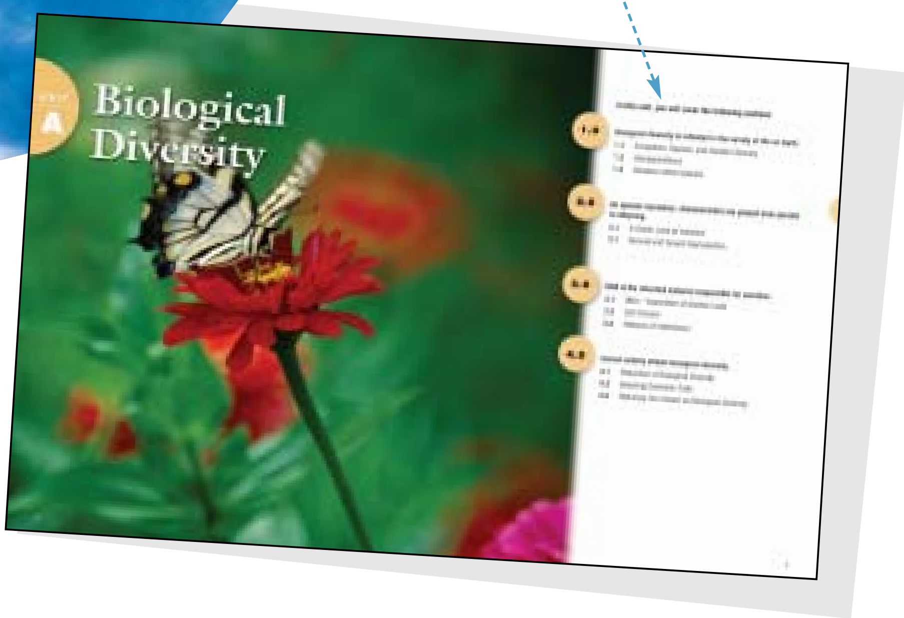


You are about to begin a scientific exploration using *Science in Action 9*. To assist you in your journey, this book has been designed with the following features to help you.

An outline gives you an overview of what you will be learning. You may want to use this as a guide to help you study.



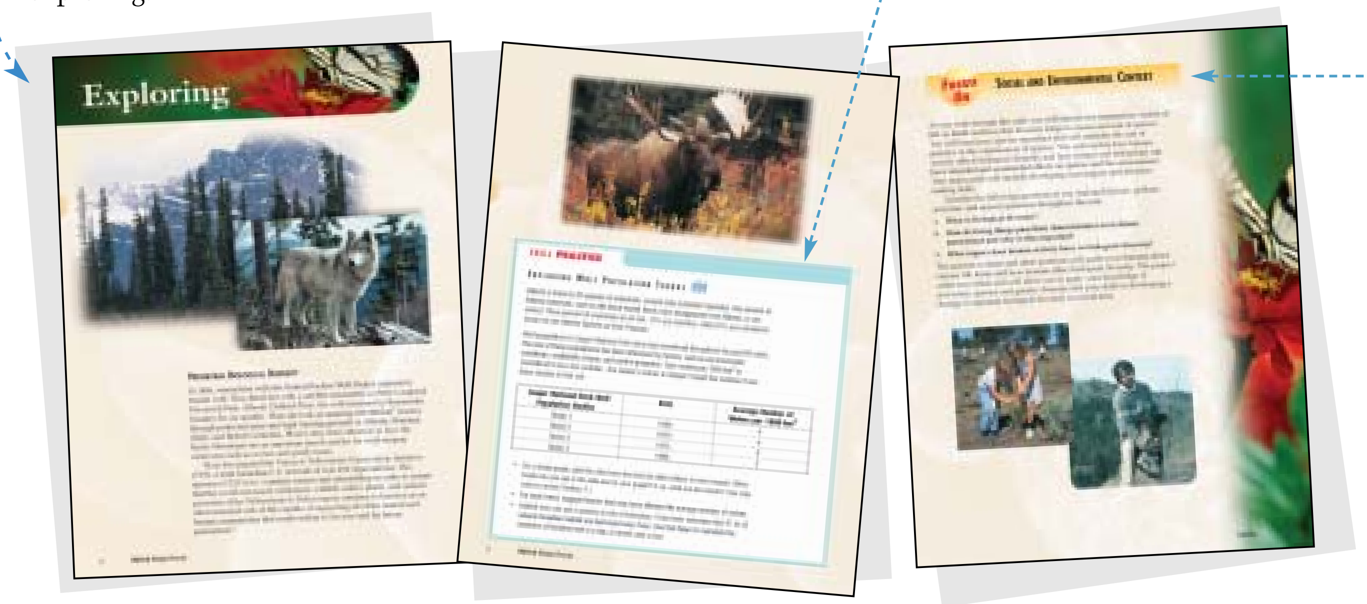
1 Unit Outline

The book is divided into five **units**. Each unit opens with a large photograph that captures one of the ideas that will be covered in the unit.

2 Exploring

This section is an introduction. It has an interesting real-world example to introduce the unit. A hands-on activity introduces the topic of the unit and allows you to start thinking about what you will be exploring.

***SKILL* PRACTICE** activities give you an opportunity to practice and reinforce skills.



3 The Sections

Each section heading summarizes what you will learn in this section. These can help you organize your thoughts when you study.

Each section has two to five subsections. Each subsection heading clarifies and provides more information about the statement in the section heading.

The **Key Concepts** are the main ideas you will learn in this section. By the end of the section, you should be able to describe each concept.

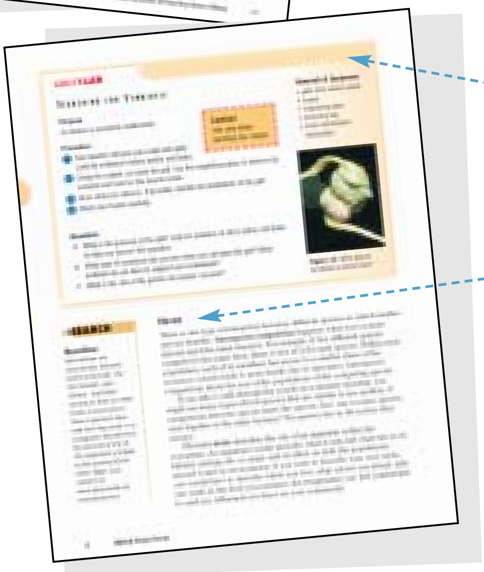
The **Learning Outcomes** outline what you should know and be able to demonstrate your understanding of on completing the section.

Check out this **Web site** for relevant links.

An ***info*BIT** is an interesting fact relevant to what you will be investigating in the subsection.

***GIVE IT A* TRY** activities will help you think about what you are learning.

The **Focus On** section has several questions to help you think about what you are learning and how it connects to your life as you work through the unit. The questions focus on one of three areas or emphases of science: the nature of science, the relationship between science and technology, and the relationship of science and technology to society and the environment.

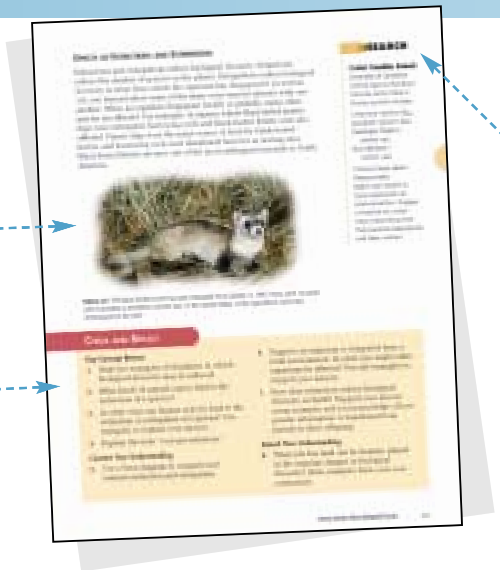


***QUICK*LAB** is a hands-on activity that explores a topic in the section.

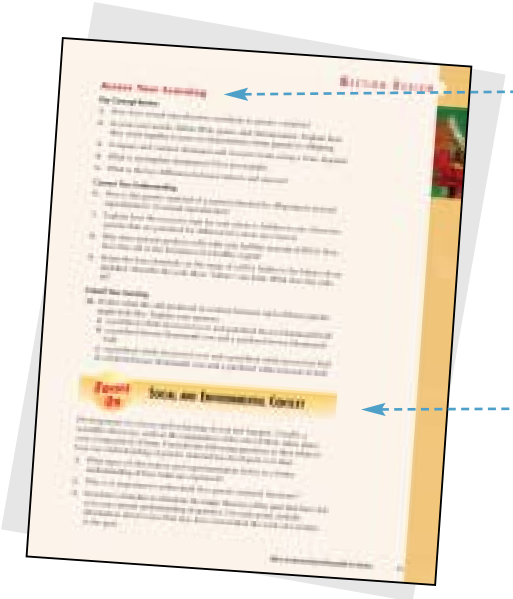
Topic subheadings make the text easier to follow.

You will find numerous photos and illustrations to help explain or clarify many of the ideas in this unit.

Check and Reflect questions provide opportunities for you to review the main ideas you have learned.



At the end of the subsection is a ***re*SEARCH**. This is an additional way to study one of the ideas in the subsection.



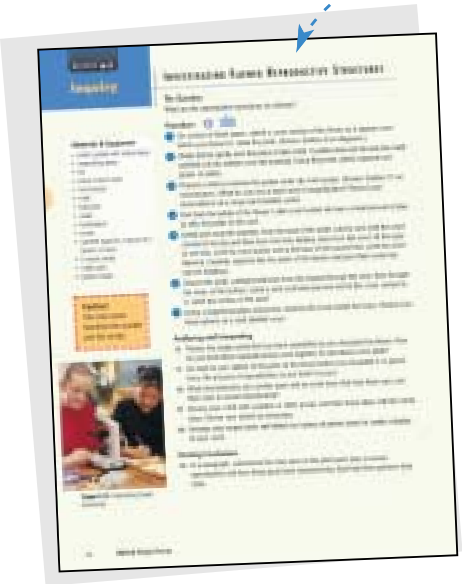
The **Section Review** has questions relevant to the whole section. Answering the questions will help you consolidate what you have learned in the various parts of the section.

The **Focus On** feature helps you organize and apply what you have learned in the section.

4 Science Activities

There are three main types of activities.

Problem Solving Activity: These are open-ended activities that allow you to be creative. You will identify a problem, make a plan, and then construct a solution. These activities tend to have very little set-up and there is usually no one correct solution.

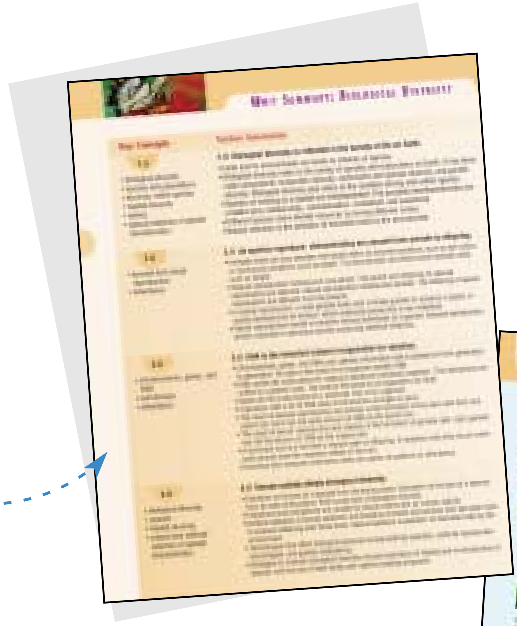


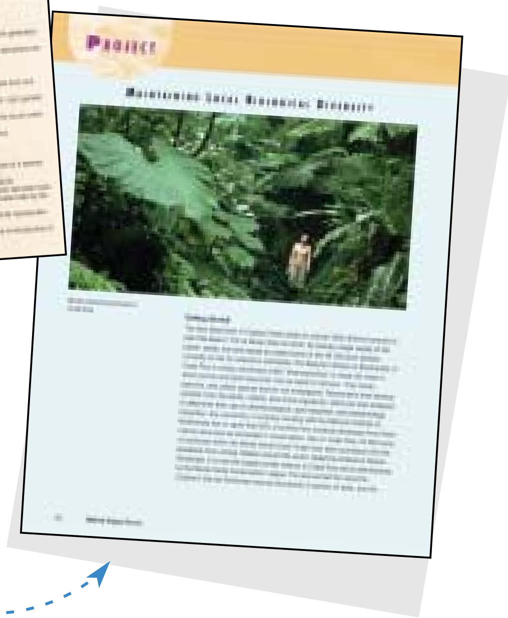
Inquiry Activity: These activities provide the opportunity for you to work in a lab setting. You will develop scientific skills of predicting, observing, measuring, recording, inferring, analyzing, and many more. In these activities, you investigate many different phenomena found in our world.

Decision Making Activity: These activities present issues or questions related to everyday life. You will need to analyze the issue and develop a conclusion based on the evidence you collect. Be prepared to present your conclusion to your classmates.

5 Unit Summary

At a glance, you can find out all the key concepts you have learned within the unit. You can also read the summary of ideas in each section of the unit. This is a good page to help you organize your notes for studying.





6 Unit Project

A project at the end of each unit presents a hands-on opportunity for you to demonstrate what you've learned. You'll work both in a group and individually. The project requires you to apply some of the skills and knowledge that you've acquired to a new situation.

7 Unit Review

The **Unit Review** presents:

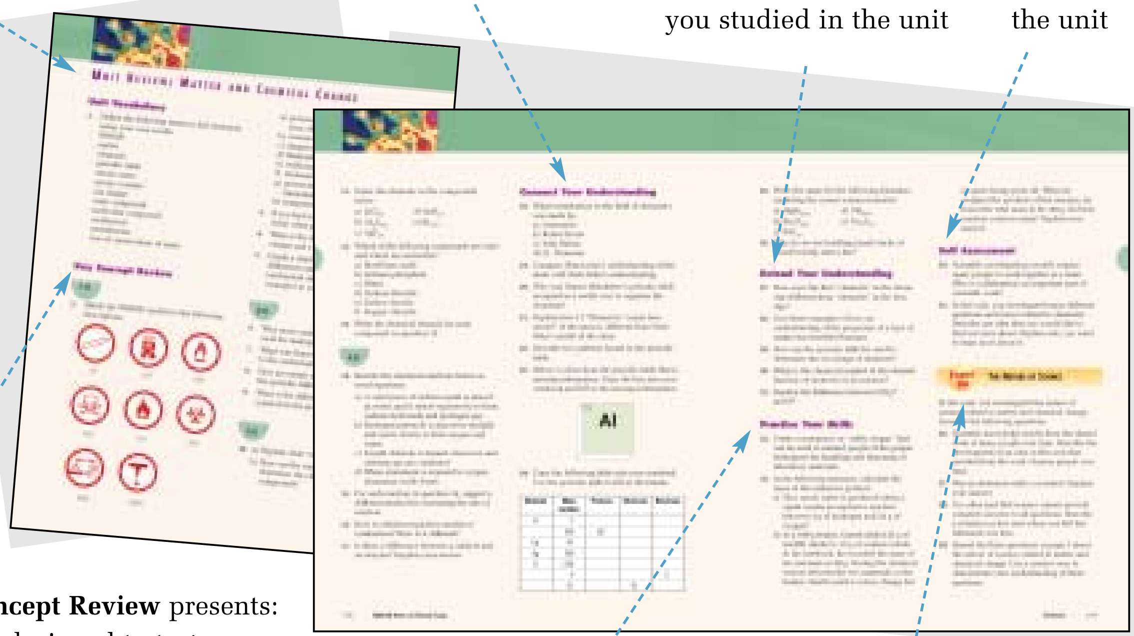
- a chance to review the important terms in the unit

The **Key Concept Review** presents:

- questions designed to test your basic understanding of the key concepts in each section of the unit
- questions that require you to use the ideas in more than one section in the unit to answer

The **Extend Your Understanding** has:

- questions that have you apply your learning beyond what you studied in the unit
- questions that are related to specific skills you have learned in the unit
- opportunities to express your thoughts about ideas you have discovered in the unit
- questions that relate to the specific emphasis of the unit

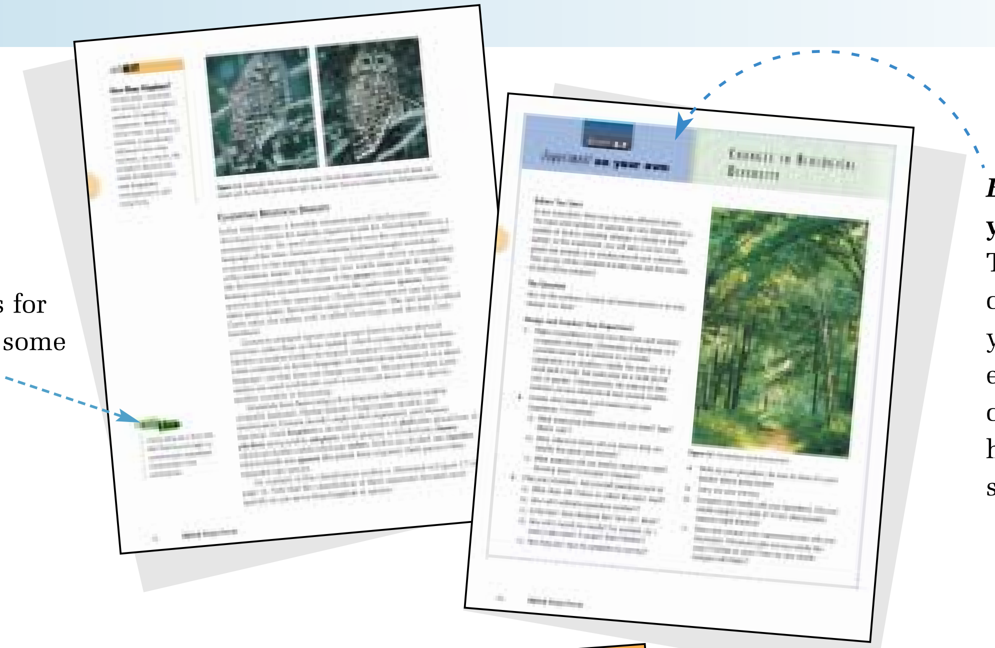


8 Other Features

Here are other features you will find in each unit. Each one has a different purpose and is designed to help you learn about the ideas in the unit.

Science World
This feature is a case study about an issue that can have more than one solution or may involve several viewpoints.

Careers and Profiles
Here you will find profiles or interviews with people whose careers use the science and technology you study in the unit.

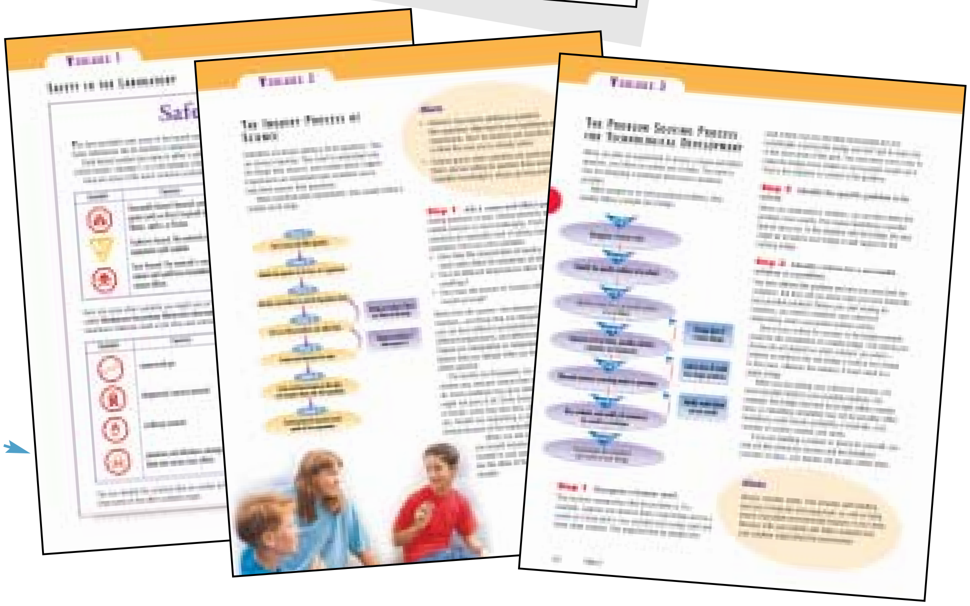


***math*Link**
These are opportunities for you to apply some of your math skills.

***Experiment* on your own**
This is your chance to design your own experiment to check out a hypothesis or to solve a problem.

9 The Toolbox

These pages provide references to lab safety and other basic scientific skills that will help you as you do the activities. Remember to check the toolbox when you need a reminder about these skills.



10 Icons

 means you will be working with toxic or unknown materials and should wear safety goggles for protection or precaution

 means you should wear a lab apron to protect clothing

 means you should wear rubber gloves for protection when handling the materials

 means you will be working with glassware and you should exercise caution to avoid breakage

reminds you that you can find more information in the Toolbox section of the book

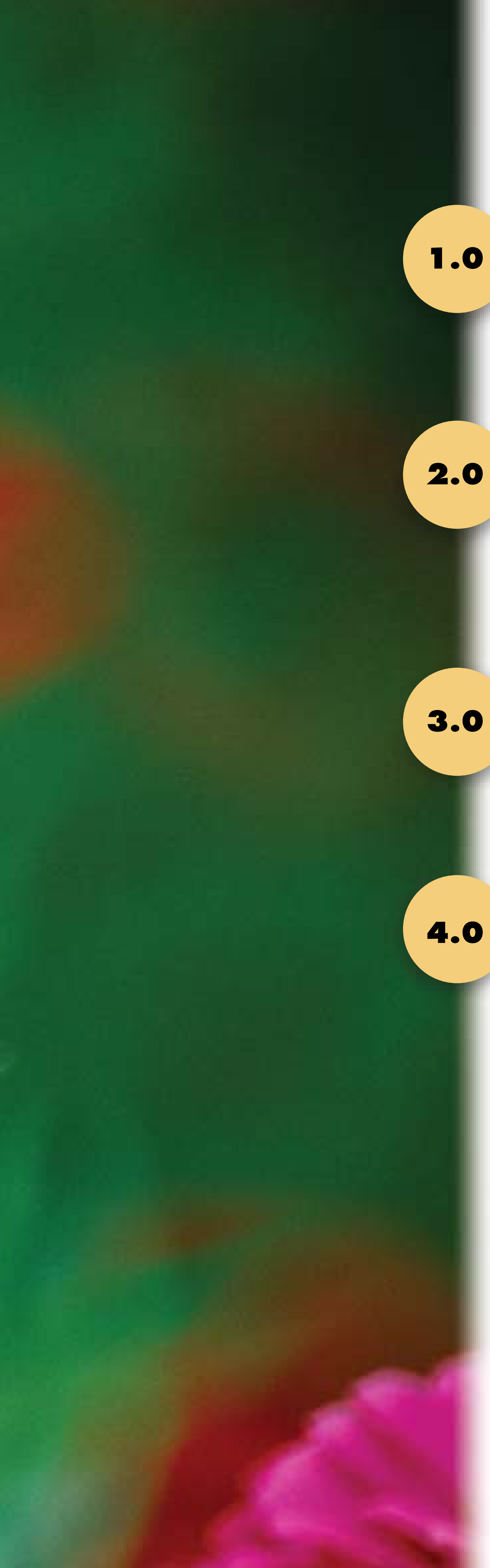
11 Glossary

The Glossary provides a comprehensive, alphabetical list of the important terms in the book and their definitions.

Now it's time to start. We hope you will enjoy your scientific exploration using *Science in Action 9*!

UNIT A

Biological Diversity



In this unit, you will cover the following sections:

1.0

Biological diversity is reflected in the variety of life on Earth.

1.1 Examining Diversity
1.2 Interdependence
1.3 Variation within Species

2.0

As species reproduce, characteristics are passed from parents to offspring.

2.1 A Closer Look at Variation
2.2 Asexual and Sexual Reproduction

3.0

DNA is the inherited material responsible for variation.

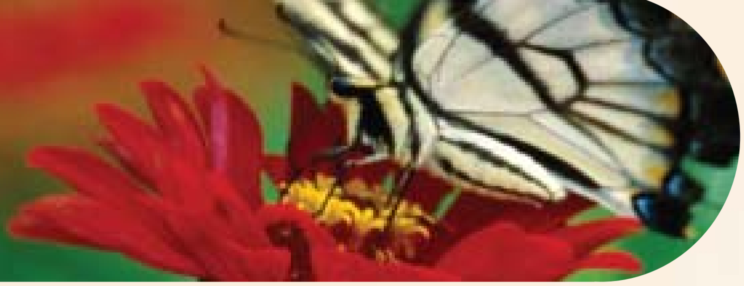
3.1 DNA—Transmitter of Genetic Code
3.2 Cell Division
3.3 Patterns of Inheritance

4.0

Human activity affects biological diversity.

4.1 Reduction of Biological Diversity
4.2 Selecting Desirable Traits
4.3 Reducing Our Impact on Biological Diversity

Exploring



Preserving Biological Diversity

In 1991, researchers with the Central Rockies Wolf Project captured a female wolf. They fitted her with a satellite transmitter in Peter Lougheed Provincial Park, Alberta. Dubbed Pluie, the wolf remained in Kananaskis Country for six months. Then she took an amazing journey through 100 000 km^2 of protected areas and legal hunting grounds in Alberta, Montana, Idaho, and British Columbia. Pluie's story drew attention to how the Rocky Mountains are an important travel corridor for wide-ranging carnivores such as wolves and grizzly bears.

Pluie has inspired the Yellowstone to Yukon Conservation Initiative (Y2Y), a joint Canadian-U.S. network of over 270 organizations. The mission of Y2Y is to "combine science and stewardship in order to ensure that the world-renowned wilderness, wildlife, native plants, and natural processes of the Yellowstone to Yukon region continue to function as an interconnected web of life capable of supporting all of the natural and human communities that reside within it, for now and for future generations."

To reach this goal, Y2Y is working to establish a connected network of protected areas and wildlife movement corridors that run from the Greater Yellowstone ecosystem in Montana to the MacKenzie Mountains in the Northwest Territories and Yukon. Co-operating organizations include environmental advocacy groups such as the Canadian Parks and Wilderness Society (CPAWS), research-based groups such as the Eastern Slopes Grizzly Bear Project, and groups that represent recreation groups, such as Orion—The Hunter's Institute.

The Y2Y initiative is based on the well-established guidelines of conservation biology. Conservation biology is a wide-ranging field. It combines aspects of landscape ecology, economics, species variation, and genetics to help solve the difficult problems of preserving biological diversity. How will protecting a fully functioning mountain ecosystem help to preserve biological diversity? In this unit, you will find out by investigating the processes that enable species to survive.

SKILL **PRACTICE**

EXPLORING WOLF POPULATION TRENDS

Alberta is home to 95 species of mammals, second only to British Columbia. One mammal, the black-footed ferret, has disappeared from Alberta. Three of Alberta's mammal species are considered at risk, 10 species are considered sensitive, while 57 species are considered secure by the Alberta Species at Risk Program.

Wolf populations in Jasper National Park have been monitored throughout the past 60 years. The size of these populations has been influenced by factors such as environmental conditions, availability of prey, and control programs. Four wolves per 1000 km^2 is considered to be a low number. Are Jasper's wolves in danger? Graph the numbers from these studies to find out.

Jasper National Park Wolf Population Studies	Date	Average Number of Wolves per 1000 km^2
Study 1	1946	4
Study 2	1970	4
Study 3	1975	8
Study 4	1986	3

- On a single graph, plot the data from the chart by date (oldest to most recent). What trends do you see in the data and in your graph? (You may wish to review Toolbox 7.)
- For each trend, suggest factors that may have affected the average number of wolves.
- Habitat loss can put a species at risk of extinction. It has been estimated that 97 ha of natural Canadian habitat are destroyed every hour. Use that figure to calculate the numbers of hectares lost in a day, a month, and a year.

Focus On: Social and Environmental Context

As you work through this unit, you will observe the tremendous variety of life on Earth and how this diversity helps to ensure survival of species. You will learn how species reproduce and will consider the role of genetics in the continuation of species. You will explore how human activity affects biological diversity and how science and technology can have intended and unintended effects on species and the environment. Your major goals will include developing your inquiry and decision-making skills.

Consider the following questions as you read and discuss, perform activities, and answer questions throughout the unit.

1. **What is biological diversity?**
2. **How do living things pass their characteristics on to future generations and why is this important?**
3. **What impact does human activity have on biological diversity?**

The answers to these and other questions will guide your learning about various life forms and how humans affect biological diversity. The project at the end of this unit will allow you to apply your knowledge of ecosystem, species, and genetic diversity and your skills in developing a strategy to maintain biological diversity in a local area.

1.0 Biological diversity is reflected in the variety of life on Earth.

Key Concepts

In this section, you will learn about the following key concepts:

- biological diversity
- species and populations
- diversity within species
- habitat diversity
- niches
- natural selection of genetic characteristics

Learning Outcomes

When you have completed this section, you will be able to:

- describe the relative abundance of species on Earth and in different environments
- describe examples of variation among species and within species
- explain the role variation plays in survival
- identify examples of niches and describe how closely related living things can survive in the same ecosystem
- explain how the survival of one species may be dependent on another species
- identify examples of natural selection

If you took a trip to a wetland ecosystem or carefully observed the life forms underneath a rotting log, you would realize that we are surrounded by an incredible diversity of life forms. If you consider the wide range of environmental conditions that exist on Earth, from the frigid cold of the poles to the steamy heat of the tropics, there is no single kind of organism that can survive in all of Earth's regions. Each area possesses its own unique community of characteristic life forms.

Tropical regions such as Costa Rica, Central America, contain the greatest variety of organisms. The picture above shows a small sample of the scarab beetles found in Costa Rica. Although they have many obvious similarities, each beetle is from a different species, each with its own unique characteristics.

Globally, the rate of extinction is on the rise. In the past, natural forces have caused extinctions, but increasingly they are being attributed to human influences. As a consequence, the variety of genetic material is decreasing.

1.1 Examining Diversity

Life exists on our planet in many forms. Biologists have identified over 1.5 million species of animals and more than 350 000 species of plants. A **species** is a group of organisms that have the same structure and can reproduce with one another. There are more species of insect than all of the other kinds of life forms combined. It is no wonder that they are considered the most successful form of life. Biologists estimate that there are probably somewhere between 30 million and 100 million kinds of organisms existing today. They have described only a small percentage of this total. Regardless of how unique they may appear, all life forms share certain characteristics. All living things are made of cells, need energy, grow and develop, reproduce, and have adaptations that suit them for the environment in which they live.

*info***BIT**

Species Numbers

Even though scientists estimate that millions of species live on Earth today, this is just a tiny number compared with the total number of species believed to have lived on Earth since life began roughly 5 billion years ago. Scientists estimate that the species alive today represent only 1% of all the species that have ever lived.

Understanding Biological Diversity

Biological diversity refers to all the different types of organisms on Earth. However, scientists don't usually examine the entire Earth's biological diversity. They examine it in smaller groupings.

Diversity Between Ecosystems

In an **ecosystem**, living (biotic) things interact with other living and non-living (abiotic) things in a shared environment. Abiotic factors include air, water, and sunlight. Together, the living and non-living factors function as a system, hence the term "eco*system*." There is a huge variety, or diversity, of ecosystems on Earth. The number and types of species and abiotic elements can vary from ecosystem to ecosystem. A boreal forest ecosystem (Figure 1.1) has different types and levels of abiotic factors than a prairie slough ecosystem (Figure 1.2). These differences affect the number and type of species that can live there.

Figure 1.1 These woodland caribou share a boreal forest ecosystem with mosses, lichens, pine trees, black spruce, white spruce, poplars, wolves, grizzlies, wolverines, lynx, and a variety of birds.

Figure 1.2 This prairie slough teems with life such as dragonflies, mosquitoes, mallards and ruddy ducks, red wing blackbirds, bulrushes, sedge, and muskrats.

GIVE IT A TRY

TREKKING THROUGH ALBERTA'S LANDSCAPE

Alberta Environment and the provincial government have approved the names of six natural regions making up the vast landscape of Alberta. Each region represents an ecological unit that has its own plants, animals, landscapes, and weather patterns. Each ecological unit is home to many different ecosystems. These regions are the Canadian Shield Natural Region, the Boreal Forest Natural Region, the Foothills Natural Region, the Rocky Mountain Natural Region, the Parkland Natural Region, and the Grassland Natural Region.

- Look at the map showing the location of these regions supplied by your teacher or on the Web site below. Brainstorm with a partner at least *three* plant and animal species you might expect to find on a trek through each region. Record your ideas in a table.
- Using the Internet or library resources, verify whether the plant and animal species you identified live in each region. Compile a class table of all the different species for each region and post it in your class. Begin your search at www.pearsoned.ca/scienceinaction.

Diversity Within Ecosystems

Scientists often examine the biotic factors of an ecosystem. When members of a species live in a specific area and share the same resources, these individuals form a **population**. For example, a population might be all the magpies that live in a certain park. When populations of different species live in the same area, these populations form a **community**. For example, the park contains a community because there are other populations that live in the park besides the magpies. It has populations of aspen trees, grasses, gophers, and so on. The community is the biotic component of an ecosystem. Different communities can also vary widely. For example a park with many formal gardens (but no trees) has a different community because it contains different populations of species than the park mentioned above.

Figure 1.3 The wildebeests, antelopes, and zebras in this picture are all different populations, but together they form part of the diverse community of living things on the Serengeti Plain in Tanzania, Africa.

Diversity Within Species

A species is a group of organisms that all have the same basic structure. However, if you look closely at any population, you will notice that there are subtle variations between the individual members of the population. For example, if you examined a population of magpies very closely, you might notice that bill shape or wingspan varied between individuals. Genetic diversity refers to the variations between members of a population. In any population, these variations are, for the most part, caused by subtle variations in the cells of the organisms.

An organism that shows a great deal of genetic diversity is the banded snail. Members of this species show a tremendous amount of variation in shell colouring as well as the banding on their shells. The colour can range from yellow to brown, and the bands on the shell can range from no bands to bands covering the whole of the shell. Each variation is a result of a variation in the genetic information in the animal's cells.

Some variations between individuals aren't even visible. For example, all human blood looks the same, but it can be classified into blood types. An individual can have one of four basic blood types: A, B, AB, or O.

In certain cases, humans purposely reduce the amount of variation between individual organisms. Over time, humans have bred plants and animals so that as many individuals as possible show the same useful characteristics. For example, individual wheat plants in a crop all have strong stalks and many large seeds.

You will learn more about genetic diversity in later sections.

Figure 1.4 In a field of wheat, individual wheat plants show very little variation. This lack of variation is a result of years of plant breeding.

Species Distribution

The species on our planet are not distributed evenly. Areas around the equator have the greatest number of plant species. These diverse plant communities in turn provide food and shelter to a wide variety of organisms. The number of plant and animal species is greatest in tropical regions. So the tropical rain forests in equatorial regions contain the greatest biological diversity. As you move north to the temperate and then the polar regions, you will find less biological diversity. For example, a survey of snake species in three regions revealed there were 293 species in tropical regions of Mexico, 126 species in the United States, and only 22 in Canada. This trend is found for all organisms. The Arctic and Antarctic regions contain the lowest biological diversity.

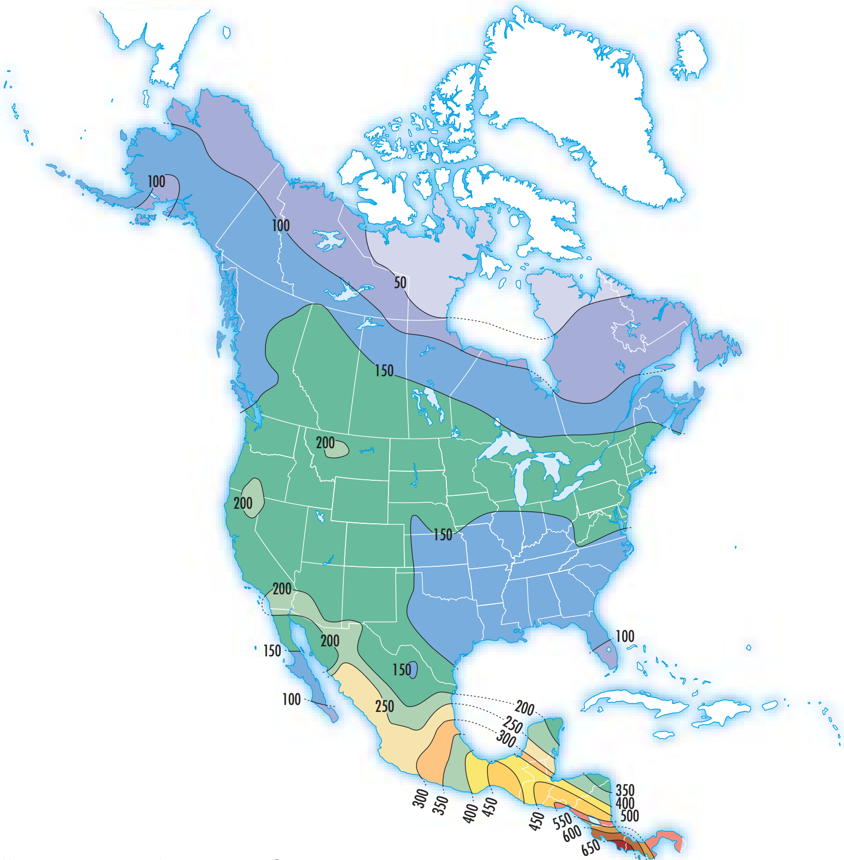


Figure 1.5 This map shows the number of bird species in different regions of North and Central America.

*info***BIT**

How Many Kingdoms?
Increasingly, scientists are using a six-kingdom system of classifying organisms. Research has shown that one group of bacteria is genetically different from other bacteria. As a result, the kingdom Monera has been divided into two new kingdoms: Archaebacteria and Eubacteria.

Figure 1.6 Although the two owls look alike, the northern spotted owl on the right does not breed with the barred owl on the left. As a result, they are considered two different species.

Classifying Biological Diversity

In the 18th century, a Swedish scientist named Carolus Linnaeus, developed a system for naming organisms and for classifying them in a meaningful way. He used Latin because that was the common scientific language of his time. Linnaeus's naming system brought worldwide consistency to the naming of species, which could not be accomplished with common names. In his system, two words name each living thing: the first word indicates the name of the **genus** to which the organism belongs and the second word indicates the particular **species**. No two species can have the same name. Closely related species can have the same genus name, but not the same species name. The red wolf is called *Canis rufus*, the timber wolf is called *Canis lupus*, and the dog, *Canis familiaris*.

Linnaeus arranged species into groups based on their physical structure rather than on their habitat, which earlier systems had done. Modern scientists further developed Linnaeus's classification system. Latin continues to be the language of classification because it is a dead language, one that does not change over time. Because the same Latin names are used worldwide, each scientist will know which species another scientist is discussing.

Scientists have been using a five-kingdom classification system: Animalia (animals), Plantae (plants), Fungi (yeasts, moulds, and mushrooms), Protista (mostly single-celled organisms), and Monera (bacteria). Each **kingdom** is divided into a series of **phyla** (the plural form of **phylum**) and possibly **subphyla**. Each phylum is divided into **classes**, which are further subdivided into **orders**. Orders are divided into **families**, which divide into **genera** (the plural form of genus). Each genus is then separated into species.

An example of this classification system is illustrated in Figure 1.7 on page 13. Note that the classification of the three organisms becomes more specific as you move from kingdom to species.

*math***Link**

Using data set 2 from the Skill Practice on page 13, convert each nanometre measurement into centimetres.

	White spruce	Wolf	Bull trout
Kingdoms	Plantae	Animalia	Animalia
Phyla	Coniferophyta (Conifers)	Chordata	Chordata
Subphyla	—	Vertebrata	Vertebrata
Classes	Pinopsida	Mammalia	Osteichthyes (Fish)
Orders	Pinales	Carnivora	Salmoniformes
Families	Pinaceae	Canidae	Salmonidae
Genera	*Picea*	*Canis*	*Salvelinus*
Species	*Picea glauca*	*Canis lupus*	*Salvelinus confluentus*

Figure 1.7 Classification of three organisms from a montane ecosystem

SKILL PRACTICE

Representing Data

Information comes in many forms including information represented in numbers. Often numerical data are hard to interpret, and scientists use charts or graphs to illustrate the patterns or trends in the data. For example, scientists use a pie chart to display data that is part of a whole. They also use bar graphs to show relationships between sets of data.

Below are two different sets of data. Determine which type of chart or graph would best represent these data sets and create the appropriate chart or graph for each set. (You may wish to review graphing in Toolbox 7.)

Data Set 1

- Two red-eyed, long-winged fruit flies could produce the following combinations for 16 offspring:

  9 out of 16 would have red eyes and long wings
  3 out of 16 would have red eyes and small wings
  3 out of 16 would have white eyes and long wings
  1 out of 16 would have white eyes and small wings

Data Set 2

- The size in nanometres (nm or 10^{-9} m) for the following viruses are:

smallpox virus	250 nm
flu virus	100 nm
yellow fever virus	22 nm
polio virus	20 nm
foot and mouth virus	10 nm

Activity A-1

Problem Solving

Representing Biological Diversity

Biological Diversity on Earth	
Group of organisms	**Number of species**
plants	270 000
fungi and lichens	100 000
protozoans and algae	80 000
spiders and scorpions	75 000
mollusks	70 000
crustaceans	40 000
roundworms	25 000
fish	22 000
flatworms	20 000
earthworms and leeches	12 000
reptiles and amphibians	10 500
jellyfish, corals, and anemones	10 000
sponges	10 000
birds	10 000
bacteria	4 000
mammals	4 500
insects, centipedes, and millipedes	963 000
other	10 000

Recognize a Need

Scientists working to classify the range of life on Earth have come to a startling conclusion: Species of insects, centipedes, and millipedes outnumber mammals by a ratio of 214 to 1. That is, for every recorded species of mammal, there are 214 species of bugs that have been discovered. Scientists estimate that we have only just begun to uncover the diversity of insects on our planet.

The chart on the left lists the number of species in each of the major groups of organisms.

The Problem

TOOLBOX

For people to care about the biological diversity on Earth, they have to be aware of the number and types of organisms that share the planet with us. Design a way to visually summarize the information in the chart to clearly represent the numbers of different species that have been identified. Your model may be two- or three-dimensional, and you may use technology as appropriate.

Criteria for Success

To be successful, your representation must meet the following criteria:

1 solve the problem described above

2 be accurate

3 reflect the proportions of different species in relation to one another

4 be visually appealing to convey the information to a general audience

Brainstorm Ideas

5 Work with a partner or in a small group. Brainstorm ideas that would fit the criteria. All ideas should be considered and written down.

6 Look for ways to blend the best of the group's ideas.

Design a Model

7 Plan the design. Write down all the steps you will follow.

8 Create your representation.

Test and Evaluate

9 How effectively does your design convey the information? How does your work compare with that of your classmates?

Communicate

10 Share and compare your design with others in the class. Highlight the features that make your representation both accurate and effective.

Biological Diversity Under the Sea

Coral reefs have been called the "amazons of the oceans" because of the richness of their species diversity. Like tropical rainforests, coral reefs support many different communities of organisms surviving on limited nutrients. As in tropical rainforests, organisms that inhabit coral reefs have very efficient ways of recycling the limited nutrients that are available. Coral polyps form the living layer of a coral reef. These tiny organisms, in which some algae species live, provide energy for coral communities by converting sunlight to fuel. The hard, calcium carbonate layers of a coral reef are constructed by reef-building corals and certain types of algae. Coral reefs can be massive and thousands of years old.

Figure 1.8 Large coral reefs, like the Great Barrier Reef, can contain hundreds of species of coral and thousands of species of mollusks. Many fish, bird, and whale species are also associated with this ecosystem.

reSEARCH

"Cat-egories "

Trace the classification for a house cat, including the kingdom, phylum, subphylum, class, order, family, genus, and species. What are some of the house cat's relatives? Prepare a poster or an electronic presentation of your findings. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Explain what is meant by the term biological diversity.
2. In one or two sentences explain why so many different types of organisms exist on Earth today.
3. Describe how scientists classify an organism.

Connect Your Understanding

4 Explain how the classification system helps us to understand how living things are different from or related to each other.

5. Summarize, in your own words, ecosystem diversity, community diversity, and genetic diversity.
6. Compare and contrast the meanings of population and community.
7. Why is there more biological diversity closer to the equator than in Canada? Give reasons for your answer.

Extend Your Understanding

8. Imagine that you have to classify all the birds on Earth based on where they live. Design a system that starts with very broad categories of many members and goes to very specific groupings of one type of member.
9. Explain why preseving biological diversity is important to life on Earth.

1.2 Interdependence

No species can survive by itself. Each species is dependent on many other species in its environment. For example, plants produce oxygen as a by-product of photosynthesis and are therefore a major source of atmospheric oxygen needed by most other organisms on Earth. Plants also provide shelter and cover for many organisms. Mule deer, for example, need trees to shelter them from the wind and from predators such as wolves. Animals such as insects depend on flowering plants for food. Flowering plants depend on insects to transfer pollen from one flower to another, providing a means of fertilizing the plants.

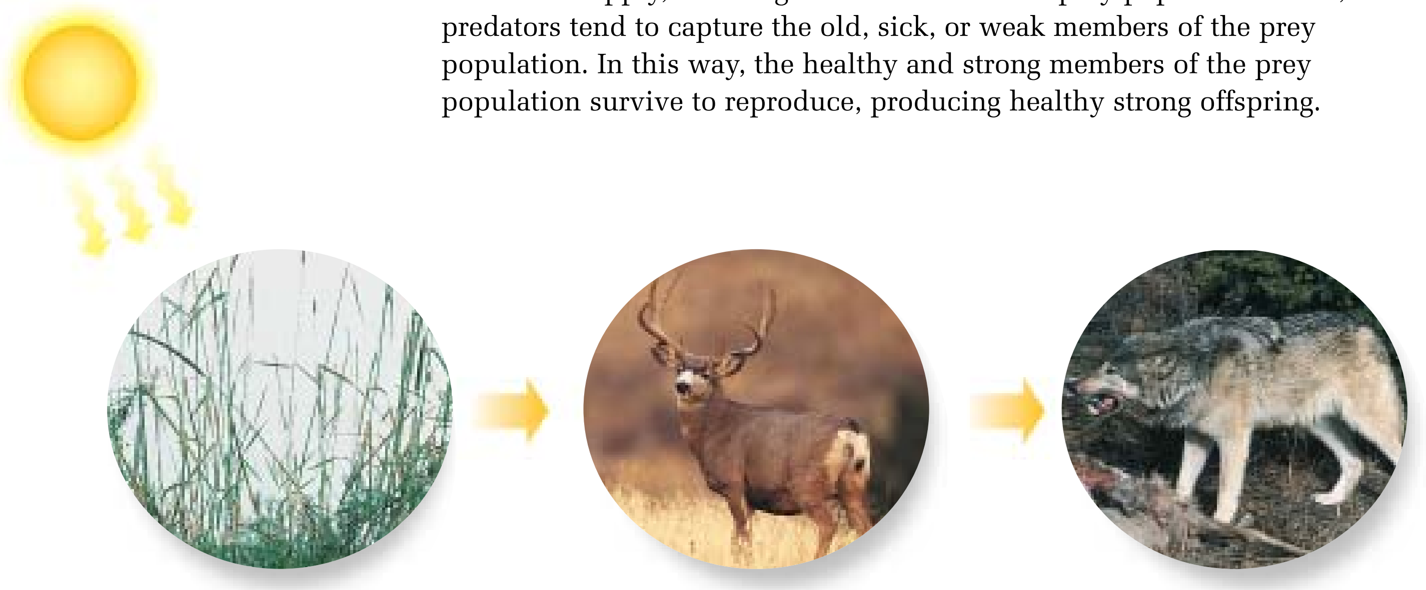
In earlier studies, you learned that food chains and food webs illustrate the relationships between populations of organisms. Herbivores such as mule deer eat plants. Carnivores such as wolves eat herbivores. Decomposers such as bacteria and fungi break down both animals and plants once they're dead. The predator-prey relationship is one of the most obvious examples of interdependence between populations of species. If a population of predators such as the lynx grows so large that it eats too many of its prey, the snow-shoe hare, then lynx numbers must eventually decrease as its members die of starvation. As the lynx population decreases, the hare population will have a chance to recover and its numbers will increase. The cycle will then continue.

Although predators eat individuals in a prey population, the prey population benefits in many ways from this relationship. Predators reduce the size of the prey population. This prevents the prey from outstripping their food supply, resulting in starvation for the prey population. Also, predators tend to capture the old, sick, or weak members of the prey population. In this way, the healthy and strong members of the prey population survive to reproduce, producing healthy strong offspring.

*info***BIT**

Sharing Resources

Many species—especially birds—have restricted areas in which they forage (collect food). Researchers have found that the male red-eyed vireo forages for insect food in the upper canopy (9–15 m) of the trees they live in. The female collects insects in the lower canopy and nearer the ground (0–3 m). Male and female red-eyed vireos overlap only about 35% in their feeding areas. So even though they eat the same insects and are members of the same species, these birds find their food source in different areas and don't compete with each other.



Timothy grass **Mule deer** **Wolf**

Figure 1.9 This food chain in a montane ecosystem illustrates interdependence. Timothy grass depends on the Sun's energy for growth. Mule deer (herbivores) depend on timothy grass as a food source. Wolves (carnivores) depend on animals such as mule deer for survival.

Symbiosis

Another type of interdependence is called **symbiosis** (*sym* meaning together, *bios* meaning life), which is an association between members of different species. There are several types of symbiosis and the difference among them is determined by whether the organisms benefit from or are harmed by the relationship.

In **commensalism**, one of the participating organisms benefits but the other does not. However, there is no harm done to the second organism. A bird that builds its nest in a tree, or a plant that grows high up on a tree to get sunlight but doesn't take nutrients from the tree are both examples of commensalism. Barnacles that attach themselves to whales in order to move to other areas are involved in commensalism. The barnacles benefit, but the whales are not affected (Figure 1.10).

Figure 1.10 The grey bumps on this whale are barnacles. The whale provides a method of transportation for the barnacles.

As its root word *mutual* suggests, **mutualism** benefits both organisms. A lichen growing in the arctic tundra is a combination of two organisms: a fungus and an alga. Algal cells produce food for themselves and the fungus through photosynthesis, while the fungus protects the algal cells from dehydration. The bull's horn acacia tree is home to large numbers of ants. The tree gives the ants food and shelter, while the ants protect the tree from other animals feeding on it by attacking them. The ants have also been known to gnaw through vines that attach to the tree.

Another interesting example comes from Central America. The flower *Clusia* dispenses medicine to bees. As a bee pollinates the flower, it gets doused with a sticky resin spiked with a powerful antibiotic. Scientists suggest that the antibiotic in the resin kills bacteria commonly found in the bee's nest. When the bee makes an important house call to the plant, the bee gets medical attention free of charge!

Figure 1.11 The interactions between the fungi and algae making up these lichens enhance the survival of each species.

In **parasitism**, one organism benefits and the other is harmed. A tapeworm attached to the intestinal wall of a human is an example. The tapeworm absorbs nutrients from the food in the intestine, leaving little food for the human host to absorb. Unlike the predator-prey relationship, parasites usually do not kill their hosts because the hosts represent their food supply. Parasitism is not limited to two organisms. For example, the Mexican bean beetle is a plant parasite. However, the beetle is parasitized by the tachinid fly which, in turn, is parasitized by the ichneumon wasp.

Symbiotic relationships are extreme examples of interdependence. One species' survival—particularly in a parasitic relationship such as a tapeworm and its host—depends directly on the health and survival of another species. For example, the tapeworm depends on its host for both its food and its habitat. Organisms involved in symbiotic relationships illustrate the importance of adaptations that help species survive in their unique environments.

QUICKLAB

Searching for Symbiosis

Purpose

To observe a symbiotic relationship

Caution!
Use care when handling the scalpel.

Procedure

1. Your teacher will give you a leaf with galls. Look for evidence of entry and/or exit holes.
2. Using the scalpel, cut open the gall. Use the magnifying glass to observe its contents and look for the insects inside.
3. Draw what you observe. If possible, identify the inhabitants of the gall.
4. Wash your hands carefully.

Questions

5. What is the purpose of the gall? Look for evidence of entry and/or exit holes to help you answer this question.
6. What type of symbiosis did you see when you cut open the gall? What evidence do you have to support your conclusion?
7. What is the role of the gall for the insects' survival?

Materials & Equipment

- galls from various plants
- scalpel
- magnifying glass
- dissecting tray
- insect identification keys/guides

Figure 1.12 What type of symbiosis is shown here?

reSEARCH

Mycorrhizae

Mycorrhizae are associations between plants and fungi. Use the Internet, your library, and other sources to find out what kinds of associations these organisms have and how they work. In a paragraph describe how the survival of one of the organisms is linked to the survival of the other. Begin your research at www.pearsoned.ca/scienceinaction.

Niches

There is one type of interaction between different species in which neither species benefits. **Interspecies competition** happens when two or more species need the same resource. For example, if two different species compete for the same food, there is less of it for each species. Within each population, each of its members has access to a smaller share of the resources, which leads to more deaths due to starvation. Interspecies competition limits the size of the populations of the competing species.

If you take a walk through the woods on a summer morning, you might see many types of bird species that are similar to one another. If competition between species hurts the species, how can so many species exist together in the same location? The answer lies in the niches they occupy.

The term **niche** describes the role of an organism within the ecosystem. An organism's niche includes what it eats and what eats it, its habitat, nesting site, or range, and its effect on both the populations around it and its environment. If you were to describe your own niche, you would have to describe where you live, what school you attend, jobs you work at, the food you consume, the temperature you feel comfortable in, and any influences you have on your community.

The niche occupied by a population in one area may not be the same as the niche occupied in a different area because the food supply and competitors may be different. In addition, the niche occupied by a species may change throughout its lifetime. The frog tadpole lives in an aquatic environment and consumes plant matter while the adult frog lives in both aquatic and terrestrial environments and is carnivorous.

Resource Partitioning

For similar species to coexist in an area, they must have slightly different niches. For example, five species of warblers (small songbirds) all feed on spruce bud worms. You would think that competition among the five species would harm them all. But because these species have different behavioural adaptations, each prefers to feed on worms at different parts of the tree. By doing this, the five species don't directly compete for the worms. Instead, they have divided up the resource (worms) among them in what is known as **resource partitioning**. Resource partitioning doesn't always involve food. For example, species may have slightly different niches in terms of nesting preferences or heat tolerance.

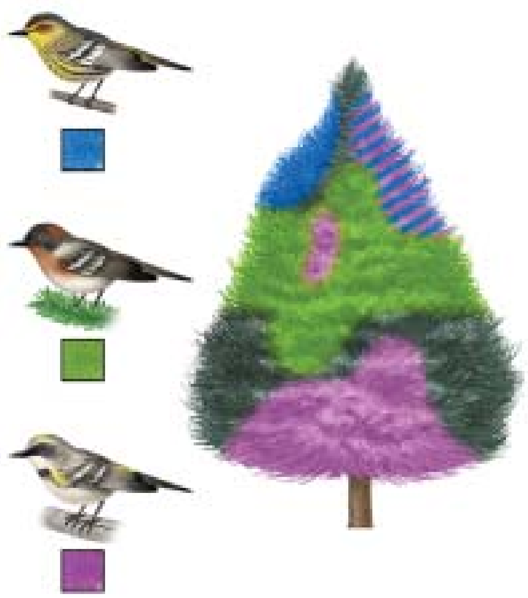


Figure 1.13 These three warbler species feed on spruce bud worms in different parts of a spruce tree. Their niches differ in the feeding location they prefer. Note that there is some overlap between the species.

Check and Reflect

Key Concept Review

1. List three different types of interdependence among living organisms. Provide an example of each.
2. How does the prey population benefit when individuals in this population are eaten by a predator?

Connect Your Understanding

3. Classify the following symbiotic relationships. Create a chart to record your data, use the coding "+" to represent a benefit, "–" to represent harm, and "n" to represent no benefit or harm. How would you use this coding to represent each organism involved in the following relationships? Explain your answer.
   a) mutualism b) parasitism c) commensalism
4. A student observes the following organisms in a 30 cm^2 section of the front lawn of your school: a dandelion; a small butterfly on the flower of the dandelion; a caterpillar eating the leaves of the dandelion; and a worm in the soil. Describe the niche of each organism.

Extend Your Understanding

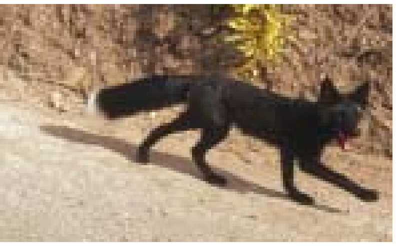
5. Imagine your school is an ecosystem. Create a concept map showing the interdependence among students, teachers, classes, and grades in this "ecosystem."

1.3 Variation Within Species

Figure 1.14 Although the members of this species may look alike, they vary genetically from one another.

*info***BIT**

Coats of Many Colours



Even though its common name is the red fox, members of this species can have a wide variety of coat colours. Aside from the typical red coat, individuals may have grey-brown, silver, or even completely black coats.

So far in this unit, you have seen that the stability of an ecosystem relies on the diversity of its communities and species and on the interactions among species. The many different species survive because of the relationships established in this complicated "jigsaw puzzle." Healthy ecosystems have a great deal of genetic diversity among the species that inhabit them. But biologists have also observed a great deal of variation *within* a population of a single species. For example, you and your classmates are all members of the same species, *Homo sapiens*, but each of you differs slightly in appearance. Some may have black hair, others blonde; some may be tall, others less tall. This kind of variation is seen in all species. Variation within a species is called **variability**.

Variability and Survival

Variability is important if the environment of the species changes. When the species has a great deal of variation among its individuals, it is more likely that some of the individuals will survive environmental changes. Environmental changes do not necessarily have to involve climatic changes. The introduction of a new predator, the spread of a new disease, the introduction of a toxic substance, or the elimination of a food source are all examples of environmental changes that could affect the survival of a species. In these cases, variability within the species will help the species survive.

For example, the fox shown in the infoBIT on page 20 has a dark coat instead of the more common red coat. Its dark coat may make it more conspicuous in fields and woods. But if this fox roams into a new habitat that has many black rocks, its dark coat may blend in better with its surroundings. By blending in better, the fox could pounce on its prey more easily. The fox's predators, such as wolves and lynx, might not spot it as easily. So variations in coat colour may allow different fox populations to survive in different habitats.

How variability helps in survival can also be seen in the growing resistance of certain strains of bacteria to antibiotics. One of the first antibiotics, penicillin, used to be very effective against some forms of bacteria. Today, it is far less effective. Researchers think that the over-prescription of antibiotics has allowed bacterial populations with variability to survive the application of antibiotics. A few resistant bacteria are not eliminated by the antibiotic that is administered, and reproduce to produce new generations of resistant bacteria. There is some fear that if this trend continues, resistant strains of bacteria may completely replace current strains and antibiotics will no longer be effective. To avoid this problem, most physicians believe that antibiotics should only be used when absolutely necessary.

reSEARCH

"Super Bugs"
Over time, some germs have become very resistant to medicines. Scientists sometimes refer to these as "super bugs." Find out more about a "super bug" and how it is now treated in human beings. Write a brief report based on your research. Begin your research at www.pearsoned.ca/scienceinaction.

SKILL PRACTICE

Measuring Variation in the Human Hand

Variation within a species may not be something that is immediately noticeable. Try this activity to measure the amount of variation within one human characteristic—hand span. Spread your left hand on a flat surface so that the tip of your thumb is as far as possible from the tip of your little finger. Ask a partner to measure and record your hand span in centimetres. Switch roles and measure your partner's hand span. Prepare a frequency distribution chart like the one below for hand span data from the class. Then plot your results in a line graph. (Review Toolbox 7.)

Hand span in cm	12 or less	13 to 16	17 to 20	21 to 24	25 to 28	29 or more
Number of students						

- What shape does the graph have? What does it show about variation in hand span among your classmates?
- Predict whether the graph would have the same shape if you measured the hand spans of students in grade 1 and in university.
- What advantage might large hands have given to early *Homo sapiens*? Small hands?
- What other human characteristics might be measured in the same way? What prediction could you make about index finger length in humans?

ACTIVITY A-2

Inquiry

PROTECTIVE COLORATION AND SURVIVAL

Before You Begin

Many species show variation in colour and patterning which can allow individuals to blend in with their surroundings. Species that are found in a variety of habitats may show a wider range of colour and pattern variation than those that are found in only one habitat.

In this activity, you will model a population that exists in three different colours. Your task will be to investigate the relationship between an organism's survival and its colour relative to the colour of its surroundings. Coloured chips or blocks will represent a prey population and some students in your group will play the role of predators.

Materials & Equipment

- 60 chips of each of three different colours (coloured counters, coloured algebra tiles, lego blocks or similar)
- a piece of paper or cloth 75 cm × 75 cm, which matches one of the chip colours
- graph paper
- colour markers or pencil crayons

The Question

TOOLBOX

Does the colour of an organism affect the organism's chance of survival?

The Hypothesis

Reword the question in the form of a hypothesis.

Procedure

1. Your teacher will divide the class into groups of five. Three students are to play the role of predator, one student monitors the population and sets up the population for each generation, and one student records the results.
2. Your teacher will provide each group with a piece of paper or cloth, 75 cm × 75 cm, to represent the habitat. The colour of the paper or cloth will match one of the colours of the prey organisms.
3. Set up a data table similar to the one below and record the colour composition of generation 1. You will start with 20 chips of each colour in generation 1.

	Number of Colour #1	Number of Colour #2	Number of Colour #3
Generation 1			
Survivors of Selection 1			
Generation 2			
Survivors of Selection 2			
Generation 3			
Survivors of Selection 3			
Generation 4			
Survivors of Selection 4			
Generation 5			
Survivors of Selection 5			

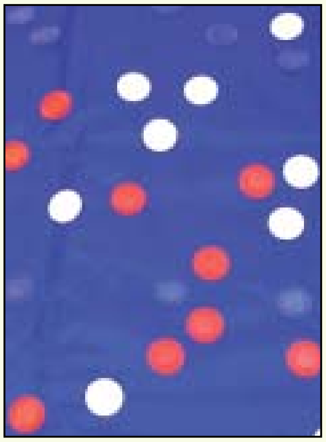


Figure 1.15(a) Step 4. Set-up for generation 1.

4. With the predators looking away, the designated monitor will set up the first generation of 60 individuals of the prey population on the habitat by randomly scattering 20 chips of each of the three different colours on the habitat. See Figure 1.15(a) for the set-up. The predators continue to look away from the habitat.
5. Have a predator turn around and very quickly take any chip, and then turn back. This represents selection of a prey animal to be eaten. Repeat the process with each of the other predators until each predator has taken 10 chips. The 30 chips that remain are the survivors.

6 Record the colour of the survivors and remove them from the habitat.

7 Assuming that each survivor produces 2 offspring of the same colour, the monitor and recorder determine the population composition for generation 2. The recorder records the number of chips of each colour that will make up generation 2.

8 The population monitor will set up generation 2 by placing the appropriate number of chips of each colour on the habitat.

9 Repeat steps 5–8 until 5 rounds of selection have been completed.

10 Compare the number of survivors of each colour that remain after each selection.

Analyzing and Interpreting

11 Plot bar graphs to show the number of survivors of different colours that remain after each selection. Decide first how you will show these results; for example, decide if you will show the results on one graph or three. Examine your set of graphs for trends.

12 How does the composition of the prey population at the end of selection 5 compare with the original composition of the prey population?

13 Share your results with groups who used a different background colour for the habitat. Compare your graphs with the graphs of the other groups. Do you see any trends?

14 How do the colours of the survivors relate to their habitat background? Suggest a possible explanation for this pattern.

Forming Conclusions

15 Based on class results, what conclusions can you draw about the role of coloration in an organism's survival?

Applying and Connecting

Imagine a species with two colour variations, one mostly green and one mostly brown. How might populations of this species change:

a) if the environment changes from green to brown?

b) if the environment becomes a patchwork of tiny green and brown splotches?

Survival of the Banded Snail

The banded snail, *Cepea nemoralis*, shown in Figure 1.15(b), lives in a wide range of habitats that vary from dark beech and oak woods to leafy hedges and grassy meadows. Its shell colour can vary from yellow through a range of pinkish browns to brown. Bands on the shell can be thin or thick and can range from one band to many covering the whole shell.

Scientists explain this range in variation by referring to the colour of the ground and vegetation in the snail's habitat. The foliage changes with the seasons. In spring there is little vegetation and the ground is brown, giving brown snails an advantage. Predators, like the song thrush, may not find them because they blend in with their surroundings. In summer, brown snails are more at risk when their shells contrast with green meadows. Because of the great variation, only part of the snail population may be predated in any season, ensuring the survival of the species.

Figure 1.15(b) Banded snails

NATURAL SELECTION

Figure 1.16 Cliff swallows

Another aspect of species survival and variability is natural selection. **Natural selection** occurs when the environment "selects" which individuals will survive long enough to reproduce.

An example of natural selection in our own time occurred in southwestern Nebraska. In May 1996, a severe cold spell gripped the area for six days. Dr. Charles Brown, who had been studying the same colony of cliff swallows for 17 years, watched about 30 000 birds, or about half of the colony, die of starvation. Why did some birds die and others survive? To answer this question, Dr. Brown and Mary Bomberger Brown collected more than 1800 dead cliff swallows. They measured the beaks, wings, and legs of the dead birds and then measured the same structures on about 1000 survivors. They discovered that the survivors were larger overall, with bigger beaks and legs. They were also more symmetrical—both sides of their bodies matched. Because of an extensive banding program, the Browns were able to determine that before the severe weather, the non-survivors were just as healthy as the survivors. The Browns hypothesized that the bigger birds were selected for survival because their larger size allowed them to store more fat and their greater symmetry allowed them to forage with less energy loss. The offspring of the survivors were also large and symmetrical.

CHECK AND REFLECT

Key Concept Review

1. What is variability?
2. In your own words, define natural selection.

Connect Your Understanding

3. Describe several examples of changes in the environment that might select some individuals in a species for survival over other individuals. Explain your answers.
4. Describe an example where variability within a species has helped a species survive an environmental change.

Extend Your Understanding

5. Suppose a population of sparrows migrating south for the winter is blown off course by a storm and the sparrows become isolated on an island. The only food source available on the island is a plant that produces large seeds. Predict which birds in the population, those with large beaks or those with small beaks, will survive to continue their migration or to populate the island. Explain your answer.

Assess Your Learning

Key Concept Review

1. Write a definition of biological diversity that includes a description of its three main components.
2. Define the terms niche and symbiosis. Explain how these terms are related.
3. How does variability within a species affect its survival?

Connect Your Understanding

4. Using examples, explain ways in which different species living within an ecosystem depend on one another.
5. How does natural selection enhance or reduce the variability of a species? Explain your answer using an example.
6. Restate the meaning of interspecies competition in your own words. Use an example to illustrate.
7. How does variation within a species contribute to the health of the species? Of an ecosystem?
8. Describe your niche.

Extend Your Understanding

9. To help you organize your learning about biological diversity, construct a mind map as a frame in which to record your notes. Compare your work with a partner to be sure you have captured all the main ideas and important details in this section.
10. Rewrite the information in this section, simplifying it so that it could be easily understood by a grade 4 student. Be sure to explain how diversity among species and within species contributes to species survival.

Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Activities designed to meet human needs and encourage technological development can have intended and unintended effects on other species and the environment.

1. Explain how you think biological diversity benefits humans and other forms of life on Earth.
2. Almost half of all animal life forms on the planet are insects. How important is it to preserve those species? Should we be concerned about ensuring that something as small as the fruit fly is not eliminated? Why or why not? Would we be better off without insects? Support your answer.

2.0 As species reproduce, characteristics are passed from parents to offspring.

Key Concepts

In this section, you will learn about the following key concepts:

- asexual and sexual reproduction
- inheritance

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between asexual and sexual reproduction and describe examples of each type of reproduction
- describe types of variations found within a species and determine whether they are discrete or continuous
- distinguish between heritable and non-heritable characteristics

When you walk around a greenhouse, you might notice the number of possible shapes and sizes of plants. You might also notice that particular species have particular characteristics. For example, a Boston fern has large green leaves and no real stem. The coleus plant, however, has leaves of many different colours growing out of a central stem. What process ensures that these characteristics in a species are passed down from generation to generation? The answer is reproduction.

If you look at two coleus plants, you would see that although they have many similarities in their characteristics, each plant can also have its own unique versions of certain characteristics. For example, all coleus plants have velvety leaves, but one plant's leaf colour may be dark purple, while another's is red and yellow. In this section, you will discover how these variations in characteristics occur.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 A Closer Look at Variation

In subsection 1.0, you explored how variation contributes to species survival. In the example of the coleus plant, you can see that certain characteristics, such as leaf colour, can vary among plants of the same species. Not all variations are as evident as leaf colour. For example, Jack pines exhibit variation because some trees of this species resist drought better than other Jack pines. Magpies show variation because some members of this species can fly longer distances. Different cells of the same bacteria may vary, making some more resistant to antibiotics.

Figure 2.1 Although these penguins look almost identical, they vary from one another in subtle ways.

To better understand variation, scientists may explore which characteristics species pass along from generation to generation, and how these characteristics show up in individuals. Scientists may also examine other factors, such as the role of the environment in variation.

*info***BIT**

Ancient Breeding Activities

Although the people living near the Persian Gulf during ancient times did not know about modern-day genetics, they did understand that characteristics were passed from parents to offspring. Archeologists discovered a 6000-year-old engraved stone tablet that was used to record the characteristics of five generations of horses. As well, they found evidence that these people followed the same rules that plant and animal breeders of today use to "shape" the characteristics of offspring.

GIVE IT A **TRY**

Observing Variation in Human Characteristics

Humans have many characteristics that can vary. Some of us are tall, others are short; some have curly hair, some have straight hair. Some people can bend their thumbs back toward their wrists. And some have earlobes that hang loose, but others have earlobes attached to their heads. Even hairlines can vary.

Take a quick survey of your class to find out how many people:

- can or cannot bend their thumb joint "backward" without adding pressure
- have earlobes that are attached or separate
- have a pointed or smooth hairline

Draw a data table to record your results. Create a graph that will best illustrate your results.

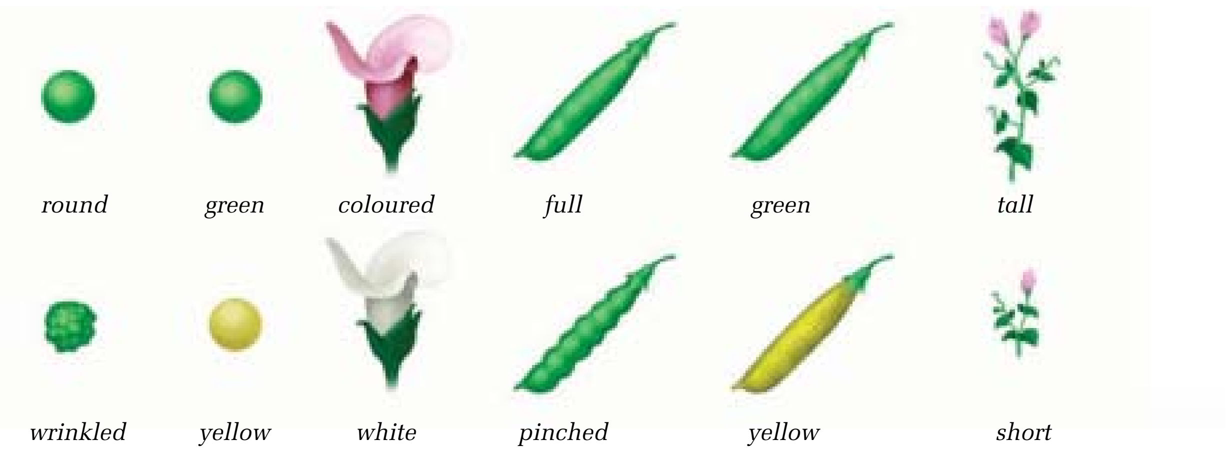


Figure 2.2 Some of the characteristics in pea plants that scientists have studied include seed shape, seed colour, flower colour, pod shape, pod colour, and plant height.

Heritable and Non-Heritable Characteristics

Heritable characteristics are passed on from generation to generation. Some examples of inherited characteristics are eye colour, hair type, and skin colour. **Non-heritable characteristics** are acquired. That is, they are not passed on to other generations. A person who has learned to play the piano, for example, will not have children who are born knowing how to play. The ability to play an instrument is an acquired characteristic. Similarly, if someone dyes his or her hair a different colour, his or her children will not inherit the dyed colour.

Figure 2.3 This kangaroo is an albino. Pigmentation is a discrete variation: albino or pigmented.

Discrete and Continuous Variation

Variations can be either discrete or continuous. **Discrete variation** refers to differences in characteristics that have a defined form. You can think of discrete variation as being the "either/or" form of a characteristic. For example, a cat either has blue eyes or does not have blue eyes. A mouse is either an albino or it is not an albino. Your earlobes are either attached or they are not. **Continuous variation** refers to differences in characteristics that have a range of forms. They are not one form or another. For example, the height of adult humans can range from 1.2 m to 2.1 m. In squirrels, mass can range anywhere between 133 g and 249 g.

Variation and the Environment

Some variations in individual organisms result from interactions with the environment. Imagine, for example, you have two plants that are completely identical. If you put one plant in a sunny window and the other in a dim closet, they would soon begin to look very different. The one in the sunlight would be green and bushy, but the plant in low light would be a pale green and spindly.

Height is a heritable characteristic. But height can be affected by diet. In general, North Americans are taller than they were in the 19th century because of better nutrition and access to a wide variety of food. There have always been shorter people and taller people, but North Americans living in the 19th century would likely have been somewhat shorter than North Americans living today.

Variations caused by interactions with the environment are not heritable. You would not expect all the offspring of a plant grown in dim light to look like its parents unless they too were grown in low-light conditions. Similarly, if a child of tall parents doesn't receive proper nutrition, he or she probably will not be as tall as his or her parents.

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Environment's Role

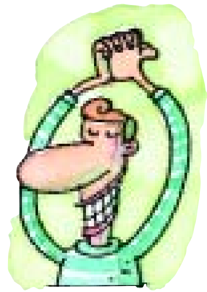
Investigate how plants, such as hydrangea and the water buttercup, exhibit variation depending on the environment they live in. Use books or electronic resources for your research. Prepare a chart to display your findings.

GIVE IT A TRY

Is It Discrete or Continuous?

On a signal from your teacher, and with your eyes closed, quickly clasp your hands together above your head, interlocking your fingers. Now look to see which thumb is on top: left or right? Try clasping your hands with the other thumb on top. Note which way feels more natural. Report your personal hand-clasping preference.

- On a chart, record the observations of the class for *Left Thumb on Top* versus *Right Thumb on Top*.
- From the class data, try to determine if there is a hand-clasping preference. Decide whether it seems to be discrete or continuous. Explain your answer.



Check and Reflect

Key Concept Review

1. Give one example of a heritable characteristic and one example of a non-heritable characteristic. Use examples different from those in the text.
2. What is discrete variation? What is continuous variation?

Connect Your Understanding

3. Some characteristics are heritable but can also be affected by the environment. Explain how this is true for height in humans.
4. Describe how the environment may affect variation in plants.
5. A scientist wants to study continuous variation in a mouse population. What mouse characteristics would she or he investigate?

Extend Your Understanding

6. Observe your thumb and the thumbs of your classmates. You will see that there are two types: a straight thumb and a bent-backward (or hitchhiker's) thumb. What type of variation does thumb shape show?

*info***BIT**

Parthenogenesis
In some species of animals, particularly social insects, such as ants and bees, and in rotifers (microscopic invertebrates), a unique method of asexual reproduction has been observed. Parthenogenesis, meaning "virgin birth" in Greek, is the term used to describe the process that transforms unfertilized eggs into mature organisms. In bees, unfertilized eggs become male drones, while the fertilized eggs become female workers and queens. The process has also been observed in more complex animals, such as snakes, and more rarely in plants, such as figs, where it is called parthenocarpy.

Figure 2.4 Yeast cell budding

2.2 Asexual and Sexual Reproduction

Reproduction produces new individuals of a species. The way a species reproduces determines how much variation the new individuals will have.

Reproduction can produce new individuals that are identical to or very different from one another.

Asexual Reproduction

Asexual reproduction involves only one parent. All the offspring that result from asexual reproduction are identical to that parent. In other words, they all inherit identical characteristics because the adult makes an exact copy of itself. There are several different forms of asexual reproduction, such as binary fission, budding, spore production, and vegetative reproduction.

Binary Fission

Only one-celled organisms, such as bacteria, and some protists, such as amoebas and some algae, reproduce by binary fission. During **binary fission**, a cell splits exactly in two, producing two identical individuals.

Budding

Organisms such as hydra and yeast reproduce asexually by **budding**. During budding, the parent produces a small bud, or a smaller version of itself. In animals, such as hydra, the bud eventually detaches and becomes a new individual identical to its parent. This is also true of yeast, which is a unicellular fungus. In other animals, such as coral, the offspring remains attached to the parent, forming a large structure composed of many identical individuals.

Spore Production

Many fungi, green algae, some moulds, and non-flowering plants such as ferns reproduce by producing spores. **Spores** are similar to seeds, but are produced by the division of cells of the parent, not by the union of two cells. One individual will produce many spores, and each spore can develop into a new individual identical to the parent.

Figure 2.5 Spores can survive unsuitable growing conditions because they remain dormant. When conditions improve, spores can produce new plants.

Vegetative Reproduction

Most plants are able to reproduce by vegetative reproduction, another form of asexual reproduction. **Vegetative reproduction** is the reproduction of a plant that does not involve the formation of a seed. If you take a cutting from a coleus plant and place it in water, the cutting will grow roots and eventually develop into a whole new plant. This is one form of vegetative reproduction. Many plants, such as strawberries or spider plants, grow runners that produce new plants along them. Tubers, such as potatoes on a potato plant, and bulbs, from which daffodils and tulips develop, are also forms of vegetative reproduction. The roots of aspen trees produce a form of shoot called a sucker. If the sucker becomes physically separated from the original tree, it will grow into a new aspen tree (Figure 2.6). In all these cases, the new individual plants that are produced will be genetically identical to their parent plant and to one another.

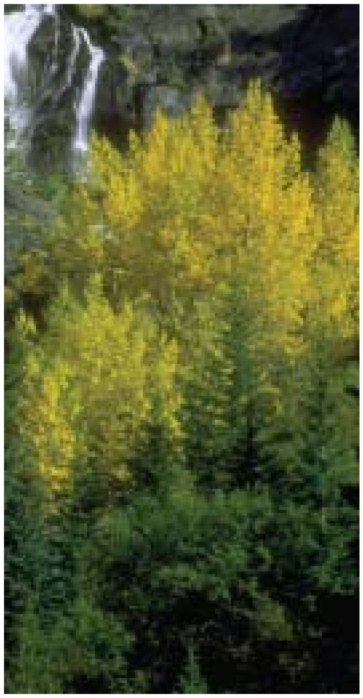


Figure 2.6 The individual trees in a stand of aspens are often identical to one another, as a result of vegetative reproduction.

Figure 2.7 Offspring of this plant form at the edges of the leaf.

SKILL PRACTICE

REPRESENTING ASEXUAL REPRODUCTION

TOOLBOX

To help them better understand the processes of asexual reproduction, scientists use diagrams to record their observations. By comparing such illustrations, they can identify differences and similarities among asexually reproducing organisms.

Review the different forms of asexual reproduction described on pages 30–31. Make notes on each type and make a labelled diagram to show how an organism reproduces by that form.

- Compare your diagrams. Describe any similarities among them.
- Describe any differences.
- Using print and electronic resources, find and illustrate an example of an asexually reproducing organism not described in this section.

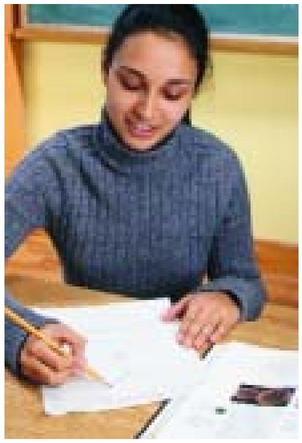


Figure 2.8 Diagrams help scientists compare organisms.

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Hermaphrodites

Common garden worms and slugs are hermaphrodites. Hermaphrodites can produce both male and female gametes. Although most slugs and worms usually prefer to mate with other individuals of their species, in times of environmental stress, they can fertilize themselves.

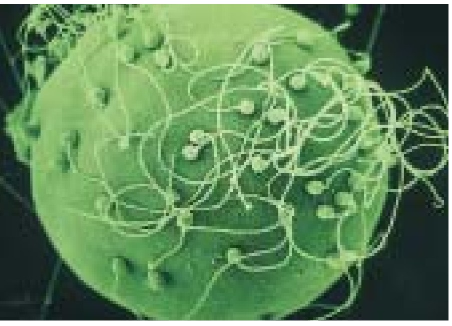

Figure 2.9 Only one of the many sperm cells surrounding the egg will fertilize the egg.

Sexual Reproduction

Sexual reproduction usually involves two individuals. Most species of animals and flowering plants reproduce sexually. The offspring of sexual reproduction will have a mix of the characteristics of both individuals, ensuring that there is always a mix of characteristics in each generation.

You might think that sexual reproduction always involves a male and a female, as it does in humans and other mammals. However, sexual reproduction also occurs in species that we may not think of as having males and females, such as flowering plants and coral. These species have specialized forms of sexual reproduction.

Sexual reproduction in plants or animals relies on the union of two specialized cells known as **gametes**. A gamete is a cell that has one role only, which is to join with another gamete during reproduction.

Sexual Reproduction in Animals

Almost all animal species, from fungi to protists, from salmon to dragonflies to bears, reproduce sexually. Although the details may vary, the important events in animal reproduction are the same. Sexual reproduction involves specialized cells known as gametes (sex cells). The male gametes are called **sperm cells**, and the female gametes are known as **egg cells (ova)**. The union of the sperm cell with the egg cell occurs during mating and is called **fertilization** (Figure 2.10). The cell created by the joining of the two gametes is known as a **zygote**. The zygote is the first cell of a new individual. The zygote then divides into two cells. The same divisions are repeated during a process called **cleavage**. Continued cell division results in a new multicellular life form referred to as an **embryo**.

Depending on the species, the development of the embryo may occur inside the female parent, which happens in most mammals, or outside, in an egg, which happens in most other types of animals. The new individual will show some of the characteristics of its female parent and some of its male parent. Although the new individual may resemble one parent more than the other, it will not be identical to either parent.

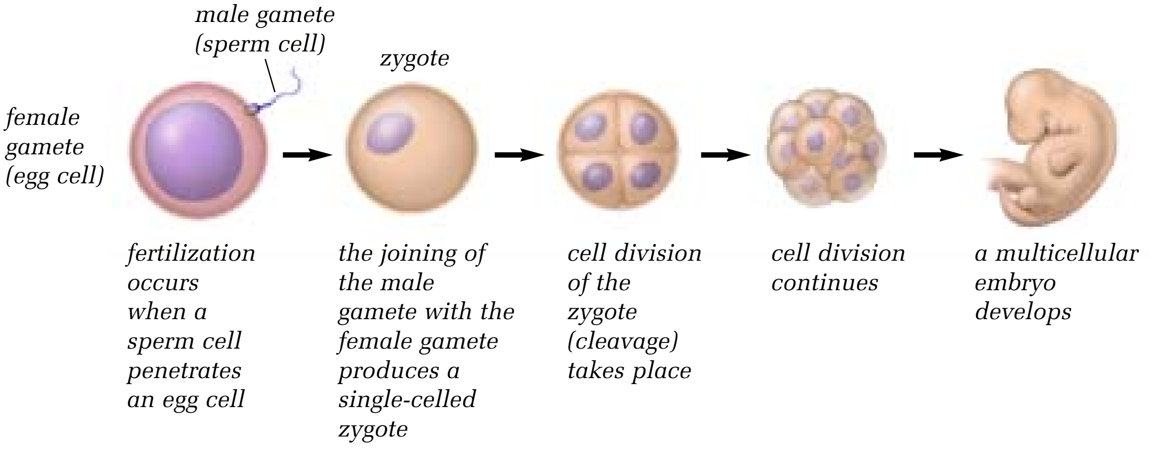

Figure 2.10 Sexual reproduction in animals involves specialized cells called gametes.

Sexual Reproduction in Plants

As in animals, sexual reproduction in plants requires the joining of a male gamete with a female gamete to produce a zygote and an embryo. Most plants produce both male and female gametes. However, some produce only female gametes and others only male.

Figure 2.11 shows the parts of a flower that are involved in reproduction. Most flowers have all of these parts, although the shapes and sizes of each flower vary. Some flowers are large and showy. Others are hardly noticeable (Figure 2.12). **Pollen** contains the male gametes of a plant. Pollen is found on the **stamen**, or male part, of the plant. **Ovules** contain the female gametes of a plant. Ovules are found in the **pistil**, or female part of the plant.

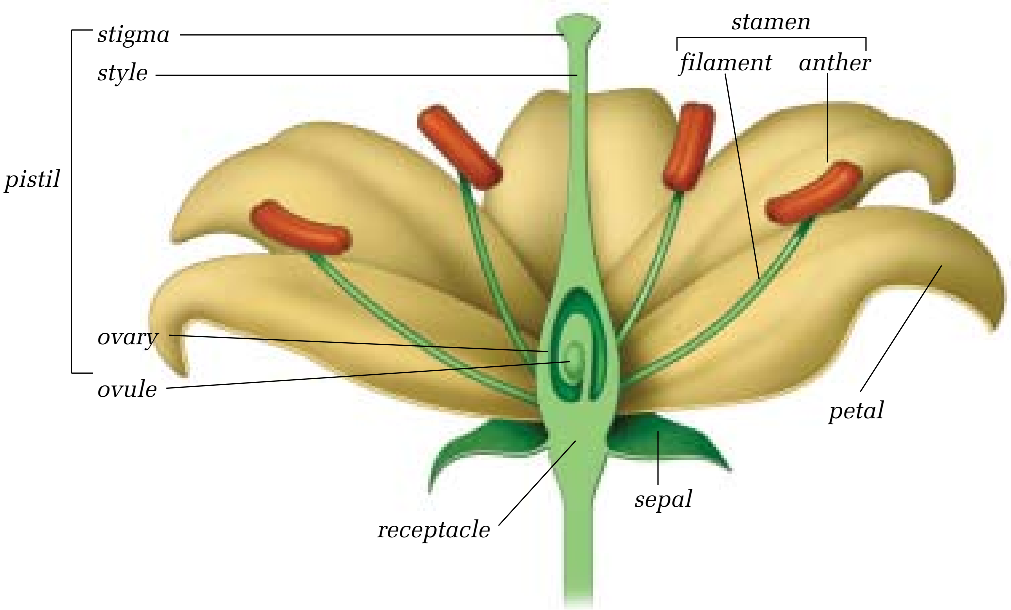

Figure 2.11 Flower parts involved in reproduction

Pollination occurs when pollen is transferred from the **anther** of the stamen to the **stigma** of the pistil. Fertilization occurs when the male and female gametes unite. **Cross-pollination** occurs when the pollen of one plant is carried to the stigma of another by wind, water, or animals, such as bees or butterflies. **Cross-fertilization** occurs when a grain of this pollen produces a long tube that eventually grows down the **style** into the **ovary** that contains the ovules. (Pollen grains and ovules are sacs that contain sex cells.) A gamete in the pollen grain and a gamete in an ovule join and, as in animals, a zygote is formed. The zygote then begins a series of divisions to produce an embryo.

The embryo will eventually develop into a new individual. In most plants, the embryo is produced inside a seed. The seed protects the embryo and stores food for the embryo to use when it begins to grow into a new individual. Unlike animals, the new embryo may not begin to grow for some time, but stays dormant within the seed until it has suitable growing conditions. Plants that are produced from cross-fertilization will show some of the characteristics from the parent that donated female gametes and some from the parent that donated male gametes. It will not be identical to either parent.

Figure 2.12 Unlike roses and lilies, the flowers of prairie cord grass are very small and hardly noticeable. Grasses like this depend on wind for pollination.

ACTIVITY A-3

Inquiry

INVESTIGATING FLOWER REPRODUCTIVE STRUCTURES

The Question

What are the reproductive structures of a flower?

Materials & Equipment

- small scalpel with sharp blade
- magnifying glass
- lily
- piece of dark cloth
- microscope
- slide
- coverslip
- water
- eyedropper
- probe
- labelled diagram of parts of a flower (in text)
- 5 recipe cards
- white glue
- poster board

Caution!
Use care when handling the scalpel and the probe.

Procedure

TOOLBOX

1. On a piece of blank paper, sketch a cross section of the flower as it appears now, before you dissect it. Label the parts.
2. Shake the lily gently over the piece of dark cloth. If pollen does not fall onto the cloth, carefully rub the anthers over the material. Using the probe, gently separate out grains of pollen.
3. Prepare a slide to examine the pollen under the microscope. (Review Toolbox 11 on microscopes.) What do you see at each level of magnification? Record your observations on a recipe card labelled *pollen*.
4. Peel back the petals of the flower. Label a card *petals* and use a small amount of glue to affix the petals to the card.
5. Gently pull away the stamens from the base of the pistil. Label a card with the word *stamen* at the top and then draw two lines leading away from the word. At the base of one line, write the word *anther* and at the base of the second line, write the word *filament*. Carefully separate the two parts of the stamen and glue them under the correct headings.
6. Dissect the pistil, cutting lengthwise from the stigma through the style, then through the ovary at the bottom. Label a card *pistil* and glue one-half of the cross section to it. Label the section of the pistil.
7. Using a magnifying glass and probe, examine the ovule inside the ovary. Record your observations on a card labelled *ovary*.

Analyzing and Interpreting

8. Review the recipe cards that you have assembled as you dissected the flower. How do you think these separate pieces work together to reproduce a new plant?
9. Go back to your sketch of the parts of the flower before you dissected it. In pencil, show the process of reproduction as you think it occurs.
10. What characteristics do a pollen grain and an ovule have that help them carry out their roles in sexual reproduction?
11. Review your work with a partner or other group, and then share ideas with the whole class. Revise your sketch as necessary.
12. Arrange your recipe cards and sketch on a piece of poster board to create a display of your work.

Forming Conclusions

13. In a paragraph, summarize the roles each of the plant parts play in sexual reproduction and how these parts have characteristics that help them perform their roles.

Figure 2.13 Examining flower structures

Advantages and Disadvantages of Asexual and Sexual Reproduction

Variation helps a species survive by giving it the ability to survive changes in its environment. You have seen that the way an organism reproduces affects how much variation will occur in its offspring. Asexual reproduction produces no variation in heritable characteristics. Could it ever help a species not to have variation?

Advantages and Disadvantages of Asexual Reproduction

Asexual reproduction does not require any specialized cells or a way of bringing gametes together. As a result, asexual reproduction can produce lots of individuals very quickly. For example, if conditions are right, a bacterium can reproduce asexually every 20 min. Over a 12-h period, a single bacterium can divide to produce 10 million copies of itself. This is a great advantage in environments that do not change very much. For example, bacteria that live in the gut of an animal will always have a warm, moist environment to live in while the animal is alive. Producing many copies of a bacterial cell that is suited to that environment is a safer bet for survival than producing a smaller number of bacteria with many variations that may never be needed. Species that reproduce asexually invest energy to produce as many identical copies of themselves as possible to build a large population quickly.

The main disadvantage of asexual reproduction is that if conditions become unfavourable, the entire population may be wiped out. For example, every single one of those 10 million identical bacteria could be killed if they have no resistance to an antibiotic that is applied to them.

Advantages and Disadvantages of Sexual Reproduction

Sexual reproduction has the advantage of providing lots of variation, which helps species survive environmental change. The main disadvantage of sexual reproduction is that it takes a lot of energy. A flowering plant, for example, has to produce all the parts of its flower, as well as pollen grains and ovules in order to reproduce. The flower parts must provide a way for the gametes to meet, such as producing lots of pollen to be blown by the wind or by attracting pollinators. The flower must also protect and nurture the embryo in a seed until the seed is dispersed. Therefore, an organism that reproduces sexually puts a lot of energy and time into producing variable offspring. Because of this great demand, sexually reproducing organisms can only produce a limited number of offspring.

Organisms that Reproduce both Sexually and Asexually

Some species have the ability to reproduce both sexually and asexually by various means. Most plants that produce seeds by sexual reproduction can also reproduce asexually, either from cuttings or by producing structures such as bulbs or runners.

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Alternating Asexual and Sexual Reproduction

Some simple life forms, such as the jellyfish, will alternate between sexual and asexual reproduction. That is, one generation will be produced sexually and the next, asexually. Mosses also follow this pattern. Research other examples of life forms that fall into this category. Write a paragraph about the advantage to a species of alternating different forms of reproduction? Begin your research at www.pearsoned.ca/scienceinaction.

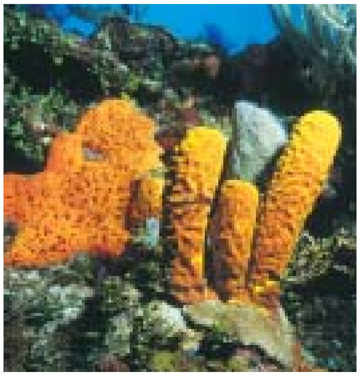

Figure 2.14 To reproduce sexually, sponges release sperm cells into the water, which are captured by special cells and carried to egg cells.

Some plants can use their seeds to reproduce both asexually and sexually. In the asexual method, embryos develop in the seeds without the contribution of sperm cells. These seeds will grow into plants that are genetically identical to the parent plant. Some species of grasses, sunflowers, and roses can do this.

Some animal species can also reproduce both ways. Aphids are small insects that feed on the sap of certain plants. Throughout the growing season, females produce live female young without fertilization, or asexually. These all-female young mature and also reproduce asexually. Over the summer, several generations are produced. In the fall, when days shorten and the temperature drops, the females produce a generation that includes both males and females. These males and females reproduce sexually and lay eggs that will hatch in the spring to produce new colonies. Sponges can also reproduce both sexually and asexually (Figure 2.14).

Check and Reflect

Key Concept Review

1. What is a zygote and how is it formed?

2. Define asexual reproduction. List three examples of asexual reproduction.

3. Make a table to compare the male and female gametes in plants. Indicate where they are found.

4. List three ways in which pollination can occur. Give an example of each.

Connect Your Understanding

5. What is similar about sperm cells and egg cells? What is different?

6. List the steps of fertilization and embryo development in animal sexual reproduction. Be sure to include the words "gametes" and "zygote" in your description.

7. Explain what happens to male and female gametes during sexual reproduction in plants and animals.

8. Using a Venn diagram, compare and contrast sexual and asexual reproduction.

Extend Your Understanding

9. *An individual produced by asexual reproduction may be identical to one of its parents.* Do you agree or disagree with this statement? Support your answer.

10. Use a simple sketch to illustrate the process of fertilization in plants.

11. A flower produces a seed. Explain why this is an example of sexual reproduction.

Assess Your Learning

Key Concept Review

1. Give three examples of a heritable characteristic.
2. Make a table to compare the advantages and disadvantages of sexual and asexual reproduction.
3. An amoeba reproduces by binary fission. Briefly describe the process of binary fission. Explain whether it is an example of sexual or asexual reproduction.

Connect Your Understanding

4. A person with hitchhiker's thumb plays guitar with a local rock band. Explain how she displays both heritable and non-heritable characteristics.
5. Compare the process of fertilization in plants and animals.
6. Using a diagram, explain how a zygote forms in a flowering plant.
7. Compare discrete and continuous variation using a Venn diagram.
8. Describe the steps of vegetative reproduction that occur when a plant is grown from a cutting. Why is this process considered to be an example of asexual reproduction?

Extend Your Understanding

9. Imagine a population of Martians. In this population, there are only three types of eye colour: black, bright purple, and orange. However, there are many different leg and arm lengths in the population. How would you describe the variation for eye colour as opposed to the variation for arm and leg length in the Martian population?
10. Imagine an organism that lives where there are often big changes in environmental conditions. What type of reproduction would be more advantageous for this organism? Explain your answer.

Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Our knowledge about how organisms reproduce and how variation within species is maintained has been enhanced by increasingly sophisticated technology. Think about what you have learned in this section about variation and answer these questions.

1. If you were researching plants to grow in colder climates, why would an understanding of the variations within a plant species be important?
2. Why is it important to understand the advantages and disadvantages of both sexual and asexual reproduction?
3. Based on what you have learned in this section, what are three questions you have that are related to the information presented?

3.0 DNA is the inherited material responsible for variation.

Key Concepts

In this section, you will learn about the following key concepts:

- chromosomes, genes, and DNA
- cell division
- inheritance

Learning Outcomes

When you have completed this section, you will be able to:

- describe the relationship among chromosomes, genes, and DNA, and their role in storing genetic information
- distinguish between cell division during asexual reproduction and cell division during sexual reproduction
- investigate the transmission of characteristics from parents to offspring, and identify examples of different patterns of inheritance
- identify examples of dominant and recessive characteristics

One of the most endangered species on Earth is the Bengal tiger. These tigers, once plentiful on the subcontinent of India, have dwindled from 40 000 in 1900 to 4500–6000 today. Most scientists speculate that the Bengal tiger will disappear unless humans act to prevent its extinction. One important way to save the Bengal tiger (and other species threatened with extinction) is to develop captive breeding programs.

Like all sexually reproducing species, the Bengal tiger has the best chance of long-term survival if there is a lot of variation within the species. Without variation, the species would be unable to survive changes in the environment, and would be more vulnerable to extinction. But with so few Bengal tigers left, how can that variation be maintained?

One tiger looks very like another to our eyes, but there are ways of finding subtle differences between individuals. Using modern technology, geneticists and zoo staff can analyze the tigers' genetic material to determine how similar two tigers are. To do this, scientists and breeders must have a thorough knowledge of the structure of genetic material and how it functions. They also have to be familiar with patterns of inheritance. This knowledge helps them analyze the tigers' genetic material, decide if the two tigers are different enough from each other to breed, and predict the characteristics the cubs are likely to have.

For Web links relating to 3.0, visit www.pearsoned.ca/scienceinaction

3.1 DNA—Transmitter of Genetic Code

In section 2.0, you learned that the offspring of a sexually reproducing species are not genetically identical to their parents. If they were identical, there would be little variation among the members of a species. However, these offspring do resemble their parents because particular characteristics are passed on from generation to generation. People have taken advantage of this transmission of genetic information between parents and offspring to produce many breeds of domestic plants and animals. However, unlike breeding programs to help save the Bengal tiger, the breeding of purebred dogs was not intended to promote variation. But many different breeds of dogs were developed that had specific, desired characteristics. This has made *Canis familiaris* one of the most physically varied species on Earth (Figure 3.1).

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Gene Map Complete

In February 2001, two groups of scientists simultaneously announced they had completed a first draft of a map of all the genes in a human. They estimated that humans have about 30 000 genes. Previously, scientists had thought we had about 100 000 genes.

GIVE IT A TRY

SUPERDOGS

Humans and dogs have had a close relationship since the end of the Ice Age, roughly 12 000 years ago. Descended from wolves, many of the approximately 400 modern breeds of dog we see today still share many physical characteristics with wolves. Some scientists think that canids (early dogs) adapted to human settlement. Others think that humans chose canids whose aggressive behaviours had been selected out. One of the extraordinary abilities of dogs is their capacity to learn and be trained.

As a class brainstorm a list of superdogs, such as TV show dogs or dogs that perform special tasks, such as police dogs.

- Determine the breed of each superdog.
- Choose one dog and, in pairs, brainstorm a list of characteristics your dog displays that help it do its job. Infer which characteristics are typical of the breed.
- If you have time, research the characteristics your dog's breed typically has. Begin your search at www.pearsoned.ca/scienceinaction.
- Prepare a chart to compare and contrast the characteristics of your superdog with those of a typical dog of the breed. What similarities and differences do you find?

Figure 3.1 These animals are all the same species. Selecting parents, over many generations, for a particular characteristic, such as ear shape, eventually produced these very different breeds.

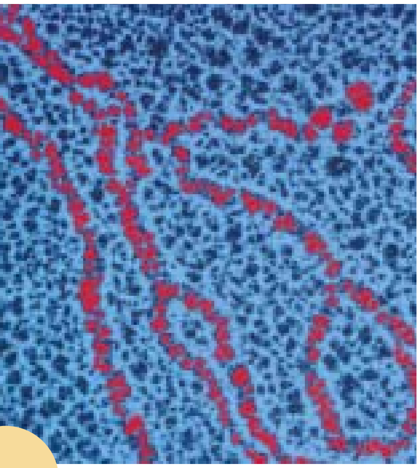

Figure 3.2 Micrograph of DNA

DNA

Why do the puppies of Chihuahua dogs turn out to be Chihuahuas? Why don't they turn out looking like Dalmations instead? The reason is that the Chihuahua parents pass on a "blueprint" to their offspring, so that each puppy receives a complete set of instructions for making a Chihuahua dog. Every multicellular organism on Earth contains a blueprint for making a copy of itself in each of its body cells.

Imagine how much information must be in these blueprints and how many different blueprints there are. For example, a parrot's blueprint must describe how to make all its different coloured feathers, its specially designed beak, and its remarkable voice. The blueprint for a spruce tree must have instructions for making the straight, slim needles, the sticky, perfumed resin, and the thick, tall trunk. What could store so much information, and pass it on from generation to generation? Canadian scientist Oswald Avery helped to answer this question when he proposed that a large molecule first found in cells' nuclei is responsible for storing such information and passing it on. This molecule, deoxyribonucleic acid, or **DNA** for short, is the inherited material responsible for variation.

All living organisms contain DNA in their cells. When the cells of the organism, such as the cells of mammals and plants, contain a nucleus, DNA is found in the nucleus. Figure 3.3 will remind you of where the nucleus of a cell can be found.

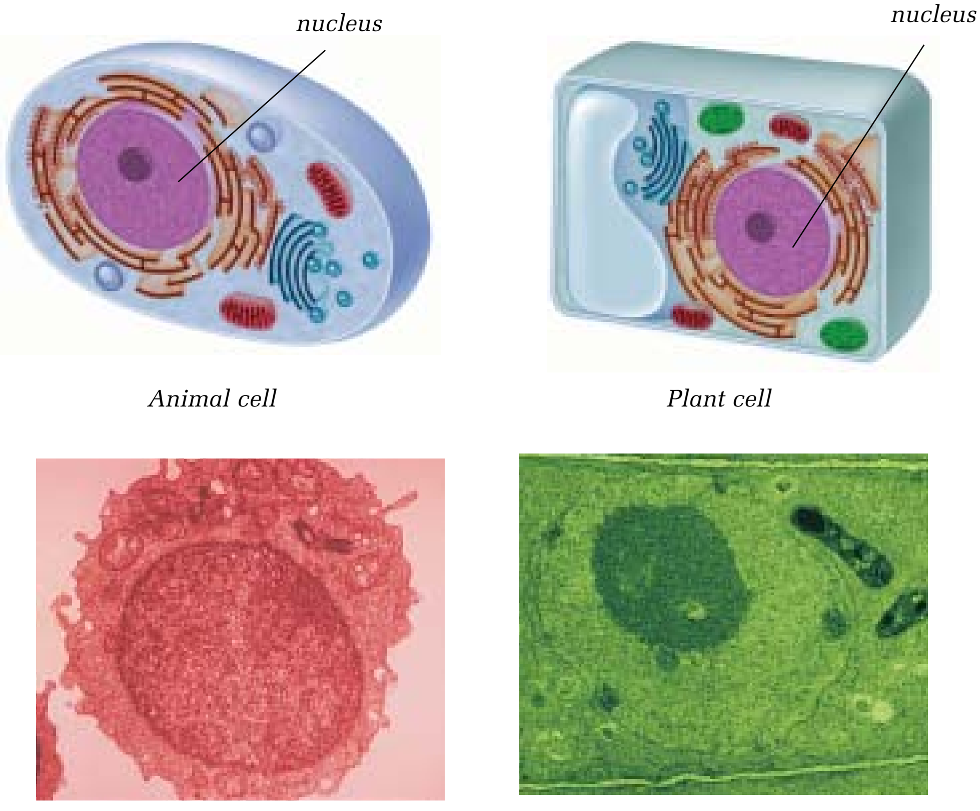

Figure 3.3 Study the location of the nucleus in the animal cell diagram and the plant cell diagram. Now locate the nucleus of each cell in the micrographs below the diagrams.

DNA and the Genetic Code

DNA was first identified in 1869, but little was known about the structure of the molecule or its role in heredity. After analyzing cells of many different organisms—ranging from bacteria to plants and animals—scientists found DNA in all of them. In 1944, Avery confirmed that DNA was the material of inheritance and this posed a new question. How could the blueprints for so many different organisms be passed on by what seemed to be exactly the same molecule? Solving this puzzle was one of the greatest scientific achievements of the last century, and involved two scientists whose names became known worldwide, James Watson and Francis Crick. By unravelling the structure of DNA, Watson and Crick revealed how the same chemical building blocks could carry such a wide range of instructions needed for the diversity we observe in the living world.

The DNA molecule can be compared to a ladder that has been twisted into a continuous spiral (Figure 3.4). The uprights of the twisted molecular ladder are identical all along its length. However, the rungs *vary* in composition. Each individual rung pairs up just two of the following four chemicals: guanine (orange), cytosine (blue), adenine (green), and thiamine (violet), or G, C, A, and T, for short.

The arrangement of these four chemicals, G, C, A, and T, forms a code that cells can read. You know that the 26 letters in our alphabet can be rearranged to form the millions of words we can read. Similarly, the **genetic code** is based on arranging the four chemical "letters" into "words," or instructions, that describe how to make any particular organism. In other words, all the blueprints for all the species on Earth are written in the same language!

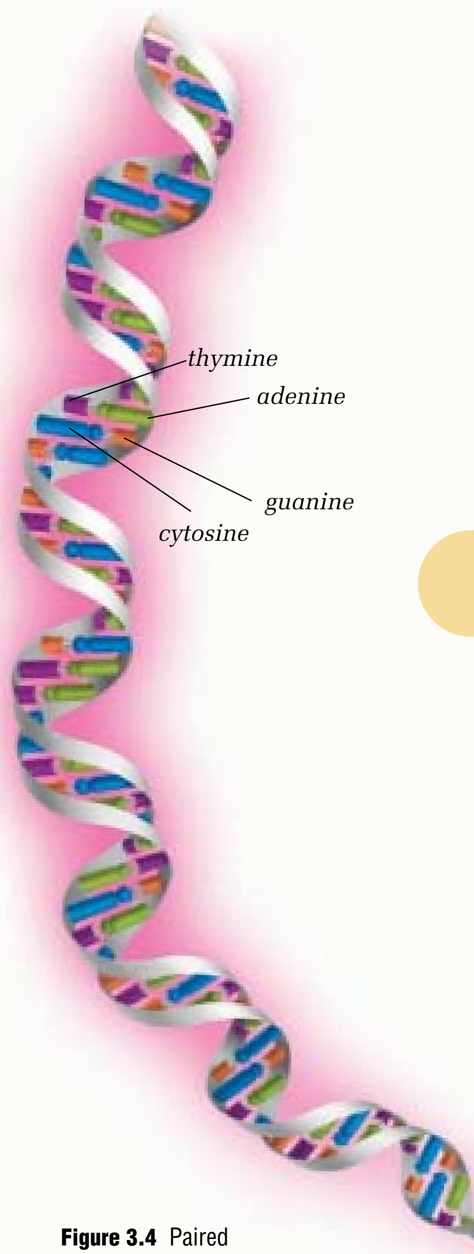

Figure 3.4 Paired chemicals make up the "rungs" of the DNA "ladder" and form the genetic code. The overall shape of the DNA molecule is helical, like the spiral binding on a notebook.

Chromosomes

DNA contains all the instructions for an organism's characteristic features. Because every organism has so many physical and chemical characteristics, there is a lot of DNA in a cell. If the DNA from a typical human body cell was stretched out, it would be about two metres long, more than 1 000 000 times longer than the cell it came from! To fit such a large amount of DNA into their cells, organisms arrange their DNA into packages. These packages are called **chromosomes**.

In organisms such as plants and animals, the chromosomes are located inside the cell nucleus. Each human cell nucleus, for example, contains 46 chromosomes. You could think of one chromosome as a single volume of an encyclopedia, and the set of chromosomes as the complete encyclopedia. If you were missing a single volume of an encyclopedia, you could be missing information you might need some time in the future. This is also true for our chromosomes. One chromosome contains only part of the instructions for making a human. All of our nuclei, except for those in the gametes, must have a complete set of chromosomes.

Activity A-4

Decision Making

Useful Genes?

The Issue

What are the questions and issues raised by new technologies for recombining genetic material?

Background Information

New genetic technologies and research like the Human Genome Project have allowed scientists to investigate the human genetic code better than ever before. The goal of the project was to identify all of the genes that comprise the human body. In the course of their research, scientists discovered that the human genome consists of about 30 000 genes. This was surprising as scientists expected to find 100 000 genes. Scientists now suggest that the role of human genes is much more complex than originally thought.

Having such detailed information on human DNA has advanced research on a variety of genetic technologies, such as cloning, and genetic disorders, such as cystic fibrosis, muscular dystrophy, and Huntington's disease. Such emerging technologies have led to a variety of questions and issues related to their development and application in both genetic research and treating genetic disorders.

Figure 3.5 Collecting samples for the Human Genome Project

Analyze and Evaluate

Select Part A or B and write a short report using the following questions as your guide. Use library resources and internet resources that have been approved by your teacher. Begin your search for information at www.pearsoned.ca/scienceinaction. Be sure to evaluate your sources in terms of how recent they are and how reliable the information seems.

Part A—New Genetic Technologies to Treat Genetic Disorders

1. Select one of the genetic disorders mentioned on this page or a disorder of your choice.
2. Research how the disorder is being treated today.
3. Describe how emerging genetic technologies may be used to treat this disorder in the future.
4. What potential questions or issues may arise from the use of this new treatment?

Part B—Emerging Recombinant Genetic Technologies

1. Select one of the genetic technologies from Section 4.2 on pages 67 and 68 or another genetic technology you have heard about.
2. Research and describe how this technology works.
3. Describe possible applications for this technology.
4. What potential questions or issues may arise from the use of this new technology?

For humans, a complete set has 46 chromosomes. For dogs, however, a complete set has 78 chromosomes, and for cats, the number is 38. In most familiar organisms, the chromosomes are organized into pairs. So the body cells of a human contain 23 pairs of chromosomes, while a dog's body cells contain 39 pairs, and a cat's body cells contain 19 pairs.

These examples show that chromosome number varies from one species to another. It is important to realize that the composition of the chromosomes varies as well. For example, the eyes of a typical dog have round pupils, while the eyes of a typical cat have slit-shaped pupils. So the dog's chromosomes must contain genetic code that reads "make round pupil." The cat's chromosomes must contain a different genetic code, one that reads "make slit-shaped pupil." Such differences are the source of diversity from one species to another.

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Canadian Contributions to Genetics

Research the work of Canadian scientists, such as Oswald Avery and Irene Ayako Uchida, and their contributions to our knowledge of inheritance and genetics. Develop a short script for a documentary that could be made about their achievements.

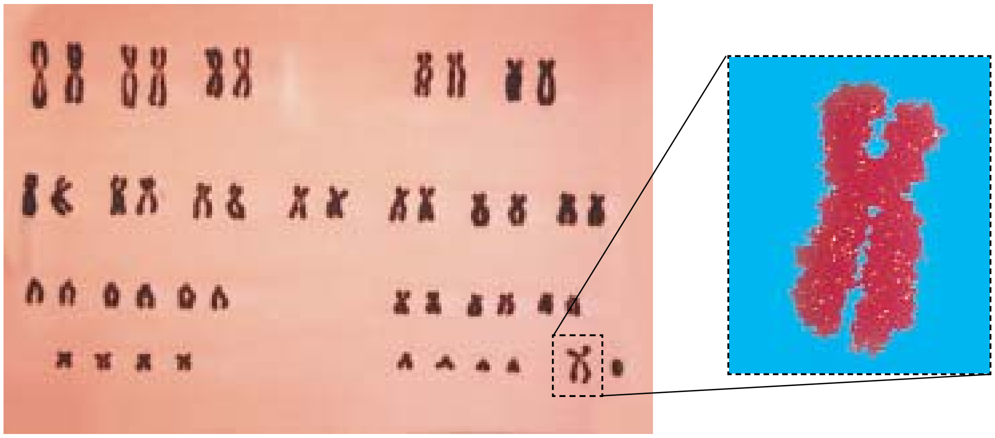

Figure 3.6 The 23 pairs of chromosomes of the human male. On the right, a close up of the X chromosome.

Genes

Current scientific thinking is that genes are responsible for the inheritance of an organism's characteristic features. A single **gene** is an uninterrupted segment of DNA, which contains coded instructions.

Much of the early research into genes was carried out on the fruit fly. Researchers found that:

- Genes are located on the chromosomes.
- Each chromosome contains numerous gene locations.
- Like chromosomes, genes come in pairs.
- Both genes in a pair carry DNA instructions for the same thing. Leg length in the fruit fly is an example.
- In the fruit fly, the two leg-length genes occupy matching locations on the two chromosomes.
- The DNA code may not be exactly the same in both locations.

Figure 3.7 David Vetter, the "bubble boy," lived for 12 years inside a plastic bubble. He had Severe Combined Immune Deficiency (SCID), a genetic disorder that made his body incapable of fighting disease. The gene for SCID is found on the X chromosome.

Activity A-5

Problem Solving

Showing the Relationships

Recognize a Need

A grade 8 class has just studied the structure of cells and the students are interested in learning more about genetic material and how it is organized. Their science teacher has asked you to explain to them the relationships among DNA, genes, and chromosomes.

The Problem

Design a way to visually summarize the relationships among DNA, genes, and chromosomes. Be creative. It could be a poster, Web page, model, skit, story, song, or any other method you choose to convey the information.

Criteria for Success

To be successful, your presentation must meet the following criteria:

- solve the problem described above
- show the relationships accurately
- be appealing and understandable for grade 8 students

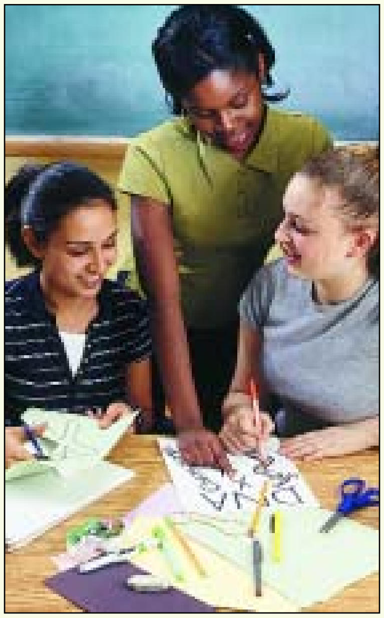

Figure 3.8 Planning a presentation to explain relationships among DNA, genes, and chromosomes

Brainstorm Ideas

1. Work with a partner or in a small group. Brainstorm ways to convey the information. All ideas should be considered.
2. Look for ways to blend the best of the group's suggestions.

Design Your Presentation

3. Plan out your presentation. Write out your plan in detail.
4. Create your presentation.

Test and Evaluate

5. How effectively does your presentation convey the information?
6. How does your work compare with that of your classmates?

Communicate

7. Share and compare your design with others in the class. Highlight the features that make your presentation both accurate and effective.
8. Is there anything you could do to improve your design?
9. As you were completing your presentation, did you have any questions about the relationships among DNA, genes, and chromosomes?
10. Assess your group's effectiveness at planning and creating your design. What did you do well? What could you improve?

Offspring inherit genes from both parents. For example, a fruit fly inherits one gene for leg length from its mother and one from its father. However, the leg-length gene exists in two possible forms: short leg or long leg. The wing-shape gene also exists in two possible forms: long or dumpy. So the two genes in a particular pair may not be identical.

Much of what scientists have learned about inheritance in fruit flies can be applied to most other organisms, including humans. In fact, most genes in most species exist in an array of possible forms that differ as to their exact DNA sequence. These possible forms are known as **alleles**.

To understand how chromosomes, genes, and alleles are linked to inherited characteristics, think about dogs. All dogs belong to the same species, and all ordinary, healthy dogs have a hairy coat. So we could begin by thinking of "hairy coat" as an example of an inherited characteristic.

But when we observe dogs, we see many different versions of "hairy coat." The hair may be straight or curly, short or long, coarse or fine, and the alternative versions of coat colour are almost too numerous to count.

Observing this variation, we can make three inferences. First, "hairy coat" is almost certainly more than just a single characteristic, it must involve a combination of several characteristics. Second, more than one gene pair may be involved in determining the individual details of a dog's hairy coat. For example, there could be one gene pair for hair length, a second gene pair for waviness, and another gene pair for texture. Third, there may be several possible alleles for each gene pair. For coat colour alone, there must be ten or more possible alleles, all in just one species!

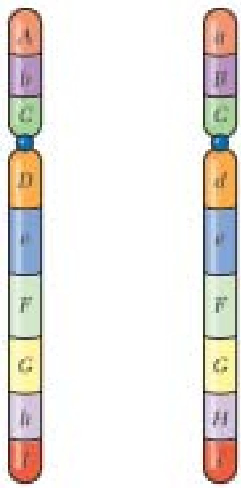

Figure 3.9 A chromosome pair. Each member carries the same genes. The different alleles are marked by uppercase and lowercase letters.

Check and Reflect

Key Concept Review

1. Define the term DNA in your own words and explain its function.

2. What four chemicals make up the genetic code? Describe how these chemicals are arranged in a DNA molecule.

3. What is a chromosome? Describe its function.

4. What is an allele? Describe its function.

5. Create a mini-dictionary of the key terms in this subsection. Use colours or illustrations as aids for remembering the terms and their meanings.

Connect Your Understanding

6. Explain why chromosomes are considered to be the "source of diversity."

7. Which of the following contain DNA? Explain your answer.

a) chromosome
b) nucleus of a cell
c) gene

8. Explain how a chromosome may be involved in the inheritance of a disease, such as Severe Combined Immune Deficiency.

Extend Your Understanding

9. Create a mind map illustrating the relationship among DNA, genes, and chromosomes. What is their role in storing genetic material?

10. If a chromosome is compared to a book, what would the words in the book be compared to? Explain your answer.

3.2 Cell Division

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A Hypothesis That Changed

Until the late 1600s, scientists hypothesized that a human child was the product of only one parent. They thought that sperm held a fully formed tiny fetus that grew in size for nine months until it was large enough to be born. Around 1685, Anton van Leeuwenhoek improved the microscope, which provided evidence that no longer supported this hypothesis.

You have learned that the outcome of asexual reproduction is the production of offspring genetically identical to the parent. You have also seen that the outcome of sexual reproduction is the production of offspring that are genetically different from their parents. Scientists have spent many centuries exploring the processes that result in these outcomes.

Cell Division and Asexual Reproduction

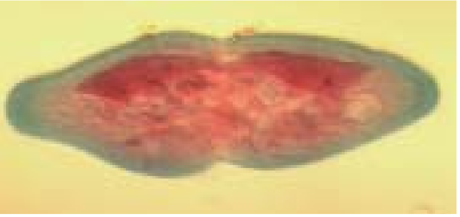

Figure 3.10 In asexual reproduction, the two new paramecium cells must get the same amount of DNA.

When a unicellular paramecium splits to form two new organisms during binary fission, its cell contents are divided equally between the two new cells (Figure 3.10). But if its DNA molecules were divided between the two organisms, each new individual would have only half the DNA of the parent cell, and half the genetic information it would need to function. To avoid this, the parent cell first makes an exact copy of its DNA, and each chromosome doubles. For a short time, the parent cell has twice the amount of DNA it usually has. When the cell eventually divides, each new cell gets one complete copy of the DNA.

In multicellular organisms, such as humans, petunias, and gophers, the process that produces two new cells with the same number of chromosomes is called **mitosis**. Mitosis occurs in the body cells of multicellular organisms and is responsible for the growth and cellular repair of a multicellular organism.

Cell Division and Sexual Reproduction in Plants and Animals

During sexual reproduction, the specialized sex cells (gametes) unite to form a zygote, which then develops into a new organism. One parent (the male) provides the male gamete and the other parent (the female) provides the female gamete. If the sex cells contained the same amount of DNA as every other cell, then the zygote would receive twice the amount of DNA it needs. **Meiosis** is a type of cell division that produces cells with only half the DNA of a normal cell. Because each gamete has only half the DNA of a normal cell, when the male and female gametes unite, the zygote has a complete set of DNA.

Meiosis involves two cell divisions, not just one. Recall that organisms that undergo sexual reproduction contain pairs of chromosomes. Each chromosome in the pair contains the same set of genes, but may contain different alleles (forms) of those genes. A gamete must contain only one copy of each different chromosome. To do this, cells must divide twice (Figure 3.11).

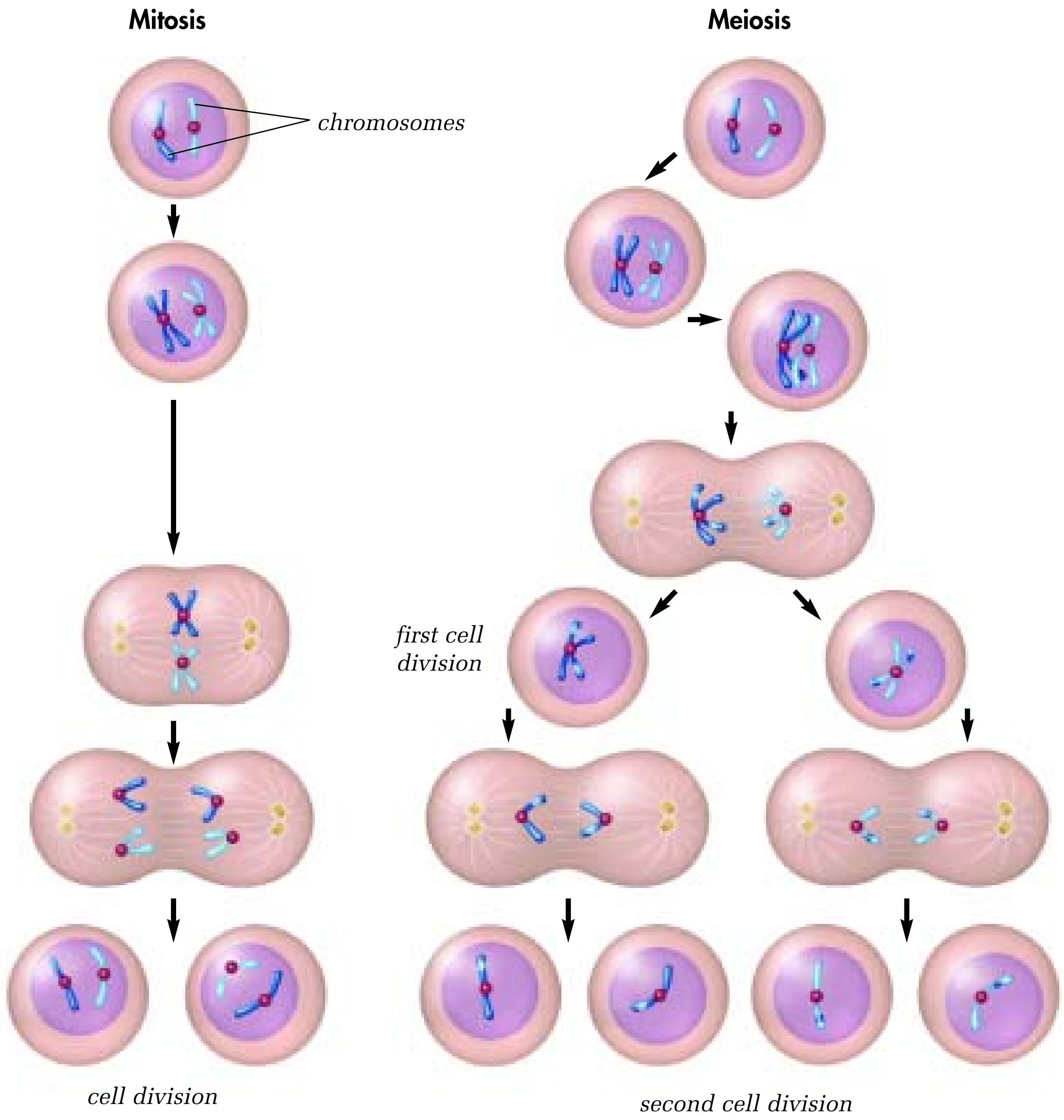

Figure 3.11 Comparison of mitosis and meiosis. Mitosis produces two offspring cells with the same number of chromosomes as the parent cell. Meiosis produces four sex cells that have *half* the number of chromosomes as the parent cell.

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Neverending Cells

When Henrietta Lacks' physician removed cells from her body in 1951 to test for cervical cancer, neither of them could have imagined that these cells would still be reproducing today. Since 1951, scientists all over the world have used HeLa cells in their explorations of cell structure and genetics. Usually, human body cells can divide only about 50 times in the laboratory before they die. So what made Henrietta's cells so special? Research the history of the HeLa cell and prepare a report. Begin your search at www. pearsoned.ca/scienceinaction. Include information about Henrietta and her family. Explore any issues that may have arisen from the use of her cells for research.

GIVE IT A TRY

Who Has What Number?

Organisms of the same species have the same number of chromosomes, but different species have different numbers of chromosomes. Copy this table into your notebook and complete the table to compare chromosome numbers in some common species.

Organism	Number of chromosomes in a cell at the end of mitosis	Number of chromosomes in a body cell	Number of chromosomes in a gamete	Number of chromosomes in a zygote	Number of pairs of chromosomes
cabbage	18				
black bear					38
human			23		
peanut	40				

Check and Reflect

Key Concept Review

1. Describe a type of cell division that occurs during the asexual reproduction of a unicellular organism.
2. What type of cell division is required for sexual reproduction? How does it differ from cell division during asexual reproduction?
3. Describe the type of cell division that occurs in the body cells of multicellular organisms.

Connect Your Understanding

4. Using diagrams, explain what happens to the DNA during cell division to produce sex cells (gametes).
5. When a cell divides during asexual reproduction, it divides its cell contents between the two resulting cells. Describe what happens to the DNA of the cell during this type of cell division. Explain how this process ensures that the same characteristics are passed from generation to generation.
6. Why does sexual reproduction produce offspring with characteristics that are different from their parents, whereas offspring produced through asexual reproduction are identical to their parents?

Extend Your Understanding

7. If the amount of DNA in a gamete of an organism is n, is the amount of DNA in the body cells of that organism equal to $\frac{1}{2}n$, n, or $2n$? Explain.
8. Which form of cell division—binary fission or meiosis—poses the lower risk for the transmission of genetic disorders? Support your answer.

Careers and Profiles

Dietician/Genetic Associate

Barb Marriage holds a unique and challenging position with the University of Alberta's Department of Medical Genetics. Barb combines her background in nutrition with her knowledge of human genetics to work with people who have inherited *metabolic disorders* or *inborn errors of metabolism*. Most of her 165 patients have conditions that deal with enzyme deficiencies, including: PKU, maple sugar urine disease, galactosemia, glycogen storage disease, Gaucher disease, and lysosomal storage diseases. These conditions require specialized diets that need to be monitored by someone like Barb. Her Bachelor of Science degree and Masters of Science degree in nutrition have led to her working on completing a Ph.D. in Medical Sciences.

Diagnosing and treating the conditions are only part of Barb's role. Genetic counselling, working with lab personnel, co-ordinating other health professionals and resources, and acting as an advocate for funding and government support are also part of her job.

Because 95% of Barb's patients are children, she works closely with their families to provide ongoing support. Her relationships with these people often continue for many years, and she gets a lot of satisfaction from her involvement with the families. Receiving cards and photographs from patients' families and being invited to take part in special family events are examples of the rewards that make her career gratifying. In cases where a child's disease is especially serious, personal contact is very important. It requires a special touch and sensitivity to the family's values and beliefs.

Barb's professional schedule is hectic. An average week includes 60 hours of work. She is also on call for emergencies 24 hours a day, 7 days a week. However, that still leaves some spare time for her to be a marathon runner. She also has an interest in sports medicine. In 2001, she accompanied a men's sports team to Japan, providing medical and nutritional assistance.

Figure 3.12 Being a dietician and a genetic associate has many challenges and rewards.

1. What special skills would a person need to be a successful dietician? Genetic associate?
2. Does being a dietician or a genetic associate seem like an appealing career? Why or why not?

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The Science of Genetics
Genetics is the study of how heritable characteristics are passed on from generation to generation. Genetics began with the careful work of an Austrian monk, Gregor Mendel (1822–1884). Starting with carefully chosen parents that had several observable characteristics, Mendel traced the patterns of inheritance in pea plants over several generations, and discovered some fundamental principles that led to modern genetics.

3.3 Patterns of Inheritance

Long before research scientists discovered chromosomes and genes, plant and animal breeders were conducting experiments in controlled breeding. To prevent unwanted outcomes, only animals with the most desirable characteristics, or **traits**, were allowed to reproduce. Early experiments in controlled breeding were not always successful. Mating champion males with champion females did not always produce champion dogs, horses, cattle, or cats. But by keeping written records of failures as well as successes, the breeders began to detect certain basic patterns of inheritance. Scientists now explain the patterns they discovered in terms of alleles. In this subsection, you will focus on the inheritance of coat colour in cats, and will consider only two coat colours: black and white.

Purebred versus Hybrid

A breeder who wishes to produce white cats should choose **purebred** parents: cats whose ancestors have produced only white offspring for several generations. The term "true-breeding" is applied to such a lineage. Preferably, the chosen parents will come from two different true-breeding lineages of white cats. Similarly, a breeder who wishes to produce black cats should choose purebred parents from lineages that breed true for black coat colour.

An individual produced by crossing two purebred parents that differ in a trait such as coat colour is known as a **hybrid**. Now, suppose a purebred black cat is crossbred with a white cat. What pattern of inheritance will be observed in the hybrid offspring?

Dominant Traits

Figure 3.13 shows the result of crossbreeding a purebred white female cat with a purebred black male cat. Notice that every kitten in the resulting litter has a black coat. Crossing a purebred black female with a purebred white male will produce the same result. No matter how many times the experiment is repeated, all of the offspring will have black coats: never white, never grey, only black. Black coat colour in cats is an example of a **dominant trait**.

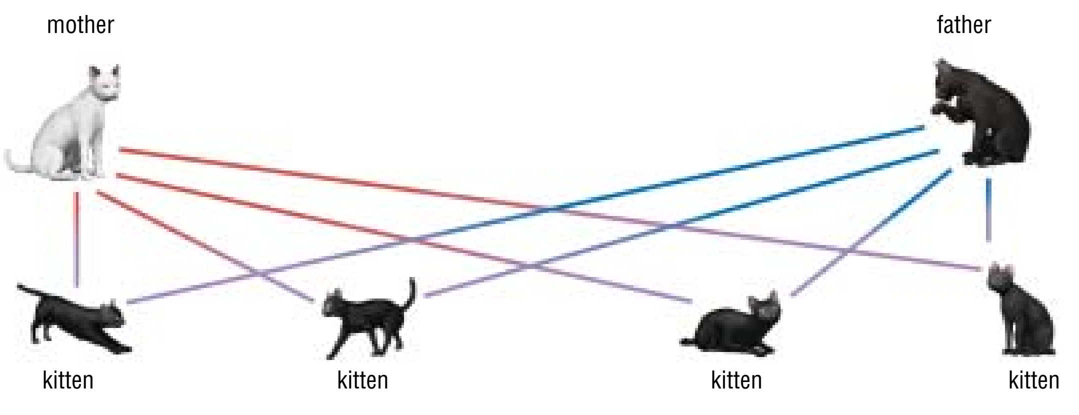

Figure 3.13 Cross between purebred white female cat and purebred black male cat. Black fur is the dominant trait.

By definition, the kittens are hybrids, but they *look* exactly like purebred black kittens. There is no outward sign that their mother had a white coat. Why is that? Recall that all offspring of sexual reproduction inherit genes from both parents. Both genes in a pair carry DNA instructions for the same thing; in this case the "thing" is coat colour. However, the specific DNA instructions carried by the alleles may not be identical.

We can see that the hybrid kittens have inherited an allele for black coat colour from their father. We can infer that the hybrid kittens must also have inherited an allele for white coat colour because no alternative alleles are present in the mother's lineage. However, the DNA code carried by the white-coat allele has somehow been ignored, or suppressed. Only the DNA instructions carried by the black-coat allele have actually been carried out. So, mating unlike purebred cats has revealed that DNA instructions carried by the black-coat allele are dominant over the DNA instructions carried by the white-coat allele.

Recessive Traits

Has the white-coat allele in the hybrid kittens been completely dominated by the black-coat allele? To find out, a second experiment can be conducted crossbreeding hybrid black offspring once they become adults. Figure 3.14 shows the average results of this experiment: three out of every four kittens will have black coats, while one will be white. If the experiment is repeated until there are 100 offspring, you might expect about 75 to be black and about 25 to be white.

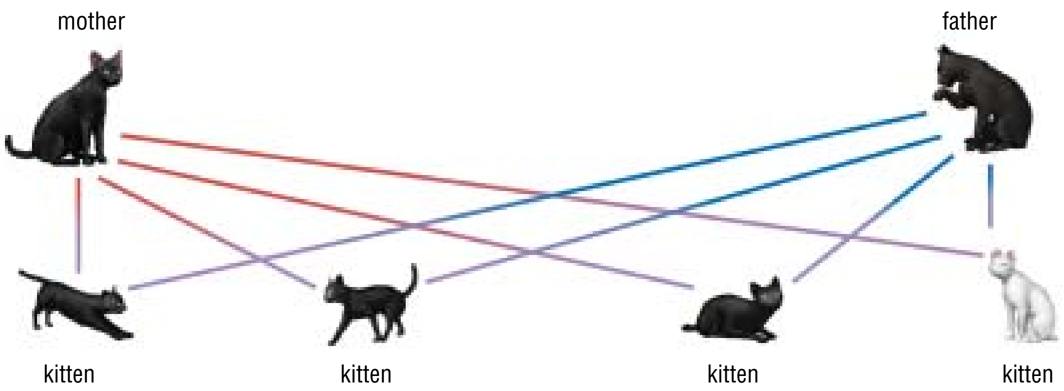

Figure 3.14 The kittens from Figure 3.13 are the parents in this cross.

In this new experiment, each hybrid parent possessed one black-coat allele, and one white-coat allele, though neither showed any sign of white fur. When the hybrid cats were crossed, each parent passed on one allele for coat colour to each kitten. (Remember, parents can only pass on half of their chromosomes, thus, half of their genes.)

A kitten from the experiment on page 51 might receive alleles in four possible combinations:

1. *One black-coat allele from its hybrid father and one black-coat allele from its hybrid mother.* The two sets of DNA instructions "agree" with each other, so the kitten will have black fur.
2. *One black-coat allele from its mother and one white-coat allele from its father.* The DNA instructions "contradict" each other, but we have seen that black fur is a dominant trait. The kitten will have black fur.
3. *One white-coat allele from its mother and one black-coat allele from its father.* Again, the DNA instructions "contradict" each other, but black fur is a dominant trait. The kitten will have black fur.
4. *One white-coat allele from its mother and one white-coat allele from its father.* This time, the DNA instructions "agree" with each other, so the kitten will have white fur.

White fur is thus an example of a **recessive trait**, and the allele for white fur is an example of a recessive allele. The allele for black fur is an example of a dominant allele. A recessive trait appears in the offspring only if two recessive alleles are inherited. In contrast, even one dominant allele will cause the dominant trait to appear.

GIVE IT A **TRY**

EXPLORING GENETIC POSSIBILITIES

In sexual reproduction, chromosomes are inherited in pairs: one from each parent. In an offspring, the combination of alleles carried on the chromosomes determines what the offspring is like.

In fruit flies, there are two possible alleles for leg length: long-leg and short-leg.

- Suppose a fruit fly inherits two long-leg alleles. Will this fruit fly develop long legs or short legs? Explain your reasoning.
- Suppose a second fruit fly inherits two copies of the short-leg allele. Will this fruit fly develop long legs or short legs? Explain your reasoning.
- Suppose a third fruit fly inherits one short-leg allele and one long-leg allele. Explain why you cannot be sure what leg length this offspring will develop.

In fruit flies, there are two possible alleles for eye colour: red-eye and purple-eye.

- List three possible ways to pair these alleles.
- For each pair, what eye colour you would expect an offspring to develop? Explain why you cannot be sure for all three cases.

In fruit flies, there are two possible alleles for wing shape: long-wing and dumpy-wing.

- List three possible ways that these alleles might be paired in an offspring.
- For each pair, what wing shape would you expect an offspring to develop? Explain why you cannot be sure for all three cases.

An individual fruit fly might have long legs, purple eyes, and long wings. What other combinations of leg length, eye colour, and wing shape are possible? Make sketches to illustrate your answer.

Other Patterns of Inheritance

Incomplete Dominance

The dominant-recessive pattern of inheritance does not always prevail. When a purebred snapdragon bearing red flowers is crossed with a purebred snapdragon bearing white flowers, the offspring are neither red nor white. Instead, the flowers are pink, a colour intermediate between red and white (Figure 3.15). This pattern of inheritance is known as **incomplete dominance**. Both the white-flower allele and the red-flower allele have played a part in determining the flower colour of the offspring plants. Neither the white trait nor the red trait is truly dominant, and neither is truly recessive.

Figure 3.15 Four o'clock flowers also show incomplete dominance. The pink-flowered plants in the middle had a parent with red flowers and a parent with white flowers.

Offspring Unlike Either Parent

You know that human babies inherit their DNA from their parents, and the offspring are never exactly like either parent. Suppose a father has black hair and brown eyes. The mother has brown hair and brown eyes. Their baby has red hair and blue eyes. Why does this happen?

Scientists once hypothesized that eye colour was determined by just one pair of alleles at a single gene location. So they thought that a baby's blue eyes were caused by two recessive alleles: one from each parent. Modern geneticists know it is not that simple. Two blue-eyed parents can produce a brown-eyed child. It is even possible for a person to have one blue eye and one brown eye. Thus, the inheritance of eye colour in humans is too complex to be explained solely by the dominant-recessive pattern or even by incomplete dominance.

Similarly, incomplete dominance cannot explain the baby's red hair. Its coppery colour is not what would be expected by "mixing" brown pigment and black pigment. For hair colour, eye colour, and skin colour, many gene locations and several possible alleles may be involved.

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More Patterns

Another pattern of inheritance is called "codominance." Compare it to incomplete dominance. Write a paragraph to explain how similar or how different the two patterns of inheritance are.

Environmental Factors

In section 2.0, you learned that environmental factors, such as poor nutrition, can prevent children from growing as strong or as tall as their genes would normally allow. While genes play a vital role in determining development, the action of the genes is greatly influenced by the environment in which an offspring develops. For example, the presence of alcohol in a pregnant woman's bloodstream can interfere with the normal development of brain structures and facial features, even though the baby's DNA is normal. This condition is known as fetal alcohol syndrome. In the late 1950s, the drug thalidomide was taken by pregnant women to lessen the effects of morning sickness. One of its many effects on the fetus was the abnormal development of limbs. Many "thalidomide babies," as they came to be known, were born with flipper-like arms or legs. As adults, however, several of these individuals had perfectly normal children, showing that their DNA was normal.

Check and Reflect

Key Concept Review

1. Explain how dominant and recessive traits differ from each other.
2. How does a purebred individual differ from a hybrid individual?
3. List examples of dominance, recessiveness, and incomplete dominance. Use a different example for each from those given in the text.

Connect Your Understanding

4. How could two black cats produce a kitten that has white fur? Use a diagram to explain your answer.
5. If you wanted to be certain that a trait would appear in the offspring of the plants or animals that you were breeding, what would you have to find out about the parents? Explain your answer.
6. Suppose a new flower in your garden displays an intermediate colour. For example, you begin to see orange flowers although you originally planted only red and yellow flowers. What pattern of inheritance would you be observing in this situation? Explain your answer.

Extend Your Understanding

7. Can dominance or recessiveness explain why two cats from the same litter may be different masses or have different leg lengths? Explain your answer.

SECTION REVIEW

Assess Your Learning

Key Concept Review

1. How does sexual reproduction contribute to genetic variation?
2. In your own words, define DNA, genes, and chromosomes. Explain how they work together to pass on characteristics from parents to offspring.
3. Compare and contrast dominant and recessive traits using a Venn diagram.
4. What is incomplete dominance? Give an example.
5. What is the key difference between mitosis and meiosis?

Connect Your Understanding

6. How is the genetic material of a parent inherited by offspring in asexual reproduction? In sexual reproduction?
7. Explain how the recessive trait for coat colour is hidden in cats when two parents that are purebred for different fur colour are crossed.
8. Why does meiosis produce cells with only half the amount of DNA? How does this aid in the formation of a healthy zygote?
9. Relate the four chemicals on the rungs of a DNA ladder to the letters of our alphabet. Describe the code these "letters" can form. What does the code do?

Extend Your Understanding

10. Predict what the calf produced in a union between each of these parents might look like. Explain your answers.
    a) a purebred white (recessive) cow and a purebred brown (dominant) bull
    b) a purebred brown (dominant) cow and a purebred brown (dominant) bull
    c) a purebred white (recessive) cow and a purebred white (recessive) bull
    d) a hybrid brown (dominant) cow and a purebred white (recessive) bull

Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Developments in science and technology do not just happen. Usually, a scientific discovery, such as the explanation of the role of DNA, takes place over a long period of time. Consider the following questions as they relate to how our understanding of genetic material has developed over time.

1. What types of observation and experimentation led us to a better understanding of how traits are expressed?
2. Why is it important to understand how genetic material functions?
3. Construct a timeline to illustrate the major theories of the past that have led us to our current understanding of genetics. Include any information about issues that may have surrounded the work of scientists in the past.

4.0 Human activity affects biological diversity.

Key Concepts

In this section, you will learn about the following key concepts

- biological diversity
- species
- habitat diversity
- natural and artificial selection of genetic characteristics

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between artificial and natural selection
- describe the effects of extinction and extirpation on biological diversity
- evaluate the success and limitations of local and global strategies in minimizing loss of species diversity
- describe new technologies for recombining genetic material
- describe the use of biotechnology in various fields

What would be the ideal vacation for you? You might tour the famous museums of the world to view masterpieces of art. You could visit the main cities of the world, to visit their architectural treasures. Or you might seek out the beautiful examples of our biological heritage in the nature preserves, national parks, and zoos of the world. More people are choosing this last type of vacation. Our appreciation and curiosity for the other types of life on Earth are increasing as we realize that species can be lost forever.

Nature preserves and national parks are not just for our enjoyment. They also play an important role in global strategies to maintain biological diversity by preserving important habitats and the species that depend on them. Today, zoos play an active role in preserving biological diversity through breeding programs and other efforts. In many cases, by trying to meet our needs, humans have unknowingly caused so much change to the environment that many species have been unable to adapt, and have disappeared. In recent years, however, both experts and volunteers have turned their attention to preserving the world's biological diversity and, sometimes, have been able to reverse some of the damage that has been caused.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Reduction of Biological Diversity

Species and ecosystems on Earth and the ecological processes of which they are part are being stressed by urbanization and the expansion of human industries such as agriculture and forestry. The resulting decline in genetic, species, and ecosystem diversity threatens the ecological, economic, and cultural benefits we currently derive from Earth's living resources. The extinction of some species, the decrease in population of other species, and the degradation of ecosystems reduces biological diversity on Earth.

Figure 4.1 Only 2100 Indian rhinoceroses remain in the wild.

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A Lesson in Extinction

One animal you will never see is the dodo, a flightless bird that once inhabited Mauritius, an island in the Indian Ocean. The dodo had no predators. Portuguese explorers first landed on the island in 1505, bringing with them cats, rats, dogs, and pigs. These introduced animals ate the dodos' eggs, and the sailors who stopped on the island used the adult dodo as a source of food. The dodo became extinct within 200 years of first human contact, probably around 1681.

GIVE IT A **TRY**

CHOICES IN OUR WORLD

Balancing human needs and the needs of other organisms is often very difficult. To grow our food, for example, land must be cleared of sensitive native plants.

With a partner, choose one of the following scenarios. Discuss the effects of the changes to the environment and to the organisms that live there. What choices will need to be made? Why? Could any of the changes be avoided? How?

1. A new school is built in a neighbourhood. Construction takes place on land that has a grove of aspen trees and native grasses. The trees are removed so the workers can park their vehicles during construction. The native grasses are replaced by the school building, tarmac basketball courts, and non-native grass for sports fields.
2. A river is dammed to provide irrigation water for neighbouring farms. During construction, all the aquatic plants at the river's edge are removed. A concrete retaining wall is built that runs about 10 km in either direction from the dam. A path is paved and fencing is installed, sod is laid, and picnic benches are installed to make a riverfront park. The grass is maintained through regular mowing and pesticide applications.

Extinction and Extirpation

Extinction is the disappearance of every individual of a species from the entire planet. Extinction is a natural part of Earth's history. Scientists estimate that 99% of all the species that have ever existed are now extinct. Most mass extinctions, like the one that killed off the dinosaurs, were likely caused by catastrophic events. These are events such as earthquakes or volcanic eruptions that cause sudden changes in the environment. The last major environmental change was about 1.8 million years ago during the Pleistocene epoch, which is commonly known as the Ice Age.

However, most extinctions are not mass extinctions. They take place over longer periods of time. Scientists speculate, though, that the rate at which species are becoming extinct is increasing. More species will disappear over the next decade than disappeared the decade before, so the biological diversity of the planet is decreasing more and more rapidly.

Figure 4.2 Fossils provide us with evidence of many species that have disappeared from our planet in the past.

Extirpation is a local extinction, or the disappearance of a species from a particular area. The grizzly bear was once commonly found from the mountains of British Columbia to the Manitoba Prairies. They had a rich supply of fish, small mammals, and plants on which to feed. Grizzlies are now mainly found only in the mountains, and their current range is threatened by increasing urbanization. Road building and other activities related to the search for natural resources, such as oil and gas, have also had an impact on the grizzlies' range.

The woodland caribou is currently at risk of being extirpated from the boreal forests of northern Alberta because of habitat degradation resulting from logging, forest fires, and increased interspecies competition.

The swift fox was once common in Alberta, but by 1928 this species was completely extirpated from Canada. The Alberta Department of Environmental Protection, working with groups such as the World Wildlife Fund, is trying to reintroduce the fox to Alberta. To do this, a major breeding program is under way.

The table below shows some of the at-risk species in Alberta. Endangered species are ones that are in immediate danger of extinction or extirpation. Threatened species are likely to become endangered if their current declines are not reversed. Species that are of special concern are ones that are particularly vulnerable to natural events or human activities.

Status	Mammals	Birds	Fish & Amphibians	Plants
Extirpated	black-footed ferret grizzly bear (prairie population)	greater prairie-chicken		
Endangered	swift fox	burrowing owl whooping crane mountain plover piping plover sage grouse sage thrasher Eskimo curlew		tiny cryptanthe
Threatened	wood bison	peregrine falcon prairie loggerhead shrike Sprague's pipit	short-jawed cisco	Western blue-flag soapweed Western spiderwort slender mouse-ear-cress sand verbena
Special Concern	woodland caribou wolverine Ord's kangaroo rat	ferruginous hawk long-billed curlew short-eared owl yellow rail	great plains toad Northern leopard frog (prairie population) Western silvery minnow	Bolander's quillwort hare-footed locoweed smooth goosefoot tall wooley-heads

Natural Causes of Extinction and Extirpation

Earlier in this unit, you learned that sexual reproduction is responsible for variation within species. These variations are important so that, through natural selection, a species can survive changes in its environment. However, if the population does have variation, why do species still disappear?

Natural selection is usually a slow process. Even if there is a lot of variation within a species, sometimes the environment changes too much and too quickly for the species to survive. For example, dinosaurs were once the most successful species on the planet, and yet all dinosaur species disappeared about 65 million years ago. In the past, most extinctions and extirpations were due to natural causes, such as:

- catastrophic events such as volcanic eruptions, floods, or fires
- lack of food due to overpopulation
- disease

Not all extinctions happened millions of years ago. In the 19th century, the American chestnut was one of the most numerous trees in forests of the eastern United States. In the summer, its creamy-white blossoms made mountains in the Appalachians appear as if snow-covered. The nuts were a source of food for wildlife, livestock, and humans. These were giant trees, up to 30 m tall, and the wood had many uses.

In 1904, the chestnut blight, a disease caused by a fungus, appeared in the American chestnuts in New York City. This fungus came from Asia and quickly spread because the North American trees had little resistance. By 1950, the species had essentially disappeared. Attempts are continuing to create a blight-resistant strain in order to bring this species back from the edge of extinction.

Catastrophic events are still occurring today. For example, some species that once lived on the side of Mount Etna, Sicily, were extirpated from that area because of the volcanic eruption in 2001 that resulted in long-term changes to that environment.

Overspecialization

Sometimes organisms have adaptations that suit them to only a narrow set of environmental conditions. This probably happens because the environment that the organism inhabits remains unchanged for a very long time. Biologists call this **overspecialization**. Overspecialization is another natural cause of extinction. The best-known example of overspecialization is the giant panda that eats only one thing, bamboo shoots. Because the panda only eats bamboo, it cannot switch to other sources of food. Bamboo forests sometimes die off or are cut down, reducing the pandas' food supply. So although habitat destruction affects the survival of the species, the pandas' overspecialization makes them even more vulnerable to extinction.

Figure 4.3 Damage caused by chestnut blight

Figure 4.4 The northern leopard frog has been extirpated from central Alberta.

Human Causes of Extinctions and Extirpations

Today, most extinctions and extirpations are due to human activity. If you have ever watched a new neighbourhood being built, you know that humans can change the environment very quickly. Because human populations continue to grow, and require land for houses and food production, human activity is now the leading cause of worldwide species loss.

Habitat Destruction

Humans cause rapid changes to habitat in a variety of ways. Construction of buildings, agricultural development, logging, and the damming of rivers all change environments. These activities are necessary to meet human needs. For example, large tracts of land were cleared of all native vegetation to make way for fields and pastures to grow crops and raise livestock, which are our food supply. But unfortunately, these changes also have brought about the loss of many species. In Canada, prairie species have been affected the most, because the grasslands provided the best farm sites. In fact, only 20% of the area once covered by native prairie species is still in its natural condition.

Pollution is a particular kind of habitat destruction. Pollution often affects not only the immediate area where humans are but also areas farther away. For example, pesticides, herbicides, and fertilizers used in farming may be washed into the nearby water system, and may unintentionally cause the death of native species. Some chemicals can cause an increase in the number of birth defects in species. This often occurs first in aquatic species such as fish, frogs, and toads. For example, pollution of breeding sites is thought to be the main cause of the dramatic reduction of the great plains toad in Alberta. This toad is now in the Special Concern category.

Figure 4.5 Habitat destruction is a global problem. This rain forest in Brazil is being cleared for farmland.

The effects of habitat destruction in tropical areas can be severe. Because tropical rain forests have the highest diversity of species of any area on the planet, loss of these habitats can cause the extinction or extirpation of a very large number of species.

Introduction of Non-Native Species

Throughout our history, migrating humans have carried with them many species on which they relied. The corn that First Nations people grew at the time of European settlement originally came from South America. Horses and cattle were unknown in the Americas until the arrival of Europeans.

When introduced species use the same resources as native species, they compete with the native species and cause the number of native species to decline, simply because there is less of everything. Cattle now graze where bison once roamed, and attempts to reintroduce the bison are limited due to the competition for grazing resources. Some introduced species, such as the invasive purple loosestrife, may have arrived in North America in a number of ways. Seeds may have been lodged in the ballast of a ship, stuck in the coats of animals, or carried by settlers who wanted to be reminded of home. Since its introduction, purple loosestrife has spread rapidly, out-competing native species, partly because no native species eat the purple loosestrife.

Figure 4.6 Wild bison once numbered in the millions.

Over-Hunting

Over-hunting was the major cause of the decline and eventual extirpation of the plains bison over most of its range, and of the extinction of the passenger pigeon. In the 19th century, flocks of passenger pigeons were so large that people reported being unable to hear the sound of a gunshot when they flew overhead. Passenger pigeons were hunted mainly for sport. The sport was so popular that the population declined dramatically. The last passenger pigeon died in captivity on September 1, 1914. Sometimes species were hunted to deliberately extirpate them. Black-tailed prairie dogs were considered a great menace to farmers and ranchers because they ate grain and dug holes causing cattle and horses to break legs. In the 1930s, large-scale poisoning campaigns reduced prairie dog numbers.

Activity A-6

Decision Making

Balancing Act

The Issue

Should human activities be restricted in our national parks?

Background Information

In Canada, grizzlies are now extirpated from the Prairies, and are found only in forested regions of Alberta, British Columbia, Yukon, Northwest Territories, and Nunavut. Here they can find an adequate food supply. They can also find appropriate habitat in which to make their dens and to provide refuge from human disturbance.

Figure 4.7 Grizzly bears need large areas of land undisturbed by human activity.

Although we may think of grizzlies as aggressive animals, they usually prefer to avoid humans. National parks are meant to preserve natural areas and the animals that inhabit them, but most of us also expect to be able to enjoy many outdoor activities in these parks. In Alberta, Banff and Jasper National Parks have ski areas, hotel facilities, swimming pools, and large camping facilities for recreation.

Analyze and Evaluate

Research the kinds of human activities currently allowed in national parks. Begin your search at www.pearsoned.ca/scienceinaction. Draw a concept map to show the social, economic, and environmental consequences of these activities.

Analyze your research and describe how these activities affect grizzly bears or other animals in the parks.

Write a proposal to Canadian Heritage Parks Canada recommending which human activities should be allowed in national parks and to what extent. Support your proposal with your research. Include a brochure for the public, to educate them about this issue.

Activity A-7

Experiment **on your own**

Changes in Biological Diversity

Before You Start

In any ecosystem, there may be many different species. The types and numbers of species can vary depending on a number of factors, including changes in climate or human activity. In this experiment, you will take a survey of all plants and animals in an existing area of your community. This survey will be repeated at a later date and the two sets of data will be compared.

The Question

How do the numbers of plant and animal species in an area change over time?

Design and Conduct Your Experiment

1. Make a hypothesis to test how the types and numbers of species will change. (Remember a hypothesis is a possible answer to a question or a possible explanation of a situation.) Ideally, the area will be a local park or field, but could also be a small plot of soil, or garden. If time permits, the interval of time between surveys should be at least several months.
2. Decide what materials you'll need to test your hypothesis. For example:
   a) What measuring instruments will you need? Tape? Metric ruler?
   b) What reference books will you need to help you identify the plants and animals?
   c) What materials will you need to record your data? Drawing paper? Grid paper? Calculator?
3. Plan your procedure. Ask yourself questions such as:
   a) What steps will I follow to collect the data I need?
   b) How will I estimate population numbers?
   c) Is the test I have designed fair? How do I know?
   d) How will I record my results? For example, do I need a data chart? A graph? Both? Neither?
   e) How long do I have to complete my surveys?

Figure 4.8 Surveying a local environment

4. Write up your procedure. Be sure to show it to your teacher before going further.
5. Carry out your surveys.
6. Compare your results with your hypothesis. Did your results support or refute it? If not, what possible reasons might there be?
7. Share and compare your experimental plan with your classmates. Did anyone plan surveys exactly like yours? Similar to yours? How do your results compare with theirs?

Effects of Extinctions and Extirpations

Extinctions and extirpations reduce biological diversity. Extinctions reduce the number of species on the planet. Extirpations reduce biological diversity in areas from which the organism has disappeared. In section 1.0, you learned about some of the many ways species interact with one another. When an organism disappears locally or globally, many other species are affected. For example, in regions where black-tailed prairie dogs were extirpated, burrowing owls and black-footed ferrets were also affected. Prairie dogs were the major source of food for black-footed ferrets, and burrowing owls used abandoned burrows as nesting sites. Black-footed ferrets are now one of the most endangered animals in North America.

Figure 4.9 The black-footed ferret has been extirpated from Canada. In 1997, there were 12 males and 18 females at the Metro Toronto Zoo. In the United States, small populations have been reintroduced to the wild.

reSEARCH

Extinct Canadian Animals

Examples of Canadian animal species that have become extinct due to human activity include:

Great Auk—extinct 1844
Sea Mink—extinct 1894
Passenger Pigeon—extinct 1914
Blue Walleye—extinct 1965

Find out more about these animals. Begin your search at www.pearsoned.ca/scienceinaction. Prepare a timeline or a short report describing how they became endangered and then, extinct.

Check and Reflect

Key Concept Review

1. State two examples of situations in which biological diversity may be reduced.

2. What kinds of natural causes lead to the extinction of a species?

3. In what ways can human activity lead to the extinction or extirpation of a species? Use examples to explain your answer.

4. Explain the term “overspecialization.”

Connect Your Understanding

5. Use a Venn diagram to compare and contrast extinction and extirpation.

6. Suppose an organism is extirpated from a local environment. In what way might other organisms be affected? Provide examples to support your answer.

7. How does extinction reduce biological diversity on Earth? Support your answer using examples and your knowledge of how genetic information is transferred from parents to their offspring.

Extend Your Understanding

8. What role has land use by humans played in the ongoing changes in biological diversity? State examples from your own community.

4.2 Selecting Desirable Traits

What did you have for breakfast this morning? Did you have cereal or toast? How about a glass of orange juice? The particular grains and fruits used in these and many other foods are probably a product of artificial selection. **Artificial selection** is the process of selecting and breeding individuals with desirable traits to produce offspring that have these desired traits. Recall that in natural selection the environment "selects" traits. In artificial selection, humans select traits.

Consider the example of horse breeding. By combining the genes of champion parents, breeders hope to create offspring that have the prized traits of both parents. If those horses are bred with other champion horses when they reach maturity, the chances of producing the desired traits in succeeding generations increase (Figure 4.10). The same is true of breeders of other animals such as livestock (cows, sheep, pigs) and domestic animals (dogs, cats, birds, guinea pigs, hamsters).

In a breeder's population, however, every individual is selected in the same way. Only those with a trait the breeder wants, such as a particular feather colour, in the case of domestic finches, will be allowed to breed. In contrast, natural selection "selects" traits that are useful for the survival of the individuals with those traits and allows them to breed.

Artificial selection can also be applied to both food and ornamental plants. For example, by taking the seeds of the healthiest or best producing plants and sowing them the following year, farmers can generally "weed out" less desirable traits and promote more desirable ones.

Humans have practised artificial selection since we first began to farm about 10 000 years ago. After so many generations of artificial selection, most of our plants no longer resemble the wild species from which they were bred. Corn, for example, was bred by native peoples from a species of grass called teosinte. Teosinte produced much smaller cobs and far fewer seeds than modern-day corn.

*info***BIT**

Beefier Cows

Scientists working at Alta Genetics Inc. of Calgary were the first to use genetically engineered cattle that would produce more beef.

Figure 4.10 These horses have been bred for their size.

Figure 4.11 The drawing of a very early variety of corn (left) is based on archeological samples. It doesn't look very similar to the corn we eat today (right).

Biotechnology

Native peoples practised an early form of **biotechnology** when they gathered seeds from the biggest and healthiest corn plants. This benefited them because they were able to develop more productive strains of corn.

Agricultural producers benefit when they can be sure that the wheat they plant or the calf that is born in their herd will have the traits that are most valuable in the marketplace. Although artificial selection has successfully produced most of our world's crops and livestock, it takes a very long time (many generations of the plants and animals) to get an organism with the desired combination of traits. For instance, livestock breeders have to breed cows over many generations to get a whole herd that produces large quantities of milk. Scientists and breeders have, therefore, developed technologies that can speed up this process. These technologies can range from "low tech" to extremely "high tech."

Figure 4.12 Identical organisms produced by technology are called clones, such as this carrot plant grown from a few cells taken from another carrot plant.

Creating Plant Clones

When a grower finds a plant that has very desirable traits, he or she would like more plants like it, or many clones of it. The simplest way to create a **clone** is by taking a cutting from a plant and growing an identical plant from the cutting. Horticulturalists do this routinely. The drawback is that this ideal plant has only so many leaves that can be cut off to use as cuttings.

Scientists have developed a quicker way to create clones. Cells are removed from an individual plant that has the particular traits that are wanted. These cells are placed on a Petri dish or bottle containing nutrients and hormones the cells need. Once these cells have developed into seedlings, they can be transplanted into the soil. Because the starting point is a cell rather than an entire part of the plant, many more clones can be produced from a single plant (Figure 4.12).

Artificial Reproductive Technology

Artificial reproductive technology refers to any artificial method of joining a male and female gamete. Most livestock in Canada are produced by some method of artificial reproduction. In **artificial insemination**, sperm are harvested from a bull with desired characteristics and are inserted into many female cows. The advantage of this technology is that the bull's sperm can be in several places at once and more cows can be inseminated.

Another reproductive technology is **in vitro fertilization**. In this technology, sperm from a prize bull and eggs from a prize cow are harvested from the animals. In a laboratory, the eggs and sperm are placed in a Petri dish, and the eggs are fertilized. This produces many more embryos than could be produced naturally. Each embryo is implanted into a different cow. These cows will eventually give birth to many calves, all of which will be brothers and sisters.

Figure 4.13 The beef industry relies on artificial reproduction technology to produce cattle with traits chosen to provide us with high quality meat.

Scientists can also determine the sex of the embryos before they are implanted into a cow to develop. By choosing only female embryos, dairy farmers can therefore be guaranteed that all their calves will be female, rather than having to use their resources to raise unneeded males.

Genetic Engineering

Genetic engineering refers to any technology that directly alters the DNA of an organism. Genetic engineering is a rapidly developing science, and every new advance increases our ability to control the characteristics of organisms.

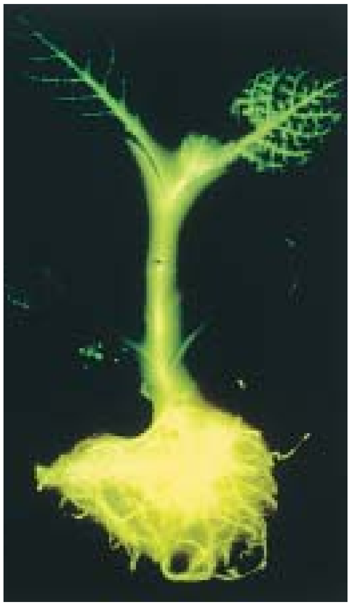


Figure 4.14 This plant was grown from cells that had a firefly gene inserted into them. When the gene is activated, the plant glows.

Many of the genetic engineering techniques involve inserting a gene from one species into another species. Bacteria are genetically engineered to produce life-saving medicines such as insulin. Insulin is a substance that many diabetics use to control the level of sugar in their blood. Just 20 years ago, insulin had to be extracted from the pancreas of cattle, and it was expensive to produce. Today, the human insulin-producing gene is inserted into the bacteria's DNA. Because the bacteria reproduce so rapidly, bacterial colonies can produce insulin quickly and cheaply. Now most of the world's supply of insulin comes from genetically engineered bacteria.

A micro-organism called *Bacillus thuringiensis* produces a toxin commonly called Bt, which is poisonous to many insects. Scientists have isolated the gene that contains the instructions for making Bt toxin and have inserted it into the DNA of plants. These genetically engineered plants now produce Bt toxin! Since the 1990s, cotton, corn, and potatoes have been engineered to produce Bt toxin. Because insects that eat the engineered plants die, growers never need to apply pesticides to the engineered plants.

Some varieties of canola are naturally resistant to an insect called the flea beetle, while others are not. When flea beetles attack a field of canola, the crop is likely to be devastated, leaving the grower with nothing to sell. Unfortunately, the most valuable varieties of canola do not have a gene for flea beetle resistance, so most growers have to use pesticides to protect their crop from the beetle. Scientists have been able to transfer this gene from beetle-resistant varieties to other canola varieties that have higher yields. The growers who use the genetically engineered canola get canola with high yields and, because it's beetle-resistant, it doesn't have to be sprayed with pesticides.

Biotechnology and Society

Development of technology that allows us to select or introduce desirable traits of the organisms around us has given humans some important benefits. However, as with any technology, we need to use these technologies responsibly and be aware of the possible risks as well as the benefits.

Risks in Animals

In agriculture, most individuals in a crop or livestock population are extremely similar as a result of generations of artificial selection. Artificial reproductive technologies can reduce the genetic variation in breeding lines of livestock. In artificial insemination, sperm from just a few animals are used to impregnate many females. With in vitro fertilization, the embryos created from the eggs and sperm of just two individuals are implanted in other cows.

Now scientists and breeders are able to produce an identical copy of a single animal. The most famous example of this is a sheep named Dolly (Figure 4.15). Dolly was produced in Scotland in 1997, and is an exact duplicate of her mother.

Animals like Dolly have been cloned for a variety of reasons. Some, like the rhesus monkey ANDi (a backward abbreviation of inserted DNA), have been genetically altered as part of research programs into human diseases. Other animals, such as cattle, are being cloned as potential large-scale producers of meat and milk. Herds of such genetically identical individuals may be far more susceptible to disease than more genetically variable herds.

Figure 4.15 Dolly's cells appear the same age as her mother's, even though Dolly is six years younger.

Cloning and genetic engineering are still in their infancy and have been fraught with difficulties. Cattle cloners have reported numerous examples of unsuccessful pregnancies, birth defects, and deaths among clones. The reasons are as yet unclear. Some researchers speculate that something about the process of removing the nucleus from the donor egg may be responsible. Dolly herself has developed arthritis, although it is not known why.

ACTIVITY A-8

Decision Making

SALMON FARMING AND VARIABILITY

The Issue

Will salmon farming help or hurt the recovery of wild salmon in Canada?

Background Information

In the 1990s, the salmon populations on both the Atlantic and Pacific coasts were on the verge of collapse, causing governments to call a halt to all commercial salmon fishing. Many people who had made a living from salmon fishing were suddenly out of work. There were various reasons why the salmon stocks had declined so suddenly, and people had different proposals as to how to let the salmon population recover while still meeting society's desire for salmon.

Fish farms mainly in New Brunswick's Bay of Fundy and off the B.C. coast produce more that 72 000 tonnes of salmon a year. The federal government is a strong supporter of fish farming and recently made available $75 million for research and development. Government estimates suggest that by the year 2025, the world will need 55 million tonnes more seafood than wild stocks can provide. To meet that demand, fish farming as an industry will have to grow by 350%.

But is the advance of fish farming practices coming at the expense of stocks of wild salmon? Why is the wild species still facing extinction? What impact does commercial fish farming have on wild populations? Tests are under way to selectively breed for bigger and faster growing salmon as well as to genetically modify the fish against common parasitic diseases. Researchers in the federal department of fisheries have now developed 20 new transgenic breeds of salmon that grow seven times faster than wild salmon.

Analyze and Evaluate

1. Research the positive and negative impacts that fish farming may have on wild populations. Begin your search at www.pearsoned.ca/scienceinaction. Decide how you will evaluate your information sources.
2. What other factors may be affecting the survival of the wild salmon population?
3. What are the costs and benefits of fish farming and commercial fishing to meet the short- and long-term food needs of society?
4. Prepare an oral presentation in which you defend your position on fish farming. Present your view by role playing from ONE of the following perspectives. You are a fish farmer speaking to a group opposed to fish farming OR you are a fish-farming opponent speaking to an association of fish farmers.

Figure 4.16 Salmon farming pens

Risks in Plants

Most of our plant crops were produced by artificial selection of wild plants. Weeds are often the wild relatives of crop plants. Some crops have been genetically engineered to resist herbicides. This allows farmers to spray the crop with herbicide, killing the weeds but not the crop. However, there have been unforeseen problems. Many crop plants can still cross with their wild weed relatives. There have been reported cases of genetically engineered canola interbreeding with weeds, and the weeds' offspring have become resistant to herbicide.

Check and Reflect

Key Concept Review

1. How does artificial selection differ from what you learned earlier in this unit about natural selection? Use examples in your explanation.
2. Describe two examples of technologies that humans use to select the traits of organisms.
3. Who were the earliest "plant technologists" in North America? What crop did they develop and how?

Connect Your Understanding

4. How have reproductive technologies benefited agricultural industries in Alberta? Provide examples. What human needs do these technologies reflect?

5 Simplify an explanation of artificial selection in a way that a student in grade 4 could easily understand it.

6. What are some advantages of biotechnology such as cloning? What are some disadvantages?
7. What are some intended and unintended consequences for the environment as a result of developments in biotechnology?

Extend Your Understanding

8. Scientists have created crops that contain a toxin that kills any insect that eats them. Some farmers have been growing corn plants that contain this toxin. Corn without this toxin is a food supply for the corn weevil, which destroys the corn crop, and the monarch butterfly, which is a protected species. What advice would you give to farmers growing this crop?
9. Predict what some potential impacts or issues might be related to an increasing use of biotechnology such as cloning and genetic engineering.

reSEARCH

Golden Rice

Rice does not normally contain vitamin A. Swiss scientists have recently created a genetically engineered strain of rice that does contain vitamin A. Research this so-called golden rice and find out the reasons for developing it and why some groups have concerns about its use. Begin your search at www.pearsoned.ca/scienceinaction. Prepare a short report.

4.3 Reducing Our Impact on Biological Diversity

Figure 4.17 Leaders of indigenous peoples living in the rain forests of South America attended the Earth Summit to voice their concerns about the clearing of rain forests.

Preserving global biological diversity was given international recognition at the Earth Summit in Rio de Janeiro in 1992. World leaders at the summit, including Canada's Prime Minister Jean Chrétien, signed a treaty called the United Nations Convention on Biological Diversity. This Convention outlined the importance of maintaining ecosystem, species, and genetic diversity in preserving the living resources of Earth. This agreement has three goals: conservation of biological diversity; sustainable use of the components of biological diversity; and fair and equitable sharing of the benefits arising from the use of genetic resources.

Each country that signed the treaty agreed to set national policies in place that outlined how to achieve these goals. In Canada, the federal government created the Canadian Biodiversity Strategy in 1995, which describes how Canada will maintain biological diversity for the future.

Strategies to Conserve Biological Diversity

The conservation of biological diversity requires the elimination or reduction of the adverse impacts to biological diversity that result from human activity. In order to promote biological diversity, the Canadian Biodiversity Strategy focusses on in-situ and ex-situ conservation, along with promoting the sustainable use of resources and an ecological approach to the management of human activities.

Protected Areas

Canada's first national park, Banff, was established in 1885. Currently, 244 540 km^2 of the Canadian landscape is protected in a series of national parks. Each province in Canada also has its own protected-area strategies, which include the future development of additional provincial parks, recreation areas, and ecological preserves. The protected areas of Canada allow organisms to live relatively undisturbed in their natural habitats. **In-situ conservation** refers to the maintenance of populations of wild organisms in their functioning ecosystems. It allows the ecological processes of an area to continue undisturbed.

Species with large ranges, such as caribou, wolves, and bears, are being given added protection as organizations, such as those involved with the Yellowstone to Yukon Conservation Initiative, work to create a network of protected areas. No single protected area can offer enough land space or habitat diversity to support all native species or ecosystems. Linking protected areas together provides corridors for movement and exchange of genetic material essential for the maintenance of biological diversity. The creation of these protected areas depends on the co-operation of national, provincial, and municipal governments, along with the support of other organizations, and citizens. The Wagner Natural Area, just west of Edmonton, is a rich peatland environment that exists today because of the efforts of individuals, groups, and the Alberta government. The area is protected under the Ecological Reserves and Natural Areas Act. Many governmental and non-governmental organizations buy land to provide habitat for plant and animal species.

Restoration of Ecosystems and Species

Canada has also developed various programs to restore endangered species, as well as damaged habitats, to a healthy state. These two goals are linked because most species can never recover unless they have habitat in which to live. This is especially true of species that were extirpated from an area, such as the prairie population of grizzly bears, because of changes made to their habitat.

Charities, not-for-profit organizations, volunteer groups, and private landowners also contribute to restoring species and habitat. The Nature Conservancy of Canada, for example, helps to acquire land or raise money to ensure the ongoing protection of natural areas. The Nature Conservancy works with local conservation groups, private citizens, and corporations to increase the amount of habitat available for native plants and animals. Many private landowners also contribute by returning a percentage of their property to its natural state. At 1943 ha, the Ann and Sandy Cross Conservation Area, just southwest of Calgary, is an example of one of the largest private gifts of land made in North America. Ducks Unlimited Canada, through its Prairie Conservation of Agriculture, Resources and the Environment (CARE) program promotes the restoration or improvement of available cover in large wetland areas. Landowners are encouraged to restore nesting areas through the seeding of native grasses and shrubs in order to improve waterfowl nesting success.

*info***BIT**

Raising Endangered Species

At the San Diego zoo, chicks of the endangered California condor are being reared by hand. Their human caregivers wear gloves that look like adult condor heads so that the birds don't associate humans with their parents. The caregivers pick up pieces of meat while wearing the glove and hand it to the chick, so it looks like an adult condor is giving the chick food. That way, when they are extremely young, chicks don't actually see humans.

Figure 4.18 The Alberta Cows and Fish Program worked with local landowners to restore Callum Creek in southern Alberta. Callum Creek before restoration (left) and five years after cows were moved to other grazing areas (right).

Restoring a species that has been extirpated requires a lot of money and time. For example, the swift fox was listed as extirpated from Canada in 1928. Native to short- and mixed-grass prairie regions, the swift fox started to decline in the late 1800s when agriculture began to change its prairie habitat, and it began to face increased competition from species such as coyotes. The swift fox was also vulnerable to poisoning programs aimed at wolves and coyotes. As you learned in subsection 4.1, a captive breeding program began in 1973 and the first swift fox was released into the wild along the Alberta and Saskatchewan border in 1983. The efforts of the Alberta government and organizations such as the World Wildlife Fund resulted in successful reintroduction efforts. A winter census in 1997 estimated the population of swift foxes in the area to be 192. The swift fox, however, is still listed as an endangered species in Alberta.

In 1992, the Friends of Fish Creek, a non-profit organization, formed to assist in the protection, preservation, and enhancement of the natural and human heritage of Fish Creek Park in Calgary. Every July, the society organizes "Purge the Spurge." Volunteers gather to hand pull leafy spurge, a non-native noxious weed that threatens to take over the park and destroy wildlife habitat. The weeds are hand pulled in areas where other control methods can't be used.

Figure 4.19 Planting native plant species is one strategy for maintaining biological diversity.

Resource Use Policies

Federal and provincial governments have laws to protect species that are endangered (species with very few individuals left in the wild) or threatened (species that are decreasing rapidly in the wild). Any species that is classified as endangered or threatened is protected by law from hunting and capture, or in the case of plants, from being picked or transplanted. The National Accord for the Protection of Species at Risk was created in 1994, and was signed by all the provinces and territories of Canada. The accord paved the way for each province to develop legislation to protect their vulnerable plants and animals.

The goal of the Accord for the Protection of Species at Risk is to "prevent species in Canada from becoming extinct as a consequence of human activity." The participants in the accord have agreed to recognize species assessments made by the Committee on the Status of Endangered

Wildlife in Canada (COSEWIC). They have also agreed to establish legislation and programs to effectively protect species within their own province or territory and to protect threatened or endangered species. Nationally, the federal government is developing the Species at Risk Act. In Alberta, the Endangered Species Conservation Committee (ESCC) was created under the Wildlife Act of 1998 to study and determine species at risk in Alberta. The ESCC produces a status document on Alberta's plants, mammals, reptiles, amphibians, and birds every five years.

Controlling the Spread of Exotic Species

Past experience has shown that bringing species into a new environment can have disastrous consequences for the native ecosystem. Recall purple loosestrife, the herbaceous wetland perennial introduced into Canada from Europe in the 1800s. Purple loosestrife invades native wetland communities forming a single species stand by germinating and growing faster than any other wetland species (Figure 4.20). Purple loosestrife has no natural enemies. No bird, mammal, or fish feeds on it or uses it for shelter. Purple loosestrife reduces the size and diversity of natural plant communities and has been designated as a noxious weed by Alberta Agriculture. If purple loosestrife is found in an area, measures must be taken to control it. Volunteers are vital in pulling purple loosestrife and monitoring infested sites throughout the province. To control purple loosestrife and other invasive species, federal, provincial, and municipal governments continue to develop policies to prevent their spread. Although these programs are developed and enforced by governments, their success ultimately depends on the actions of individuals.

Figure 4.20 (Left) Purple loosestrife takes over a wetland. (Right) This species of weevil feeds exclusively on purple loosestrife and is used by groups such as the Manitoba Purple Loosestrife Project to help control the plant's spread.

Conservation of Genetic Resources

Ex-situ conservation refers to the conservation of components of biological diversity outside of a natural habitat. Like in-situ conservation, ex-situ conservation plays a vital role in species preservation. In some cases, ex-situ conservation offers the only chance of survival for some endangered species and plays an important role in conserving economically valuable genetic resources for forest, aquatic, and agricultural purposes.

reSEARCH

Cloning Endangered Species

In 2001, a company called Advanced Cell Technologies attempted to clone an endangered species called the gaur, a wild ox from India. Look up magazine and newspaper articles about the gaur and find out how Advanced Cell Technologies planned to clone the animal and whether they were successful. Prepare a short report on your findings.

Conservation of genetic resources is any activity that helps to store as many gene variations as possible of the world's species. This is a huge task since some scientists estimate that there are as many as 10 million different species in the world. Conserving genetic resources began with seed banks, which store seeds from the many varieties of crop plants. Most seed banks started as a voluntary exchange program between farmers. By keeping a seed bank, farmers had access to all the crop varieties available, so that if environmental or market conditions changed, they could plant a more suitable variety.

As we learned more about the importance of biological diversity, seed banks were expanded. Experts realized that it was important to keep seeds of the wild ancestors of our crop species, because these species often had useful characteristics that our advancing technology might be able to use in the future. Today, the world's seed banks are administered by an international group of scientists, known as the International Plant Genetics Resources Institute (IPGRI). The scientists are responsible for determining which country will maintain the seed bank of particular species. Canada maintains the seed bank for barley and oats.

Figure 4.21 This seed bank stores varieties of wheat.

Preserving the genes of animals is much more difficult. Plant seeds can be stored for long periods. In contrast, the egg and sperm cells of animals can be stored only for relatively short periods, so populations of living animals must also be maintained. Most of us would like wild animals to be "stored" in their wild habitats, but some species may already have too little habitat for this to be possible. These animals may escape extinction by captive breeding programs run mainly by zoos. These programs assess the variation of the individuals in the collections of zoos worldwide, and breed the animals that have the most variation. Sadly, this may soon be the fate of the giant panda and the Bengal tiger. Sometimes the animals are exchanged between zoos, but many times breeding takes place by using artificial reproduction technologies such as those used in cattle farming. Some species, such as the whooping crane, will breed in captivity, while others will not.

Activity A-9

Decision Making

Saving the Whooping Crane

The Issue

Which strategies have been most effective in saving the whooping crane from extinction?

Background Information

Wetlands include marshes, swamps, and bogs, and provide habitats for a large number of species. One such species is the endangered whooping crane, which is the symbol of a government program called RENEW (Recovery of Nationally Endangered Wildlife). As of April, 2001, the number of whooping cranes in the wild in North America was only 263. Amazingly, 177 of these live in conserved wetland habitats in Wood Buffalo National Park. Most of these birds were not born in the park, but were released from captive breeding programs.

Figure 4.22 Loss of wetland habitat has pushed the whooping crane near to extinction.

The prairies were once dotted with small wetlands called "prairie potholes," which provided habitat for the whooping crane and other species. Most experts agree that the whooping crane has become endangered due to habitat loss because so many of these potholes were drained to make way for farms, industry, or housing, or to control mosquito populations. Governments, environmental groups, fishing and hunting associations, zoos, local community groups, and private land owners have started to work together to bring back the whooping crane.

Analyze and Evaluate

Use the Internet and the library to investigate the strategies being used for conservation of the whooping crane. Begin your search at www.pearsoned.ca/scienceinaction. Try to find the most recent information available from expert sources, such as conservation groups, zoos, or universities.

Write a paragraph summarizing the conservation strategies for the whooping crane. Your paragraph should describe the habitat needs of the whooping crane, any changes in areas that could provide suitable habitat, and data on the change in the whooping crane population over the last 10 years.

Based on your research, create a report card on our progress in saving the whooping crane. Which strategy or strategies was most effective in increasing the population of the whooping crane?

GIVE IT A TRY

DO YOU AFFECT BIOLOGICAL DIVERSITY?

Preserving biological diversity requires everyone to think about the world in a different way. How much do your personal activities affect other living things?

Make a record of your main activities for a week. For everything you note, ask yourself if you affected other living things. For example, if you cut across a field on the way to school, you might compact the soil and make a bare patch where plants can't grow. If you print out a Web page instead of reading it on your computer, you are indirectly reducing the amount of forest.

At the end of the week, report to your class whether you think your actions contributed to loss of biological diversity. Can you think of anything you might do differently?

CHECK AND REFLECT

Key Concept Review

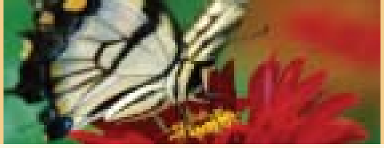
1. What is in-situ conservation? How does it preserve biological diversity?
2. Why is it important to protect networks of ecosystems and habitats? Provide an example of a species that would benefit from such protection and state why.
3. How have governments been involved in the protection of vulnerable species? Provide an example of a government policy.
4. What methods have been used to conserve genetic resources? List some examples.

Connect Your Understanding

5. In a short paragraph, explain how a protected area, such as a national park, is an example of in-situ conservation.
6. Why do exotic species have such an impact on local ecosystems? Why are exotic species, such as purple loosestrife, a threat to biological diversity?
7. What is the value of preserving the seed of wild plant ancestors and other varieties of crop plants grown today?

Extend Your Understanding

8. You have just signed up to help with the annual "Purge the Spurge" campaign in Fish Creek Provincial Park. Given what you may already know about spurge, why might this be a worthwhile activity? What impact, if any, do you predict your action will have on species diversity? Explain your answer.



Unit Summary: Biological Diversity

Key Concepts	Section Summaries
1.0 • biological diversity • species and populations • diversity within species • habitat diversity • niches • natural selection of genetic characteristics	**1.0 Biological diversity is reflected in the variety of life on Earth.** • Earth and its environments are home to millions of species. • Biological diversity refers to the variety of species and ecosystems on Earth. It has three main components: ecosystem diversity, community diversity, and genetic diversity. Biological diversity also refers to the variation among and within species. • Species co-existing in a habitat are interdependent. The possible interdependencies are predator-prey relationships, commensalism, mutualism, and parasitism. • Different species share limited resources by having different niches. • Natural selection is the selection of desirable traits by the environment.
2.0 • asexual and sexual reproduction • inheritance	**2.0 As species reproduce, characteristics are passed from parents to offspring.** • Heritable traits can vary between individuals either as discrete variations, such as eye colour, or continuous variations, such as height. The environment can affect some heritable traits, such as height. • Asexual reproduction involves only one parent. The parent and offspring of asexual reproduction are identical. Sexual reproduction involves two parents. The offspring of sexual reproduction are different from the parents. • In sexual reproduction, a male gamete fuses with a female gamete to produce a zygote. A zygote develops into an embryo, which eventually grows into a new individual. • Sexual reproduction results in variation among individuals of a species. Asexual reproduction allows a species to reproduce quickly producing identical offspring.
3.0 • chromosomes, genes, and DNA • cell division • inheritance	**3.0 DNA is the inherited material responsible for variation.** • Chromosomes, genes, and DNA carry genetic information that is passed on from generation to generation. All cells in the body of an organism contain DNA. • DNA carries the instructions for making a particular individual organism. The instructions are written in a genetic code. The code is the same for all organisms on Earth. • Genes are the instructions for the particular characteristics of an organism. • Organisms with a lot of DNA have chromosomes arranged in pairs. • The result of binary fission and mitosis is the formation of two new cells from one parent cell. Each has the same amount of DNA as the parent cell. • The result of meiosis is the formation of gamete cells. Each gamete has half the amount of DNA as the original cell. • A dominant trait is seen in offspring whenever the dominant allele is present. A recessive trait is seen in offspring only if two recessive alleles are present. • Dominant and recessive inheritance does not explain all patterns of inheritance.
4.0 • biological diversity • species • habitat diversity • natural and artificial selection of genetic characteristics	**4.0 Human activity affects biological diversity.** • Extinction is the loss of a species from the entire planet. Extirpation is the loss of a species from an area of the planet. Both cause reduction of biological diversity. • Extinctions and extirpations are caused by natural events and by human activity. • Artificial selection is human selection and breeding of plants and animals with desirable traits to produce offspring with those traits. Natural selection is selection of desirable traits by the environment. • Technologies that affect biological diversity include artificial selection, artificial reproductive technologies, and genetic engineering. • Strategies to maintain biological diversity include restoration of habitat and re-introduction of species, and the use of seed banks and captive breeding programs.

Zoos and Biological Diversity

The Issue

Do we need zoos? Many people are troubled by the idea of keeping wild animals in captivity. It can seem cruel to keep species such as the polar bear or antelope, animals that wander many kilometres every day in the wild, in small enclosures. Animals are kept in a climate that can be very different from their natural habitats. Most animals also have a unique social structure that cannot be duplicated in captivity.

It can seem that zoos keep animals in these false environments only to serve human interest. However, many zoos such as the Calgary Zoo, have taken on a leading role in conserving species at risk of extinction or extirpation. Zoo supporters argue that without these conservation projects, many animals would have an even greater risk of extinction.

Here are some of the arguments for and against keeping animals in zoos.

Zoos Have an Important Role in Maintaining Biodiversity	Zoos Meet Human Needs Far More than Animal Needs
Zoos provide refuge for animals with damaged or eliminated habitat.	Zoos design the enclosures so that humans can observe the animals, which puts many of the animals under stress.
Zoos help to maintain biodiversity by participating in animal breeding programs with other zoos.	The money spent on establishing and maintaining zoos would be better spent on habitat protection and rehabilitation of animals' natural habitats.
Zoos conduct and support research that assists efforts to improve existing habitat and to re-establish extirpated species.	Many animals will not breed in captivity, so their genes are lost forever.

Does the Calgary Zoo meet all the needs of its inhabitants?

Go Further

Now it's your turn. Look into the following resources for information to help you form your own opinion.

- Look on the Web: Check out Web sites about zoos around the world (including Calgary and Edmonton) and their research programs.
- Ask the Experts: Talk to an expert about the issue. When you do your Internet search, you may find e-mail listings of specific people who can provide you with information.
- Check Newspapers and Magazines: Follow current stories about the issue in newspapers and magazines.
- Check Out Scientific Studies: Look for scientific studies about zoos.

Analyze and Address the Issue

You are an expert on conservation of species and you have been asked to write a proposal about the role of zoos in maintaining biological diversity in our world. In your proposal, consider the different perspectives on this issue. Support your proposal with research data and include the risks and benefits of adopting your proposed strategy.

PROJECT

MAINTAINING LOCAL BIOLOGICAL DIVERSITY

Monte Verde Cloud Forest in Costa Rica

Getting Started

The Kew Seed Bank in England holds seeds for almost 4000 different species of plant life—about 1.5% of known flora on Earth. By having a large supply of the plants' seeds, the bank hopes to protect some of the 34 000 plant species currently at risk for extinction worldwide. The National Institute of Biodiversity in Costa Rica is using a technique called "bioprospecting" to study the ways in which animal and plant resources may be useful to humans. They locate, describe, and collect species that are not endangered. Researchers then develop extracts from the plants, insects, and micro-organisms, which are then analyzed to determine their use in pharmacological, agro-industrial, and biotechnology industries. Any university or company working with the National Institute of Biodiversity has to commit to reinvesting 50% of profits from products developed from these natural resources in conservation. Also in Costa Rica, 22 260 ha of rainforest within the Monte Verde Cloud Forest have been purchased with the donations from school children around the world. Called the Children's Eternal Rainforest, it is now the largest private reserve in Costa Rica and is administered by the Monte Verde Conservation League. The area earned the name the Children's Eternal Rainforest because thousands of species of trees, and the animals that depend on them, are now protected from logging and deforestation. These are only three examples of strategies that have been successful in helping to maintain biological diversity. What strategies are being used in your community?

In this unit, you have learned about the diversity of life on Earth both among species and within. You have also learned that natural selection and human activity may reduce biological diversity on Earth.

This project will allow you to apply what you've learned to researching and making a presentation on a local strategy for maintaining biological diversity.

Your Goal

Working with a partner, learn more about a local strategy for maintaining biological diversity. Put together a presentation to share this information with others. Your presentation may be multimedia (e.g., PowerPoint presentation, video), in poster format, or an oral presentation. Strive to find a creative and interesting way to convey your new learning. Include your opinion on how successful the strategy has been and any recommendations that you would have for the future.

What You Need to Know

To find a local conservation project you may wish to contact environmental groups in your area or a government agency for ideas. If you use the Internet as part of your research, be sure to follow your school's acceptable user policy. Begin your search at www.pearsoned.ca/scienceinaction.

Steps to Success

1. Work with a partner. Brainstorm possibilities for a strategy that will be the focus on your research. Writing to local environmental groups, reading newspaper and magazine articles, using e-mail, and checking Web sites are examples of ways to gather the background information that you will need for your presentation.
2. Select the type of presentation that you will use and begin to develop a plan for sharing your research findings.
3. Be sure to include your own assessment of how effective the strategy has been in terms of maintaining biological diversity, and any suggestions you have for improving the use of the strategy in the future.
4. Present your work to the class.

How Did It Go?

5. In paragraph form, answer the following questions:
   - Describe your research process. How effective was it?
   - How well did you and your partner work together? How effectively did you make decisions and come to agreements?
   - What part of this project did you find to be the most challenging? the easiest?
   - How did your presentation compare with your original ideas? What changes did you make and why?
   - What would you do differently next time?

Unit Review: Biological Diversity

Unit Vocabulary

1. Create a concept map that illustrates your understanding of the following terms and how they relate to biological diversity.

   species
   natural selection
   interdependence
   niches
   asexual reproduction
   sexual reproduction
   artificial selection
   extinction
   extirpation

Key Concept Review

1.0

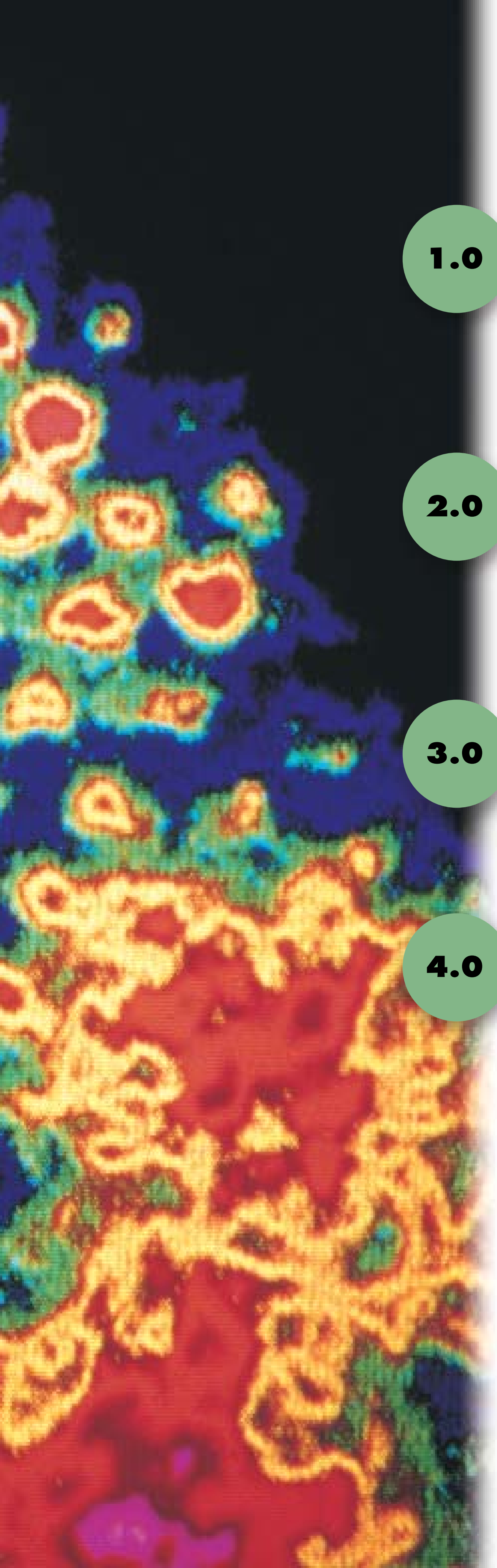
2. How is a population related to a community? Refer to a pond environment to illustrate your answer.
3. What is genetic diversity?
4. Outline the three levels of biological diversity. Give an example of each.
5. Using an example, explain how species are dependent on many other species in their environments.
6. What is a niche? Describe the niche of a wolf in the Canadian Rockies.
7. In parasitism, how does the parasite depend on its host for survival?
8. Why is the niche a species occupies important to its survival?
9. Describe one major threat to biological diversity.
10. Illustrate the meaning of ecosystem diversity.

2.0

11. What is similar about sperm cells and egg cells? What is different?
12. What is a zygote? How is it formed?
13. Differentiate between heritable and non-heritable characteristics. Provide examples of each type.
14. Distinguish between discrete and continuous variation and provide three examples of each.
15. Outline the path of development in animals from gametes to embryo.
16. Sketch the parts of a flower that are involved in reproduction. Describe how each part functions in cross-fertilization.
17. What form of asexual reproduction do yeast cells use and how does it work?
18. Explain the difference between asexual and sexual reproduction and the advantages and disadvantages of each in terms of biological diversity.
19. Use a table or Venn diagram to compare the different forms of asexual reproduction.

UNIT B

Matter and Chemical Change



In this unit, you will cover the following sections:

1.0 Matter can be described and organized by its physical and chemical properties.

1.1 Safety in the Science Class
1.2 Organizing Matter
1.3 Observing Changes in Matter

2.0 An understanding of the nature of matter has developed through observations over time.

2.1 Evolving Theories of Matter
2.2 Organizing the Elements
2.3 The Periodic Table Today

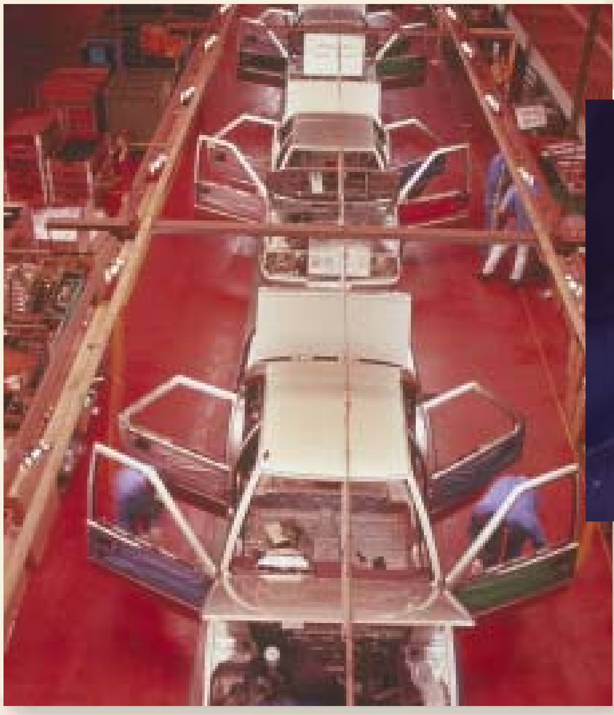
3.0 Compounds form according to a set of rules.

3.1 Naming Compounds
3.2 Ionic Compounds
3.3 Molecular Compounds

4.0 Substances undergo a chemical change when they interact to produce different substances.

4.1 Chemical Reactions
4.2 Conservation of Mass in Chemical Reactions
4.3 Factors Affecting the Rate of a Chemical Reaction

Exploring



Aluminum foam

The next time you drink pop from a can, take a good look at the container. You probably know that it's made of the metal aluminum, which is light and flexible, yet strong. These characteristics, or **properties**, make aluminum useful for holding liquids. Aluminum has many other applications as well. For example, screen doors, cars, and airplanes all use aluminum. In these applications, the metal is usually used in sheets or formed into parts. But did you know that aluminum can also be made into a foam?

Aluminum Foam

Aluminum foam is an example of combining a variety of materials to create a new material with different properties from those of the original materials. Mixing powdered aluminum with a foaming material makes aluminum foam, a substance that can be 10 times stiffer and 50% lighter than aluminum. It can also float because it has air pockets.

Engineers use this new material to create lighter, safer cars. It may sound strange that a lighter car can be a safer car. However, compared to other materials, aluminum foam is able to absorb more impact energy when a car is in a collision.

QUICKLAB

Foam in a Cup

Purpose

To observe what happens in a simple chemical reaction

Procedure

1. Pour 30 mL of corn syrup into a 250-mL beaker. Stir in 3 drops of one food colouring. Sprinkle 20 mL of baking soda on the corn syrup.
2. Tip the beaker slightly and carefully pour in 30 mL of water down one side. Add 30 mL of vegetable oil to the beaker in the same way.
3. Into a separate beaker, pour 20 mL of vinegar and add 3 drops of the other food colouring.
4. Fill the eyedropper with coloured vinegar. Squeeze 3 drops of coloured vinegar into the beaker containing the other substances. Record your observations. Repeat if necessary.
5. Push the eyedropper down to the bottom of that beaker, and release all the vinegar by squeezing the bulb of the eyedropper. Record your observations.

Questions

6. Describe how your observations were different in steps 4 and 5.
7. Work with the rest of the class to explain what is going on in the activity.

Materials & Equipment

- graduated cylinder
- 30 mL corn syrup
- two 250-mL beakers
- two different colours of food colouring
- stirring rod
- 20 mL baking soda
- 30 mL water
- 30 mL vegetable oil
- 20 mL vinegar
- eyedropper

Focus On: The Nature of Science

In this unit, you will be asked to observe how matter changes and interacts with other matter. You will collect evidence of changes by:

- investigating the properties of matter
- interpreting observations and data from experiments
- creating and interpreting models

Think about the following questions while you study how our understanding of matter and its interactions has developed. The answers to these and other questions about matter will help you understand the interactions among substances.

1. **How do we determine the properties of a variety of different substances?**
2. **How do different substances interact?**
3. **What evidence can be used to indicate that an interaction between substances has occurred?**

1.0 Matter can be described and organized by its physical and chemical properties.

Key Concepts

In this section, you will learn about the following key concepts:

- Workplace Hazardous Materials Information System (WHMIS) and safety
- substances and their properties
- elements, compounds, and atomic theory

Learning Outcomes

When you have completed this section, you will be able to:

- identify and evaluate dangers of caustic materials and potentially explosive reactions
- investigate and describe properties of materials
- describe and apply different ways of classifying materials based on their composition and properties

Imagine visiting a market where all the food is displayed in big bags, like the ones shown in the photo. How could you tell what was in each bag? One way would be to look at the colour and shape of each item. You also might handle each one to see whether it is hard or soft, rough or smooth, dense or light. If these clues still weren't enough to help you identify the unknown substances, then you might have to cut them open to see their composition. In all of this, you would be doing just what a chemist does: investigating matter.

Studying the properties of matter and how matter changes is part of the science called chemistry. **Matter** is anything that has mass and occupies space. In this section, you will first learn proper science lab safety. Then you will learn about some properties of matter and how those properties can be used to identify substances and to organize matter in a useful way.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Safety in the Science Class

In any science activity, the safety of you, your classmates, and your teacher are of the utmost importance. It is essential that everyone in your science class act in a safe and responsible manner. Before you begin investigating chemical reactions, you should review some safety rules and basic lab skills.

SKILL PRACTICE

SAFETY IN THE SCIENCE LAB

Look at Figure 1.1. Some of the students are not following proper safety procedures. Work with a partner to identify and list the problem actions in a table. Then suggest a better, safer way to perform each action. After you have finished, share your observations with the class.

Figure 1.1 Students at work in the lab

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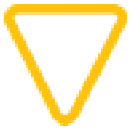
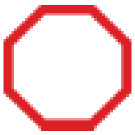
Symbol Shapes

These shapes and their colours indicate how dangerous a substance is.



caution

warning



danger

Safety Hazard Symbols

Before you do any activity in this unit, read the directions and look for "Caution" notes that will tell you if you need to take extra care. There are two areas of special consideration for people working in the lab: understanding warning labels and following safety procedures.

Some of the materials you will use in science activities are hazardous. Always pay attention to the warning labels, and follow your teacher's instructions for storing and disposing of these materials. If you are using cleaning fluids, paint, or other hazardous materials at home, read the labels for special storage and disposal advice.

All hazardous materials have a label showing a hazard symbol. You may have seen these labels on chemical substances in your kitchen or garage. For example, many kinds of window cleaner contain ammonia, which is toxic and corrosive. Car batteries contain sulfuric acid which is also toxic and corrosive, and lead which is toxic.

Each hazard symbol shows two separate pieces of information. The shape of the symbol indicates how hazardous a substance is. A yellow triangle means "caution," an orange diamond means "warning," and a red octagon means "danger." These shapes are shown in the infoBIT on this page. The second piece of information in the symbol is the type of hazard, which is indicated by the picture inside the shape. Figure 1.2 shows the common hazard warnings.

Figure 1.2 These symbols warn you of specific hazards.

WHMIS Symbols

The Workplace Hazardous Materials Information System—or **WHMIS**—is another system of easy-to-see warning symbols on hazardous materials. These symbols were designed to help protect people who use materials that might be harmful at work. Figure 1.3 shows eight WHMIS symbols.

In several activities in this unit, you will encounter the symbols for poisonous material, dangerously reactive material, and corrosive (or caustic) material. For example, hydrogen peroxide is very reactive and can burn your skin, and battery acid is corrosive. Treat both chemicals with extreme care whenever you use them.


compressed gas


dangerously reactive material


oxidizing material


poisonous and infectious causing immediate and serious toxic effects


flammable and combustible material


biohazardous infectious material


corrosive material


poisonous and infectious causing other toxic effects

Figure 1.3 WHMIS symbols

reSEARCH

MSDS

Materials and Safety Data Sheets (MSDS) are information sheets about specific chemicals. Find out what type of information is on the MSDS. Begin your search at www.pearsoned.ca/scienceinaction.

Understanding the Rules

TOOLBOX

When you perform science activities of any kind, it is very important to follow the lab safety rules shown below. Not following one or more of these rules could result in injury to you or your classmates. Your teacher will also discuss any specific rules that apply to your classroom. For more information on lab safety, see Toolbox 1.

Lab Safety Rules

TOOLBOX

1. Read all written instructions carefully before doing an activity.
2. Listen to all instructions and follow them carefully.
3. Wash your hands thoroughly after each activity and after handling chemicals.
4. Wear safety goggles, gloves, or an apron as required.
5. Think before you touch. Equipment may be hot and substances may be dangerous.
6. Smell a substance by fanning the smell toward you with your hand. Do not put your nose close to the substance.
7. Do not taste anything in the lab.
8. Tie back loose hair and roll up loose sleeves.
9. Never pour liquids into containers held in your hand. Place a test tube in a rack before pouring substances in it.
10. Clean up any spilled substances immediately as instructed by your teacher.
11. Never look into test tubes or containers from the top. Always look through the sides.
12. Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of broken glass.
13. Label any container you put chemicals in.
14. Report all accidents and spills immediately to your teacher.
15. If there are WHMIS (Workplace Hazardous Materials Information System) safety symbols on any chemical you will be using, make sure that you understand all the symbols. See Toolbox 1 at the back of this book.

Keep Safety in Mind

Remember that safety in the science class begins with you. Before you start any activity:

- Follow the safety instructions outlined by your teacher and in this textbook.
- Identify possible hazards and report them immediately.
- Show respect and concern for your own safety and the safety of your classmates and teachers.
- Read Toolbox 1: Safety in the Laboratory.

Check and Reflect

(a) (b) (c) (d)

Figure 1.4 Question 5. Warning labels on hazardous products.

Key Concept Review

1. Why is it important for all students to follow the safety rules while in a science class?
2. What does WHMIS stand for?
3. Why is there a need for a WHMIS program?
4. One area of special consideration for people working in a lab is understanding warning labels. What is the other special consideration?
5. What does each hazard warning label mean on the chemicals shown in Figure 1.4?

Connect Your Understanding

6. What type of WHMIS symbols would you expect to see on the following containers?
   a) a can of gasoline
   b) a tub of caustic cleaning chemical
   c) a bottle of oxygen gas
   d) a bottle of sulfuric acid
7. Explain the difference between WHMIS symbols and safety symbols used on commercial products.
8. List the steps a student should take before starting a science activity where safety is an issue.
9. Describe one problem that may occur with having different coloured safety symbols.

Extend Your Understanding

10. Divide the lab safety rules given on page 95 among members of your class. Have each person or group make a poster illustrating the rule. Display your safety posters in your classroom to remind everyone of the importance of following these rules.
11. What additional lab safety rules would you add to the list on page 95?

1.2 Organizing Matter

Matter exists as a solid, liquid, or gas. These are called the **states** of matter. The state of a substance—solid, liquid, or gas—depends on temperature.

Specific terms are used to describe changes of state in substances. A change from a solid to a liquid is **melting**. A change from a liquid to a gas is **evaporation** (also known as vaporization). A change from a gas to a liquid is **condensation** and from a liquid to a solid is **freezing**. A solid can also change directly into a gas; this process is called **sublimation**. A gas can change directly to a solid. This is called **deposition.**

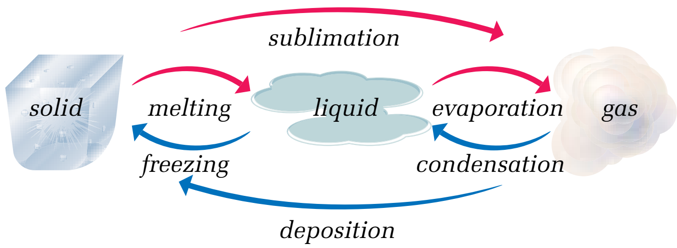


Figure 1.5 Changes in states of matter

To understand how substances differ, you need to observe their properties. **Properties** are characteristics that can be used to describe a substance. All matter has two types of properties: physical and chemical.

*info*BIT

Plasma

A fourth state of matter is the *plasma* state. Examples of plasmas are found in lightning, neon signs, and stars such as our Sun. Plasmas result when a large amount of energy is added to a gas.

*QUICK*LAB

Organizing the Properties of Matter

Purpose

To describe and classify materials by their properties

Materials & Equipment

- paper
- pencil
- scissors

Procedure

1. Cut a sheet of notepaper into eight equal pieces. These are your summary cards.
2. Your teacher will give you samples of the following materials: copper wire, vinegar, salad oil, aluminum foil, granite, graphite, rock salt, lemonade, and baking soda. At the top of each summary card, write the name of one of the materials (one card per material).
3. Study each material sample in turn, and write a short description of the material. Refer to as many different properties as you can to describe the material so you can show how it differs from the other materials you study.
4. Divide the materials into groups having similar properties. You should have at least four groups. Determine a name that best describes each of these groups, or classifications.

Questions

5. Compare your classification system with that of your classmates. What similar properties did everyone use? What different properties did everyone use?

Some Physical Properties of Matter

- colour
- lustre
- melting point
- boiling point
- hardness
- malleability
- ductility
- crystal shape
- solubility
- density
- conductivity

Physical Properties of Matter

A variety of **physical properties** can be used to identify matter. Two examples are colour and lustre (shininess). The temperature at which a substance melts is also a physical property. It's important to remember that when a substance undergoes a **physical change**, such as melting, its appearance or state may be altered, but its composition stays the same. Melted chocolate ice cream has the same composition as frozen chocolate ice cream. The table on page 99 lists several of the key physical properties used to describe matter.

Figure 1.6 This ice cream has undergone a physical change. Even though it has melted, its composition hasn't changed.

QUICKLAB

Observing a Physical Change

Purpose

To investigate a physical change and the factors that influence the rate of change

Procedure

1. Fill the two glasses about two-thirds full with soda pop.
2. Into one glass, drop a piece of the mint candy. Watch what happens in both glasses and record your observations.
3. Identify one variable you could manipulate to increase the rate of change that occurs.
4. Write a procedure to perform this test. Identify your control, the manipulated variable, and the responding variable. Also decide how you will measure your responding variable.
5. Ask your teacher to approve your procedure. Then, carry out the test.
6. Record your results.

Questions

7. Adding a candy to the pop causes a physical change to occur. The candy reduces the surface tension in the liquid, allowing gas to be released faster. Does the composition of the candy change after it is added to the pop?
8. Why were you required to fill two glasses with pop in step 1, but to add candy to only one glass in step 2?
9. What factors influenced the rate at which the gas was released from the pop? What data did you collect to support your answer?

Materials & Equipment

- soda pop
- 2 glasses (or large test tubes)
- chewy mint candy such as Menthos
- pencil and notebook

Some Physical Properties of Matter

Melting point	The melting point of a substance is the temperature at which it changes from a solid to a liquid. The melting point of ice is 0°C. At this temperature, it changes into water. Other substances have different melting points. For example, table salt melts at 801°C, and propane melts at −190°C.
Boiling point	The boiling point of a substance is the temperature at which its liquid phase changes to the gas phase. At sea level, water's boiling point is 100°C. Table salt boils at 1413°C, and propane boils at −42°C.
Hardness	Hardness is a substance's ability to resist being scratched. Hardness is usually measured on the Mohs' hardness scale from 1 to 10. The mineral talc is the softest substance on the scale (1). Diamond is the hardest (10). Figure 1.7 shows the scale.
Malleability	A substance that can be pounded or rolled into sheets is said to be **malleable**. Metals such as gold and tin are malleable. Aluminum foil is an example of a product made from a malleable substance.
Ductility	Any solid that can be stretched into a long wire is said to be **ductile**. The most common example of a ductile material is copper.
Crystal shape	The shape of a substance's crystals can help identify it. Silicon crystals, for example, are diamond shaped. Salt crystals form cubes.
Solubility	**Solubility** is the ability of a substance to be dissolved in another. For example, sugar is soluble in water, but cooking oil is not.
Density	**Density** is the amount of mass in a given volume of a substance. The density of water is 1 g/mL. The density of gold is 19 g/cm^3.
Conductivity	**Conductivity** is the ability of a substance to conduct electricity or heat. A substance that conducts electricity or heat is called a conductor. A substance with little or no conductivity is an insulator.

1	2	3	4	5
Talc	Gypsum	Calcite	Fluorite	Apatite

6	7	8	9	10
Feldspar	Quartz	Topaz	Corundum	Diamond

Figure 1.7 Mohs' hardness scale

Activity B-1

Inquiry

Identifying Mystery Substances

Materials & Equipment

- salt, baking soda, corn starch, sodium nitrate, sodium thiosulfate
- black paper
- hand lens
- water
- 5% acetic acid or 5% hydrochloric acid
- iodine solution
- wax paper or spot plate
- disposal containers

Figure 1.8 Step 7

The Question

How can the properties of a substance be used to identify it?

Procedure

Part 1—Examining Five Substances

1. Copy the table shown on the next page into your notebook.
2. Collect five substances from your teacher.
3. Perform the tests described below to identify the properties of the substances. You do not have to do the tests in the order shown below, but you must do all of them.
4. Make sure the data table is completely filled in before you begin part 2 of the activity.

Test 1—Appearance

5. Use one sheet of black paper for all your samples. Place a small amount of each powder in different places on the same sheet of black paper. Make sure that your powder samples are not touching each other.
6. Describe the appearance of each powder. Record your observations in the data table.

Test 2—Crystal shape

7. Use a hand lens or microscope to examine the grains of each powder. Record your observations in the data table.
8. Dispose of the powders and the black paper in the container provided.

Test 3—Behaviour in water

9. Use one large sheet of wax paper or a spot plate for all your samples. Place a small amount of each powder on the wax paper or spot plate.
10. Add a drop of water to each powder. Record your observations in the data table.
11. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 4—Behaviour in acid

12. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
13. Add a drop of 5% acetic acid solution or 5% hydrochloric acid solution to each powder. Record your observations in the data table.
14. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 5—Behaviour in iodine

15. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
16. Add a drop of iodine solution to each powder. Record your observations in the data table.
17. Dispose of the powders and the wax paper in the container provided. Clean the spot plate thoroughly.

Part 2—Identifying Unknown Substances

18 Collect an unknown sample from your teacher. Record the letter or number of the sample in the data table next to the word "unknown."

19 Determine the properties of the unknown sample by repeating the five tests above, and record your observations in the data table.

Analyzing and Interpreting

20 For each substance, one or two tests clearly identified it as being unique from the other substances. What were those tests for each of the white powders?

21 Were some tests more useful than others? Explain your answer.

22 Were the results of some of the tests confusing? Explain your answer.

23 What substance or substances were in your unknown sample?

Forming Conclusions

24 Describe how you inferred what substance or substances were in your unknown sample. Use your data to support your conclusions.

Applying and Connecting

Knowing the properties of a substance is essential to finding practical uses for it. For example, corn starch can be used to make glue. If corn starch is cooked with an acid, a sticky, adhesive substance is produced. A similar substance can be produced from the solid materials that form after acid is added to milk. This substance is called *casein*. Casein can be mixed with a basic solution to form a strong glue.

Substance	State	Appearance	Crystal Shape	Behaviour in Water	Behaviour in Acid	Behaviour in Iodine
salt						
baking soda						
corn starch						
sodium nitrate						
sodium thiosulfate						
unknown						

Chemical Properties of Matter

A **chemical property** describes how a substance interacts with other substances such as acids. Chemical properties are observable only when a chemical change occurs. A **chemical change** always results in the formation of a different substance or substances. For example, if you make pancakes, you mix together flour, milk, baking powder, sugar, and other ingredients, each with its own set of physical properties. When you cook them, however, they form a completely new substance—a pancake. The pancake has different properties from those of its ingredients.

Chemical Properties of Matter—Examples

- reaction with acids
- ability to burn
- reaction with water
- behaviour in air
- reaction to heat

Figure 1.9 Cooking the pancake ingredients changes them into a different substance.

Pure Substance or Mixture?

All matter is either a pure substance or a mixture. Physical and chemical properties show us whether a substance is "pure" or a mixture.

Types of Pure Substances

A **pure substance** is made of only one kind of matter and has a unique set of properties that sets it apart from any other kind of matter. Mercury and sugar are two examples. A pure substance may be either an element or a compound.

- An **element** is a material that cannot be broken down into any simpler substance. Elements are the basic building blocks for all compounds. Later in this unit, you will learn how elements are organized into a **periodic table** according to their properties. Each element has its own symbol. For example, hydrogen is H, carbon is C, and oxygen is O.
- When two or more elements combine chemically—that is, in specific, fixed proportions—they form a **compound**. When the elements hydrogen and oxygen are combined in specific proportions, they form the compound water. Carbon and oxygen chemically combined form the compound carbon dioxide, the gas that is used to create the "fizz" in carbonated drinks. Later in this unit, you will learn that compounds have chemical names and formulas. For example, water is H_2O and carbon dioxide is CO_2.

The structural composition of elements and compounds is discussed further in Section 2.0.

Types of Mixtures

A **mixture** is a combination of pure substances. However, the substances in a mixture do not combine chemically as happens when a compound is formed. They remain in their original, pure form, even though they are not always easy to see distinctly once the mixture is made. There are four main types of mixtures:

- In a **mechanical mixture**, the different substances that make up the mixture are visible. Soil is an example of a mechanical (or *heterogeneous*) mixture. So is a package of mixed vegetables.
- In a **solution**, the different substances that make it up are not separately visible. One substance is dissolved in another, creating what looks like one *homogeneous* substance. Examples of solutions are shown in the table below.

Type of Solution	Example
Solid dissolved in liquid	sugar in hot coffee
Liquid dissolved in liquid	acetic acid in water (to create white vinegar)
Gas dissolved in liquid	carbon dioxide gas in water (to create carbonated pop)
Gas dissolved in gas	oxygen and smaller amounts of other gases in nitrogen (in the atmosphere)
Solid dissolved in solid	copper in silver (to create sterling silver)

Figure 1.10 You use many different kinds of mixtures and solutions each day.

Chemists call a substance dissolved in water an **aqueous solution**. Examples include fresh water, vinegar, and cleaning solvents.

- A **suspension** is a cloudy mixture in which tiny particles of one substance are held within another. Tomato juice is an example of a suspension. These particles can be separated out when the mixture is poured through filter paper.
- A **colloid** is also a cloudy mixture, but the particles of the suspended substance are so small that they cannot be easily separated out from the other substance. Milk and ketchup are examples of colloids.

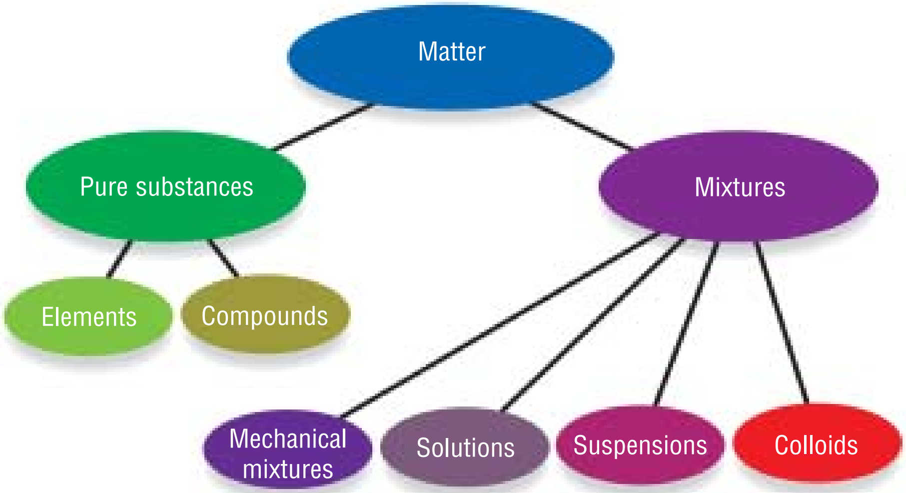


Figure 1.11 Classifying matter

reSEARCH

Other Types of Mixtures

Gels are colloids used in beauty products. Find out how these types of mixtures are created, and how they are used in various applications. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What physical properties could be used to describe a substance?
2. Give two examples to illustrate the difference between a physical and a chemical property.
3. How is an element different than a compound? Give an example of each.
4. What is the difference between a pure substance and a mixture?
5. How is a suspension different from a colloid?

Connect Your Understanding

6. The melting and boiling points of five chemical substances are shown in the table below. What state of matter does each exist in at room temperature (about 20°C)?

Substance	Melting Point (°C)	Boiling Point (°C)	State at Room Temperature
water	0	100	
oxygen	−218	−183	
ammonium nitrate	170	210	
ethanol	−117	79	
mercury	−39	357	

7. What physical property is described by each of the following statements?
   a) Solid oxygen melts at −218°C.
   b) A penny cannot scratch glass.
   c) Silver is shiny.
   d) Gold can be made into thin sheets.
   e) Both aluminum and copper can be used for making wire.
8. Classify the following substances as an element, compound, or mixture:
   a) Pop is composed of water, sugar, and carbon dioxide.
   b) Graphite in a pencil is composed of carbon.
   c) Carbon dioxide is composed of carbon and oxygen.
9. Someone sprinkles dilute acetic acid over your French fries. Are they safe to eat? Explain your answer.

Extend Your Understanding

10. Create a concept map to illustrate the different categories of matter. Use the following terms: matter, solution, element, homogeneous mixture, heterogeneous mixture. Include an example of each in your map.
11. Find out how mixtures can be modified to meet human needs. For example, a substance obtained from the sea weed carrageen is added to many brands of ice cream as a thickener.

1.3 Observing Changes in Matter

Think about the changes in matter you have observed in nature and elsewhere. For example, in the spring, you can see ice—solid water—become liquid water. At home, you can heat water in a kettle and watch it vaporize as steam. These changes are easy to see, but others are not. For example, the hemoglobin which carries oxygen in your blood changes colour when carbon dioxide and oxygen are exchanged in your lungs.

As you learned in section 1.2, changes in matter are classified as physical or chemical. A **physical change** is one in which a material changes from one state to another. The material can also physically change back into its original state. When frozen apple juice is thawed, it melts from a solid to a liquid. If you refreeze the juice, it will turn back into a solid. Its composition will remain the same in all states.

A **chemical change** occurs when two or more materials react and create new materials. The new materials have completely different properties from the original substances. How can you tell when a chemical change is underway or has taken place? The main pieces of evidence to look for are changes in colour, odour, state, or thermal energy during, or as a result of, the reaction between the original substances. Examples are shown below:

Evidence of Chemical Change	Example
Change in colour	When bleach is added to the dye on a denim jacket, a noticeable colour change occurs.
Change in odour	When a match is struck, the substances in the match head react and give off a distinctive odour.
Formation of a solid or gas	When vinegar (a liquid) is added to baking soda (a solid), carbon dioxide gas is formed.
Release or absorption of heat energy	When gasoline burns in a car engine, heat is released.

Sometimes, it can be unclear whether a material's change in state means that a chemical or a physical change has occurred. In such situations, chemical analysis in the lab is required to confirm the nature of the change.

*info*BIT

Detecting Changes in Blood

Canadian scientist Imant Lauks invented a device called the I-Stat. In 2 min, this device can perform 12 different tests to identify changes that have occurred in a person's blood. This process used to take hours or days.

SKILL PRACTICE

Identifying Physical and Chemical Changes

For each example in Figure 1.12, identify the change shown as either a physical change or chemical change. If you are not sure what type of change is happening, note that. Review all the examples again when you have finished working through this section.

(a) (b) (c) (d) (e)

Figure 1.12(a–e)

ACTIVITY B-2

Inquiry

INVESTIGATING PHYSICAL AND CHEMICAL CHANGES

The Question

What are some characteristics of physical changes and chemical changes?

Materials & Equipment

- sodium carbonate
- 250-mL beaker
- dilute hydrochloric acid
- aluminum foil
- sugar
- candle
- Plasticine
- matches
- wooden clothespin or tongs
- 3 test tubes
- sodium carbonate solution
- copper(II) sulfate solution
- 5-mL measuring spoon
- test-tube holder
- copper(II) sulfate (solid)
- water
- stirring rod

Caution!
Make sure long hair and loose clothing are tied back.

Caution!
Copper(II) sulfate is poisonous and can stain your clothes and skin.

Procedure

1. You will investigate four different reactions described below.
2. Copy the data table shown on the next page into your notebook. Fill it in as you complete each test.

Test 1—Sodium carbonate and hydrochloric acid

3. Put a pea-sized pile of sodium carbonate into a small beaker or plastic cup. In your data table, describe the appearance of the sodium carbonate.
4. Observe the dilute hydrochloric acid. If you are unable to see inside the container, use a clear eyedropper to remove a small sample of the acid. Record your observations.
5. Predict what you think will happen when you add the dilute hydrochloric acid to the sodium carbonate.
6. Add 5 to 8 drops of dilute hydrochloric acid to the sodium carbonate. Record your observations.

Test 2—Sugar and heat

7. Use a piece of aluminum foil to make a small cup shape. Put a pea-sized pile of sugar into the centre of the aluminum cup. In your data table, describe the appearance of the sugar.
8. Predict what you think will happen when the sugar is heated.
9. Stand a candle securely in some Plasticine, and light the candle.
10. Using tongs or a wooden clothespin, hold the aluminum cup containing the sugar over the candle's flame. Slowly move the cup back and forth over the flame to heat the sugar. Record your observations.
11. When you are finished, place the aluminum cup in a safe place to cool.

Test 3—Copper(II) sulfate and sodium carbonate

12. Place 5 mL of copper(II) sulfate solution in a test tube. Place 5 mL of sodium carbonate solution in another test tube. In your data table, describe the appearance of each solution.
13. Record your prediction of what will happen when the two solutions are combined.
14. Combine the two solutions and record your observations.
15. When you are finished, dispose of the solution as directed by your teacher.

Test 4—Copper(II) sulfate and water

16 Place a pea-sized pile of copper(II) sulfate in a clean test tube and place the test tube in a holder. In your data table, record the substance's appearance.

17 Record your prediction of what will happen when water is added to the copper(II) sulfate.

18 Add 15 mL of water and record your observations. Use a stirring rod to mix the water and copper(II) sulfate. Record your observations.

Figure 1.13 Test 4

Analyzing and Interpreting

19 Which of the changes that you observed were physical?

20 What observations helped you identify a physical change?

21 Which of the changes that you observed were chemical?

22 What observations helped you identify a chemical change?

Forming Conclusions

23 Create a summary, chart, or picture to illustrate the observations you might make to describe the characteristics of a chemical change and a physical change.

Change	Observations before Change	Predictions	Observations during Change	Observations after Change	Type of Change (Physical or Chemical)
Station 1: Sodium carbonate and dilute hydrochloric acid					
Station 2: Sugar and heat					
Station 3: Copper(II) sulfate and sodium carbonate					
Station 4: Copper(II) sulfate and water					

Controlling Changes in Matter to Meet Human Needs

In our everyday life, there are many examples of how understanding and controlling changes in matter help us meet our basic needs. One example you might be interested to read about is the freeze-drying of foods. Freeze-drying is a way to preserve foods so that they can be eaten months—and sometimes even years—later. As well, freeze-drying makes foods easy to prepare—all you have to do is add hot water.

In the freeze-drying process, the food is first frozen to convert the water content in the food to ice. The frozen food is then put in a pressure chamber and the pressure is reduced until the ice sublimes (changes from a solid to a gas). The result is that about 98% of the water in the original food item is removed. This leaves a food that is about 10% its original mass and that, once packaged, doesn't have to be refrigerated. When it's time to eat, all you do is stir in hot water!

Figure 1.14 If you've ever kayaked, you know the importance of keeping your supplies as light as possible. Freeze-dried foods weigh little and take only minutes to prepare.

Figure 1.15 A highly magnified photo of a "freeze-fractured" cell. In this process, plant or animal tissue is rapidly frozen. The ice formed within each cell is then removed by various evaporation techniques. The result is a clearly revealed cell structure: nucleus, pores, and membrane.

The technique of freeze-drying is also used by biologists to study tissue samples and by restoration experts to rescue important documents that are water damaged.

Another process, developed by the U.S. Army, makes freeze-dried food even more convenient. Instead of having to be heated over a fire or portable stove, the "Meal, Ready to Eat" (also referred to as an MRE) is heated in a special package called a "Flameless Ration Heater." This makes MREs especially useful for soldiers, astronauts, and mountain climbers. To be warmed up, the freeze-dried MRE is placed in the Flameless Ration Heater pouch. The pouch contains magnesium, iron, and salt. When a little water is added to these chemicals, the resulting chemical change releases heat—enough to warm the freeze-dried contents.

From Corn to Nail Polish Remover and Plastic Wrap?

Scientists are also able to change common materials into other useful products. For example, chemicals made from corn can be used to make soda pop bottles, remove paint or nail polish, and fuel some cars. Corn is put through a chemical change called fermentation. Once this chemical process is complete, the new substances are recovered, purified, and made into biodegradable plastics, solvents, and gasohol. Corn-based biodegradable plastics such as bottles and plastic wrap are better for the environment because they can be decomposed by bacteria. Corn-based solvents for removing paint and nail polish are not as harmful to the environment as other types of solvents. Gasohol provides a renewable type of fuel for automobiles.

reSEARCH

What Makes a Match Light?

When a match burns, the wood or paper undergoes combustion, but how does the match ignite? Find out about the chemical reactions that occur when a match is lit. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is the difference between a chemical change and a physical change?
2. Copy the following table into your notebook and fill in the blanks:

Event	Changes in Matter	
	Observable Changes	**Type of Change**
Baking bread		
Burning wood		
Freezing water		
Mixing sugar and water		

Connect Your Understanding

3. Describe three indicators of a chemical change. Include examples of each.
4. An unknown white solid is heated for 1 min. It is observed that (a) the solid disappears, leaving a colourless liquid; and (b) after the liquid cools, a white solid appears. What kind of change is this? Explain the reason for your choice.
5. Describe an example of how humans control changes in matter to meet their basic needs.

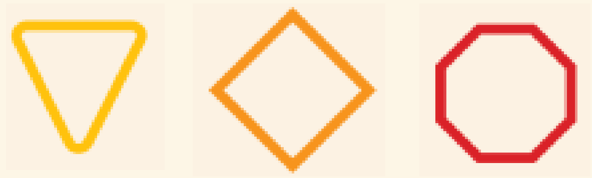
Extend Your Understanding

6. Find one example of a physical change and one of a chemical change not discussed in this section. Share your findings with the class.
7. Is popping popcorn a physical or chemical reaction? Explain your answer.

Assess Your Learning

Key Concept Review

1. Define matter.
2. What do the following symbol shapes represent?

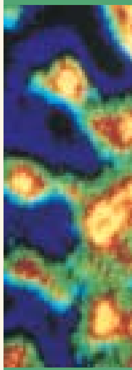


3. Why does everyone working with hazardous materials use WHMIS?
4. Create a diagram illustrating the different states of matter. Name the process that makes the change in state possible.
5. Name at least six properties of matter that can be used to describe a substance.
6. Identify each of the following as either a physical or a chemical change:
   a) Acid is dropped on limestone and bubbling occurs.
   b) Snow turns into rain just before it reaches the ground.
   c) A strip of magnesium is ignited, and it burns brightly.
   d) Solid carbon dioxide, or dry ice, sublimes into carbon dioxide gas.
7. Define the terms physical change and chemical change. Include the words *water*, *baking soda*, *sugar*, and *vinegar* in your definitions.
8. Describe the four main types of mixtures that can be formed.
9. Explain the difference between deposition and freezing.
10. List three examples of physical changes you have observed today.

Connect Your Understanding

11. Describe two occupations in which knowledge of WHMIS is important.
12. What safety symbol would appear on the following?
    a) an aerosol can of hair spray
    b) an agar plate of bacteria culture
    c) a 4-L jug of bleach
    d) a gasoline can
13. What WHMIS symbol would be used in each case listed in question 12?
14. Compare and contrast physical properties with chemical properties.
15. What physical properties could be used to identify the following?
    a) copper metal
    b) water

SECTION REVIEW



16. Using the classification of matter chart as a guide (Figure 1.11), create a classification system for the following substances: chocolate chip cookies, coffee with milk in it, aluminum foil, potting soil, a gold medal, pizza, sugar, and garbage. Be sure to list the properties you used to guide your classification.
17. Explain the difference between a suspension and a colloid.

Extend Your Understanding

18. Why are there two different sets of safety symbols for labelling chemicals?
19. Your class is going to be doing a chemistry experiment with a grade 1 class. You are partnered with two students from the younger class. What would you tell them about safety before the activity begins?
20. You are given three unlabelled containers, each with a white powder. Your teacher tells you that the powders could be baking soda, corn starch, or sodium nitrate. Describe the chemical tests you need to perform to identify each powder.

Focus On THE NATURE OF SCIENCE

The goal of science is to develop knowledge about our natural world. This includes knowledge about the nature of substances, how they interact to form new substances, and how these interactions can be controlled and used in a practical way. Working with a partner or the whole class, consider the following questions:

1. Identify an example of a physical change. How do you know a physical change has occurred? What evidence do you have?
2. Identify an example of two or more substances interacting to produce a chemical change. How do you know a chemical change has occurred? What evidence do you have?
3. Describe several chemical changes that you think are useful either to you personally or to society in general. What characteristics or properties of each of these reactions make them useful?

2.0

An understanding of the nature of matter has developed through observations over time.

Key Concepts

In this section, you will learn about the following key concepts:

- substances and their properties
- elements, compounds, and atomic theory
- periodic table

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between observation and theory, and provide examples of how models and theoretical ideas are used in explaining observations
- demonstrate understanding of the origins of the periodic table, and relate patterns in the physical and chemical properties of elements to their positions in the periodic table
- use the periodic table to:
  - identify the number of protons and electrons in each atom, as well as other information about each atom
  - describe the relationship between the structure of atoms in each group and the properties of elements in that group

Humans have been warming themselves around campfires for thousands of years. You may have sat around a campfire and enjoyed the heat. You may even have cooked over a fire. What do you think early humans might have wondered about this mysterious flame that gives off heat and light? Some of them likely puzzled over why fire turns wood black or makes it smell different. Maybe they would have wondered what happened to the wood after the fire had burned out. By being curious about the world around them, these people were the first to try to learn more about substances and how they behave.

In this section, you will learn how our understanding of matter has changed over time. As you read, you will begin to appreciate how asking questions is a key first step we use in making sense of our world. Then, from our observations and experiments, we develop theories and build models to predict and explain what we see. We test these, adjust them, try out new ideas, and eventually reach what seems to be the reasonable answers to our questions. It all begins with curiosity.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 Evolving Theories of Matter

As people observe the natural world around them, they try to make sense of their observations by suggesting explanations. They develop theories to explain what they see. Over time, the theories are modified as new evidence is discovered. The understanding of the structure of matter grew in this way.

Stone Age Chemists

The first chemists lived before 8000 B.C. in an area now called the Middle East. This period is known as the Stone Age because humans used only simple stone tools at the time. Metals had not been discovered.

Once these first chemists learned how to start and control fire, they learned how to change a range of substances to their advantage. For example, they could cook their food, fire-harden mud bricks to strengthen them, and make tougher tools. Eventually this ability to control fire led to the production of glass and ceramic material.

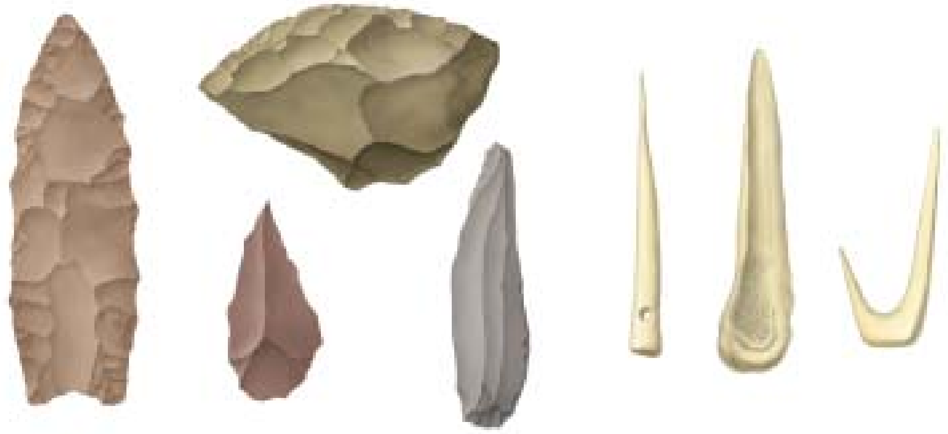


Figure 2.1 Humans in the Stone Age could make only simple stone and bone tools like these. Stone Age people improved their lives when they discovered how to start and control fires. They used fire mainly for cooking and warmth.

GIVE IT A TRY

Creating a Time Line Story of Matter

In this subsection, you will be learning how our understanding of the structure of matter has developed through history.

1. Make a time line that shows when the key ideas were proposed and who proposed them. Start your time line at 8000 B.C. and add to it as you read through the subsection. For each idea, be sure to include the observations the person made that led to the new theory.
2. Beneath your time line, sketch the model that resulted from the key idea.
3. Mark the final point in your time line "Today." Draw a diagram beneath this that shows your own understanding of the structure of matter.

Early Interest in Metals and Liquid Matter

Between 6000 B.C. and 1000 B.C., early chemists investigated only materials that had a high value to humans. Many of these materials were metals, such as gold and copper. Gold became highly valued because of its properties. It had attractive colour and lustre, and it didn't tarnish. Its softness made it easy to shape into detailed designs, form into wire, and beat into sheets. Because it is so soft, however, gold could not be used for tools or weapons.

Figure 2.2 The earliest use of gold was in jewellery, but it later became very important in the making of coins.

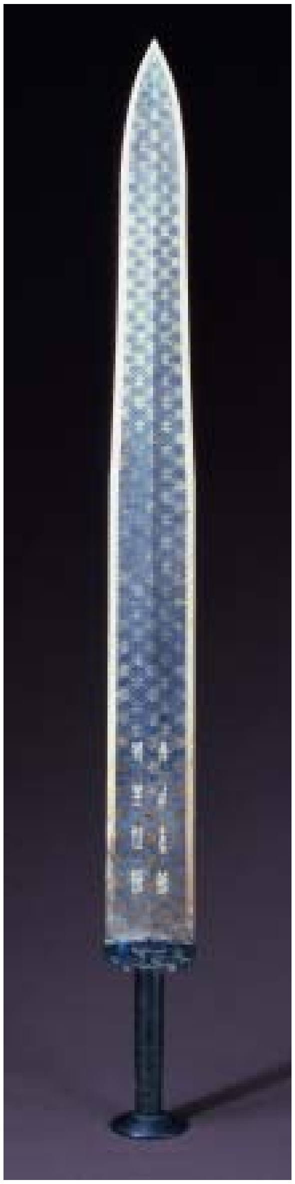


Figure 2.3 An ornate bronze sword dating from about 600 B.C.

Copper became valuable because it could be used to make pots, coins, tools, and jewellery. It was early chemists asking questions that led to an understanding of copper's properties and how the material could be controlled. A piece of natural, untreated copper is brittle—that is, it breaks easily. In that state, therefore, it isn't a useful material for making things. However, when copper is heated, it becomes very useful because it can be rolled into sheets or stretched into long wires.

The original discovery of the effect of heat on copper was possibly accidental. A chunk of copper may have fallen into a fire and whoever picked it out may have asked: Has the copper changed because it was heated? Testing it would have revealed how much softer it was and that it was less likely to shatter when hammered. Later experimenting with copper (about 4500 B.C.) led to the creation of a hard, strong material known as bronze, which is produced when copper and tin are heated together.

Figure 2.4 The discovery of copper's usefulness (such as in these copper spearheads) is a good example of how asking questions leads to scientific and technological development.

Around 1200 B.C., a group of people in the Middle East called Hittites discovered how to extract iron from rocks and turn it into a useful material. The Iron Age began. Eventually, people learned to combine iron with carbon to produce an even harder material—steel. Steel meant sharper blades could be fashioned for hunting and stronger armour could be built to protect soldiers in battle.

Metals were not the only form of matter that early people wanted to learn more about. Many cultures investigated the ways of extracting and using different types of liquids. Juices and oils were especially important both in everyday life and in rituals. (In fact, the word "chemistry" may be derived from the Greek word *khemeia*, meaning juice of a plant.) In ancient Egypt, human bodies were preserved after death by being wrapped in cloths soaked in natural pigments and resins from the juniper tree. Figure 2.6 shows a mummy preserved with this technique.

Figure 2.5 The knowledge and ability to process iron and use it to make stronger tools and weapons changed human society greatly.

Figure 2.6 The ancient Egyptians developed techniques for extracting and purifying juices and oils to use in mummifying bodies.

*re*SEARCH

Discovering Different Metals

Other metals besides gold and copper have also been long known. Find out when tin, silver, lead, and mercury were discovered and how they were first used. Begin your research at www.pearsoned.ca/scienceinaction.

Thinking About Matter

The first people who developed theories about the structure of matter were philosophers. Philosophers are people who think about the world and humans' place in it. Rather than performing experiments on the nature of matter, early philosophers just thought about the structure of matter. Their explanations and theories were based on their ideas, not on experimental evidence.

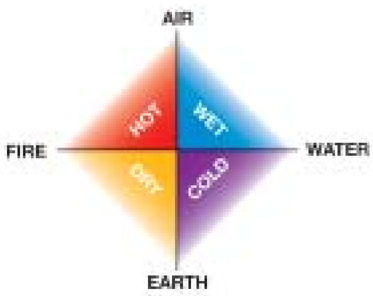


Figure 2.7 Until about A.D. 1600, most people believed Aristotle's view that matter was made up of earth, air, fire, and water. Each of these elements had two main features. For example, water was wet and cold, and earth was dry and cold.

Emerging Ideas About the Composition of Matter

The idea that all matter is made up of particles started with the Greek philosophers about 2500 years ago. They observed that a rock could be broken into smaller and smaller pieces until it became a powder. But, they asked, how many times could you continue to break the particles of powder down until they couldn't be broken down any more? In about 400 B.C., the Greek philosopher Democritus used the word *atomos* to describe the smallest particles that could not be broken further. *Atomos* means "indivisible."

Democritus stated that each type of material was made up of a different type of *atomos*. These different particles, he believed, gave each material its own unique set of properties. By mixing different *atomos*, you could make new materials with their own unique properties. However, in about 350 B.C. another Greek philosopher, Aristotle, supported a different hypothesis. He stated that everything was made of earth, air, fire, and water. Because Aristotle was well known and well respected, his description of matter was preferred over Democritus's description for 2000 years.

From Alchemy to Chemistry

For the next 2000 years after Democritus's time, experiments with matter were mainly carried out by alchemists, people who were part magician, part scientist. (The word "alchemy" comes from the Arabic word *al-kimiya*, which translates as "the chemist.") Today, the study of alchemy would be called a pseudo-science (an activity that is not a real science because it includes the use of magic). Alchemists believed that it should be possible to change metals into gold. They were not interested in understanding the nature of matter.

Figure 2.8 Alchemists continued in their search for a way to make gold until about 1600.

Even though they weren't real scientists, alchemists performed some of the first chemistry experiments. In doing so, they invented many useful tools that we still use in labs today, such as beakers and filters. They also made practical discoveries. For example, the Arab alchemist al-Razi discovered what we now call plaster of Paris—a material that today's doctors still use to hold broken bones in place until they heal. In 1597, the German alchemist Andreas Libau published *Alchemia*, a book describing the achievements of alchemists. In it, however, Libau also explained how to prepare chemicals such as hydrochloric acid. This type of information made his book the first chemistry text ever printed.

Figure 2.9 Plaster of Paris is a white, powdery combination of chemical substances that, when mixed with water, becomes a quick-hardening paste.

New Interest in Atoms

From the late 1500s on, people investigating the world around them became more like scientists today. They had a greater interest in understanding the nature of matter and change than the alchemists had. And, unlike the philosophers, they based their theories on observations and experimentation.

In the 1660s, Robert Boyle experimented with the behaviour of gases. He was interested in what happened when gases were placed under pressure. He was also interested in determining the composition of gases and other substances. Through his experiments and observations, Boyle became convinced that matter was made up of tiny particles, just as Democritus had suggested in about 400 B.C.

Boyle believed that the tiny particles, existing in various shapes and sizes, would group together in different ways to form individual substances. Boyle felt that the purpose of chemistry was to determine the types of particles making up each substance.

Figure 2.10 Robert Boyle was an Irish aristocrat living in London. He devoted his life to scientific inquiry.

Chemistry Develops as a New Science

In the 1770s, the French scientist Antoine Laurent Lavoisier studied chemical interactions. By the late 1780s, he had developed a system for naming chemicals. This was significant, for now all scientists could use the same words to describe their observations. That made it easier to compare the results of their experiments. Using his naming system, Lavoisier defined some of the substances discovered to that time, including hydrogen, oxygen, and carbon.

Because of his experimental and theoretical work, Lavoisier is called the "father of modern chemistry." Unfortunately, he supported the losing side during the French Revolution and was executed by guillotine in 1794. After his death, Lavoisier's wife, Marie, continued his work. She had worked with him as his lab assistant.

Figure 2.11 Antoine Laurent and Marie Lavoisier worked together conducting scientific investigations into chemical interactions.

An Atomic Theory Takes Shape

In 1808, English scientist John Dalton used the observations from his experiments to develop his own theory of the composition of matter. Dalton suggested that matter was made up of elements. He was the first to define an element as a pure substance that contained no other substances. Gold, oxygen, and chlorine are examples.

Dalton also put forward the first modern theory of atomic structure. He stated that each element is composed of a particle called an **atom**. All atoms in a particular element, he said, are identical in mass, and no two elements have atoms of the same mass. For instance, all oxygen atoms have the same mass, which is different from the mass of chlorine atoms. Dalton's model is sometimes called the "billiard ball model" because he thought of the tiny atoms as solid spheres. While some of Dalton's ideas were later modified based on new evidence, his basic description of the structure of an element was correct.

Figure 2.12 In John Dalton's theory, atoms are like solid billiard balls. The atoms of each element have a different mass than atoms in other elements.

Adding Electrons to the Atomic Model

Dalton's work on the structure of the atom was continued by British physicist J.J. Thomson. He is credited with being the first person to discover a subatomic particle (a particle smaller than an atom). Thomson, experimenting with cathode rays, concluded that the rays were made up of streams of negatively charged particles. He showed that these particles were much smaller in mass than even a hydrogen atom. He named them **electrons**. Although Thomson inferred that these invisible electrons were part of atoms, many people did not agree with him at first. They believed that atoms were the smallest particle of matter and could not be broken down further.

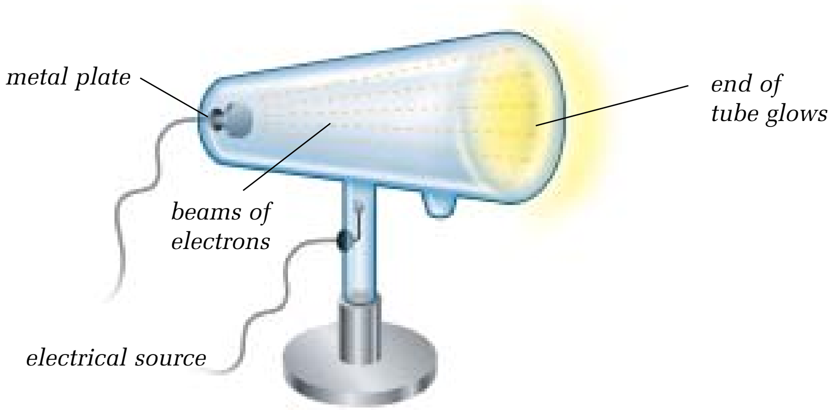


Figure 2.13 Cathode rays are produced when a piece of metal is heated at one end of a tube containing a gas. The heated metal sends out a stream of electrons toward the opposite end of the tube, causing the end of the tube to glow. Early scientists used a simple tube like the one shown here. Cathode ray tubes are now used in electrical devices such as televisions.

In 1897, Thomson proposed what is called the "raisin bun model" of the atom. He described the atom as a positively charged sphere in which negatively charged electrons were embedded like raisins in a bun. Figure 2.14 shows one way of representing this model. The negative electrons balance the positive sphere, so the whole atom has no electrical charge.

In 1904, the Japanese physicist Hantaro Nagaoka refined the model of the atom further. In his model, the atom resembled a miniature solar system (Figure 2.15). At the centre of the atom was a large positive charge. The negatively charged electrons orbited around this charge like planets orbiting around the Sun. Most scientists of the day did not agree with this model because existing theories could not explain it.

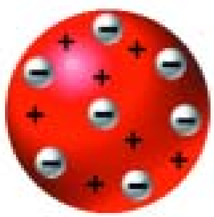


Figure 2.14 J.J.Thomson's model was the first one that described particles smaller than atoms. This model represented the atom as a positive sphere with electrons scattered throughout it—like raisins mixed in a baked bun.

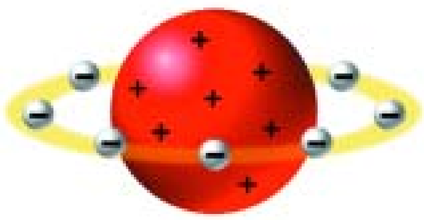


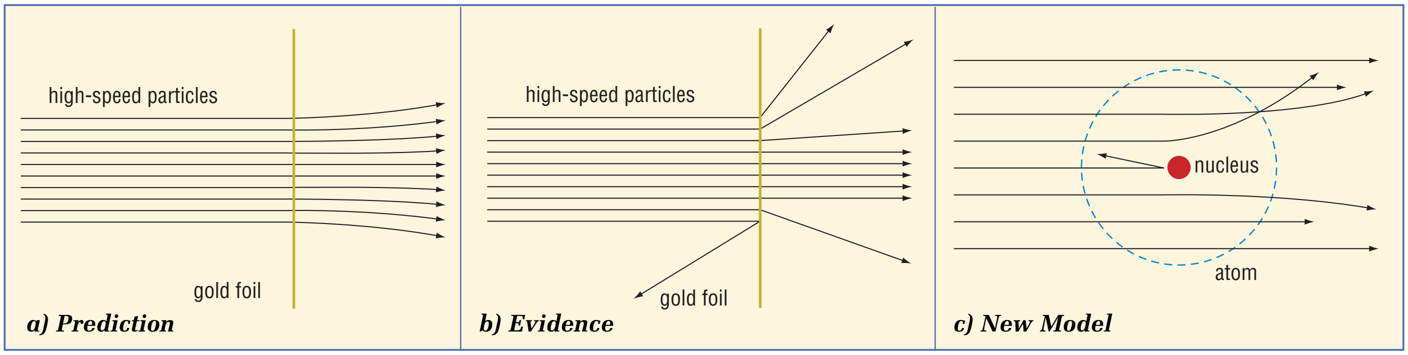
Figure 2.15 Hantaro Nagaoka's model showed the atom as a positive sphere around which electrons orbited in a ring, like Earth orbiting the Sun.

A Canadian Contribution to Atomic Theory

Support for the Nagaoka model and the idea of a central nucleus came from the British scientist Ernest Rutherford. Rutherford won a Nobel Prize in 1908 for his work in radioactivity, which he carried out at McGill University in Montreal from 1898 to 1907. This work contributed to the development of his model of the atom.

Using Thomson's model, Rutherford conducted experiments in which he shot positively charged particles through thin gold foil. He predicted that all the high-speed particles would pass straight through the foil without being affected by the gold atoms (Figure 2.16a). Instead, the results showed that while most particles did behave as predicted, some were greatly deflected (Figure 2.16b). To explain why this might happen, Rutherford proposed a new model. He suggested that atoms were mainly empty space through which the positive particles could pass, but at the core was a tiny positively charged centre. This he called the **nucleus** (Figure 2.16c). He also calculated that the nucleus was only about 1/10 000th the size of the atom—like a green pea in a football field.

Figure 2.16 From experiments with high-speed particles, Ernest Rutherford was able to infer the existence of an atom's nucleus.



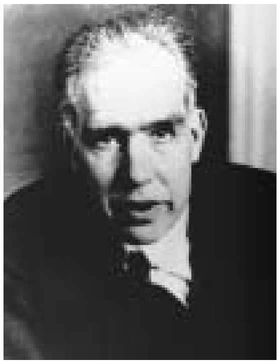


Figure 2.17 Niels Bohr was only 28 when he published his theory of the atom in 1913. In 1922, he won the Nobel Prize in physics.

Bohr's Model

It was Danish researcher Niels Bohr who, working with Rutherford, suggested that electrons do not orbit randomly in an atom. Bohr said that they move in specific circular orbits, or **electron shells**, as shown in Figure 2.18. He believed that electrons jump between these shells by gaining or losing energy. For his work in studying the atom, Bohr won the Nobel Prize in physics in 1922.

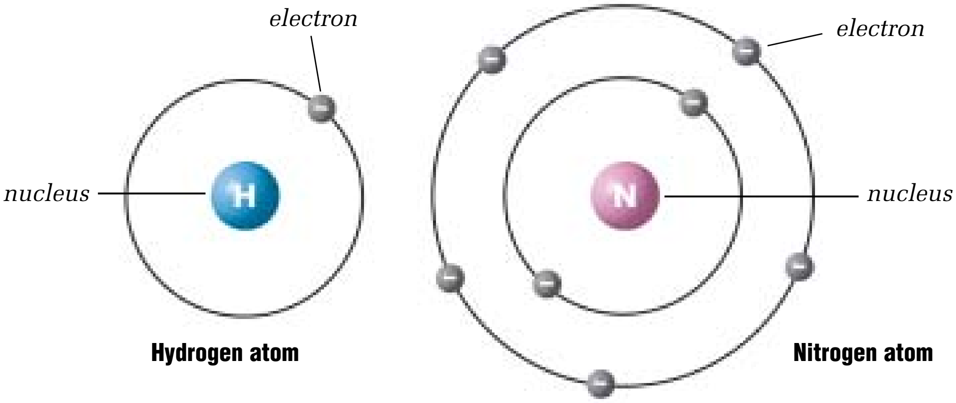


Figure 2.18 Bohr's model of the atom. Electrons orbit the nucleus in a regular pattern.

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The Quantum Atom

Find out more about the quantum nature of the atom. Use print and electronic resources to learn about orbitals and electron clouds. Begin your research at www.pearsoned.ca/scienceinaction.

Bohr's model was readily accepted, though with further refinements, by James Chadwick, another British physicist. Chadwick discovered that the nucleus contained positively charged particles called **protons**, and neutral particles called **neutrons**. The neutron has about the same mass as the proton but carries no electrical charge. An electron has only 1/1837th the mass of either a proton or a neutron.

Today, most people still use the Bohr model to describe the particles that make up the atom. However, further research in the area of quantum mechanics has found that the structure of the atom is different again from that model. The quantum mechanics model of the atom describes electrons as existing in a charged cloud around the nucleus, shown in Figure 2.19.

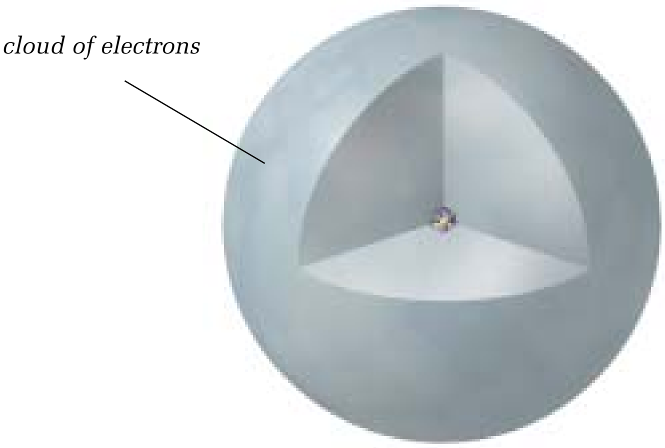

Figure 2.19 Today's quantum mechanics model describes the atom as a cloud of electrons surrounding a nucleus.

Check and Reflect

Key Concept Review

1. Gold and copper were the first forms of matter investigated by humans. Explain why.
2. Where did the word "chemistry" come from?
3. How did Democritus define the atom?
4. Why is Antoine Laurent Lavoisier considered to be the "father of chemistry"?
5. Name four examples of matter other than gold and copper that have been studied because of their value.

Connect Your Understanding

6. Describe one practical example of alchemists' work.
7. Explain the difference between J.J. Thomson's model of the atom and Ernest Rutherford's model.
8. Draw a diagram of Niels Bohr's atom, labelling the position of the three subatomic particles.
9. What was the significance of the work done by Andreas Libau?
10. What made Robert Boyle's study of matter different from the previous work done by philosophers?
11. What changes were made to Thomson's "raisin bun model"? What ideas of his remained the same?

Extend Your Understanding

12. Do you agree or disagree with the statement "In prehistoric times, people understood very little about matter"? Explain your answer.
13. Imagine you had interviewed one of the philosophers, alchemists, or scientists responsible for developing our understanding of the structure of matter. Write a one-page interview with that person.
14. Compare Boyle's model of the atom with Rutherford's model. Use a diagram and a brief description to support your comparison.
15. Scientists, like most people, have lives outside their work. Select one of the scientists discussed in this subsection and write a short biography about his or her life outside of science. Be prepared to read your biography to the class.
16. Innuit peoples are believed to have been using copper long before Europeans arrived in North America. Find out more about the Copper Inuit and present your findings to the class.

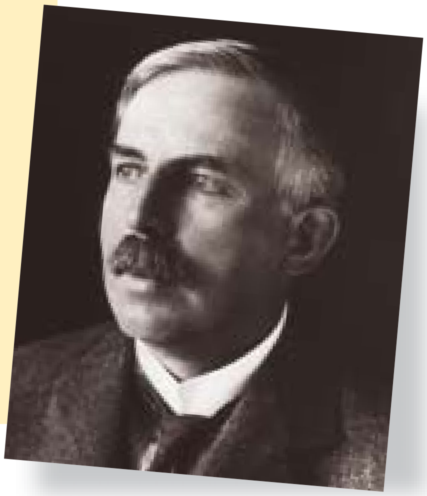

Figure 2.20 Ernest Rutherford proposed his nuclear theory of the atom in 1911.

*info***BIT**

Choose Your Carbon
Some elements exist in different forms as a solid. Carbon can be a soft black substance called graphite. Or it can be a hard, clear substance called diamond.

2.2 Organizing the Elements

Looking for patterns and classifying scientific information helps us bring order to unorganized ideas. It can also help us interpret what the information means. As you reviewed in section 1.2, matter can be organized in several different ways. It can be classified as solids, liquids, or gases; and, in any of those states, it can be classified as pure substances (elements or compounds) or mixtures (mechanical mixtures, solutions, suspensions, or colloids).

***QUICK*LAB**

Meet the Elements

Purpose

To create a table of properties for a range of elements

Procedure

1. Draw a table in your notebook with the following properties listed across the top: colour, state, appearance, hardness, magnetism, and electrical conductivity. List the samples down the left side.
2. Your teacher will put out samples of different elements in the classroom, as well as the equipment you will need to make some of your assessments. Examine each element and fill in the table with the information you gather about the properties of each one. The guidelines below will help you in your investigation:

Colour
Record the colour of each element. If the element has no colour, call it colourless.

State
Record what state the element is in at room temperature.

Appearance
Describe the appearance of each element. Use words such as "lustre" (shine) and "texture."

Hardness
Determine the hardness of each solid element.

Magnetism
Use a magnet to determine whether the element is magnetic.

Electrical Conductivity
Test electrical conductivity with a simple electrical circuit and a light bulb. If the light bulb goes on when you touch the two wires to the element, the element is a conductor. If the light bulb does not go on, the element is an insulator.

Questions

3. Sort the elements into groups that have the same or similar properties.
4. For each of the groups that share similar properties, suggest a collective name to describe the elements.
5. List these elements under their collective group headings.

Organizing the elements in a meaningful way was a goal of many early chemists. In this subsection, you will learn about that effort and the origins of the periodic table. As well, you'll learn how important advances in this classification approach not only revealed trends in the properties of known elements, but also allowed scientists to predict the existence of elements not then known. To date, scientists have identified 112 elements. Several of the common ones have been mentioned in this unit already, including gold, copper, oxygen, hydrogen, nitrogen, and carbon. The characteristics of some of the common elements are listed in Toolbox 12 at the end of this textbook.

Looking for Patterns

Early chemists used symbols of the Sun and planets to represent the seven metallic elements known at the time. The definition of element that we use today was developed in the late 1700s. By the early 1800s, more than 30 elements had been identified, including oxygen, lead, and mercury. As the science of chemistry developed, more and more elements were identified. To help in the study of elements and compounds, chemists tried to group elements according to their properties. But this became confusing because different scientists organized elements in different ways. A new organization was needed so that everyone would be using the same system.

Metal	gold	silver	iron	mercury	tin	copper	lead
Symbol	☉	☾	♂	☿	♃	♀	♄
Celestial Body	Sun	Moon	Mars	Mercury	Jupiter	Venus	Saturn

Figure 2.21 The symbols for the Sun and planets closest to Earth have long been used to represent the seven metals known from ancient times.

One of the first attempts by a scientist to create a better system for organizing the elements was made by John Dalton, an English chemist. In the early 1800s, he developed a new set of symbols for elements, as shown in Figure 2.22.

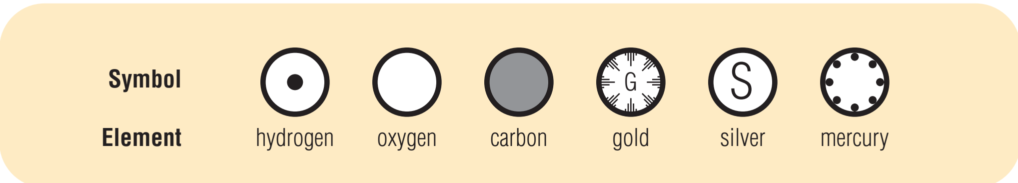

Figure 2.22 The element symbols devised by John Dalton, who lived from 1766 to 1844, were designed to improve communication between chemists.

Dalton's symbols were later modified by Swedish chemist Jöns Jacob Berzelius. In 1814, Berzelius suggested using letters rather than pictures to represent each element. The first letter (capitalized) of an element would become the symbol. For elements with the same first letter, such as hydrogen and helium, a small second letter would be added. Thus, "H" came to stand for hydrogen and "He" for helium. The new system—which remains the one used today—enabled scientists to communicate with each other in a precise and understandable manner. The next challenge was to find a way of putting the elements into an order that made sense.

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New Elements

Use electronic and print resources to find out about new elements that have been discovered or named in the past few years. Share this information with your class, using your choice of media. Begin your research at www.pearsoned.ca/scienceinaction.

An Order for the Elements

It was soon realized that the elements could be listed in order of increasing atomic mass. **Atomic mass** is the mass of one atom of an element. Scientists were able to determine the average mass of an atom of other elements by comparing it with the mass of a carbon atom (which is 12.0). Atomic mass is measured by *atomic mass unit* (amu).

In 1864, the English chemist John Newlands recognized a pattern when elements were listed by increasing atomic mass. He noticed that properties of elements seemed to repeat through this list at regular intervals. He called this pattern the "law of octaves," as the pattern was similar to the octave scale on a piano or other musical instrument. Many other scientists thought this law was silly and refused to accept the idea.

Not until 1869 did a clearer understanding of how to arrange the elements emerge. Russian chemist Dmitri Mendeleev was able to organize the elements in a way that reflected the patterns in the properties of the elements.

Finding a Pattern

Mendeleev collected the 63 elements known to exist in his time (the mid-1800s). These included lithium, carbon, nitrogen, oxygen, fluorine, sodium, silicon, phosphorus, sulfur, and chlorine. He then wrote down the properties of each element on a card, such as melting point, density, and colour. Using these cards, he tried to sort the elements into a pattern based on their properties. He also wanted to find a pattern that would allow him to predict the properties of elements not yet discovered. He felt that the ability to predict properties of new elements would prove that his pattern accurately reflected nature.

Mendeleev liked to play a form of the card game solitaire. In that game, a person looks for patterns in the layout of the cards. Mendeleev used his element cards like playing cards, laying them out and searching for patterns. Eventually, he found a pattern that seemed to work. It showed that the properties of elements vary periodically with increasing atomic mass. Figure 2.23 shows the chart that Mendeleev developed.

			Ti = 50	Zr = 90	? = 180.
			V = 51	Nb = 94	Ta = 182.
			Cr = 52	Mo = 96	W = 186.
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198.
			Ni = Co = 59	Pl = 106,6	Os = 199.
H = 1			Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Su = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		? = 45	Sr = 87,5	Ba = 137	Pb = 207
		?Er = 56	Ce = 92		
		?Yt = 60	La = 94		
		?In = 75,5	Di = 95		
			Th = 118?		

Figure 2.23 Dmitri Mendeleev's original data for the periodic table

Predicting New Elements

Mendeleev noticed some gaps in his chart of the elements, yet was convinced that his organization of the elements was correct. He predicted that new elements would be discovered that would have the properties and atomic mass needed to fit into the gaps. Many scientists didn't agree with Mendeleev's ideas and criticized his work. Within 16 years, however, the gaps were filled through the discovery of new elements that had the properties Mendeleev had predicted.

Figure 2.24 Dmitri Mendeleev, a Russian scientist, discovered a useful way of organizing the elements.

Check and Reflect

Key Concept Review

TOOLBOX

1. What is the basic building block of all compounds?
2. a) Define the term atomic mass.
   b) Why is an understanding of atomic mass important to a person trying to organize elements?
3. List five properties used in describing an element.
4. Using Toolbox 12 as a guide, identify the elements in the following common substances:
   a) Aspirin
   b) battery acid
   c) MSG food additive
   d) vitamin C

Connect Your Understanding

5. What two properties make oxygen different from copper?
6. What properties did Dmitri Mendeleev use to identify patterns in the elements? Were any properties of greater value than others in helping him find patterns?
7. Why was it important for Mendeleev to predict the properties of elements not yet discovered?

Extend Your Understanding

8. How were the patterns in the elements that Mendeleev recognized different from the patterns that John Newlands recognized?

*info***BIT**

A New Element

One of the newest elements to be discovered is ununbium. Scientists worked steadily for 24 days to find just two atoms of ununbium.

2.3 The Periodic Table Today

Dmitri Mendeleev's periodic table included the 63 known elements of his time. Since then, many more elements have been discovered. Today, about 112 elements are known (Figure 2.25).

One of the first important finds using Mendeleev's table was the element gallium. Discovered in 1875, gallium fit into one of the positions in the periodic table where Mendeleev had placed a question mark. It matched almost exactly his prediction of the properties of an element that would fit in that position.

Another question mark in the table wasn't filled until 1939 when the element francium was discovered by the French chemist Marguerite Perey. This element also matched Mendeleev's prediction almost exactly. This proved once again that the periodic table was a useful tool for organizing the elements.

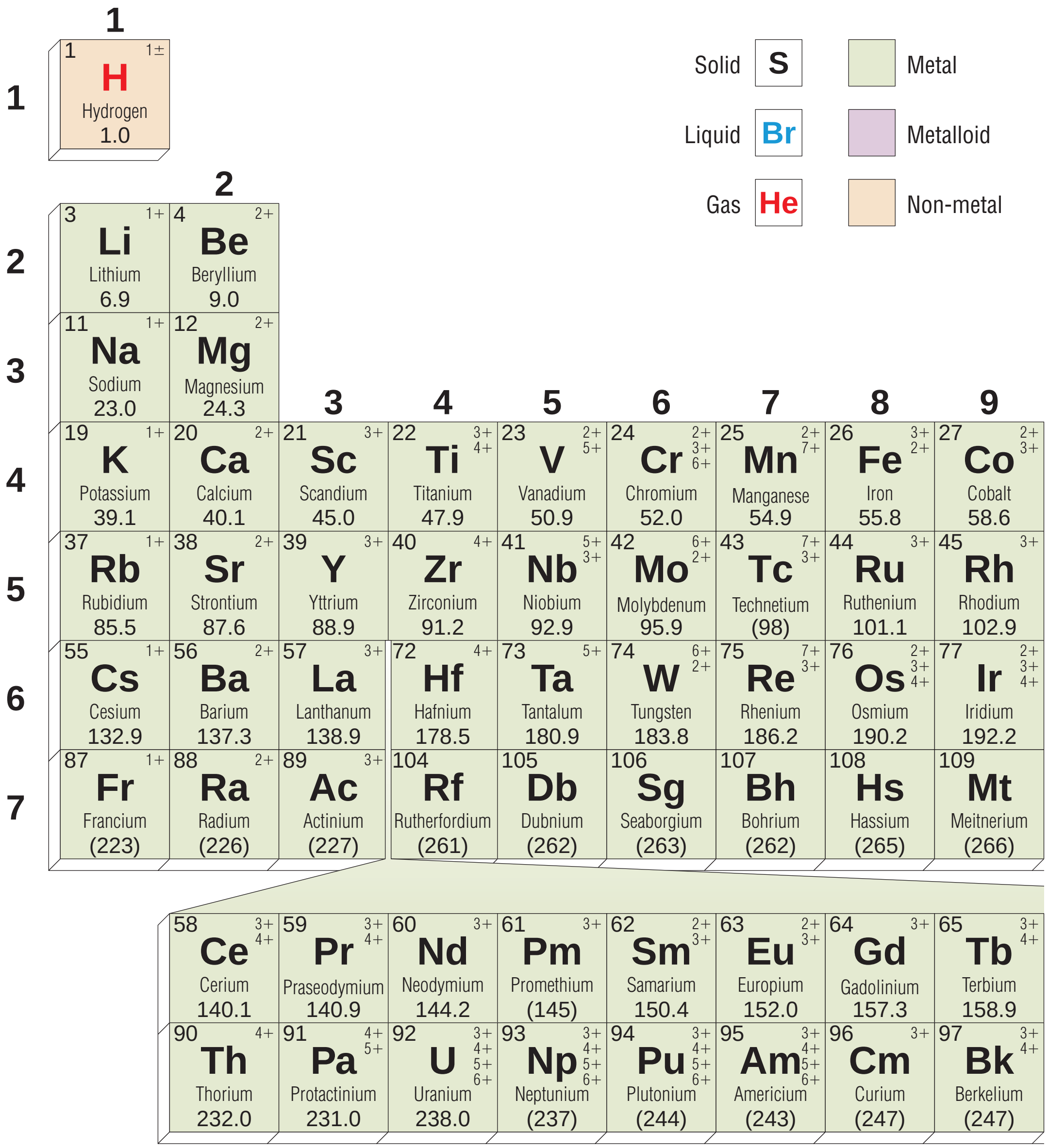
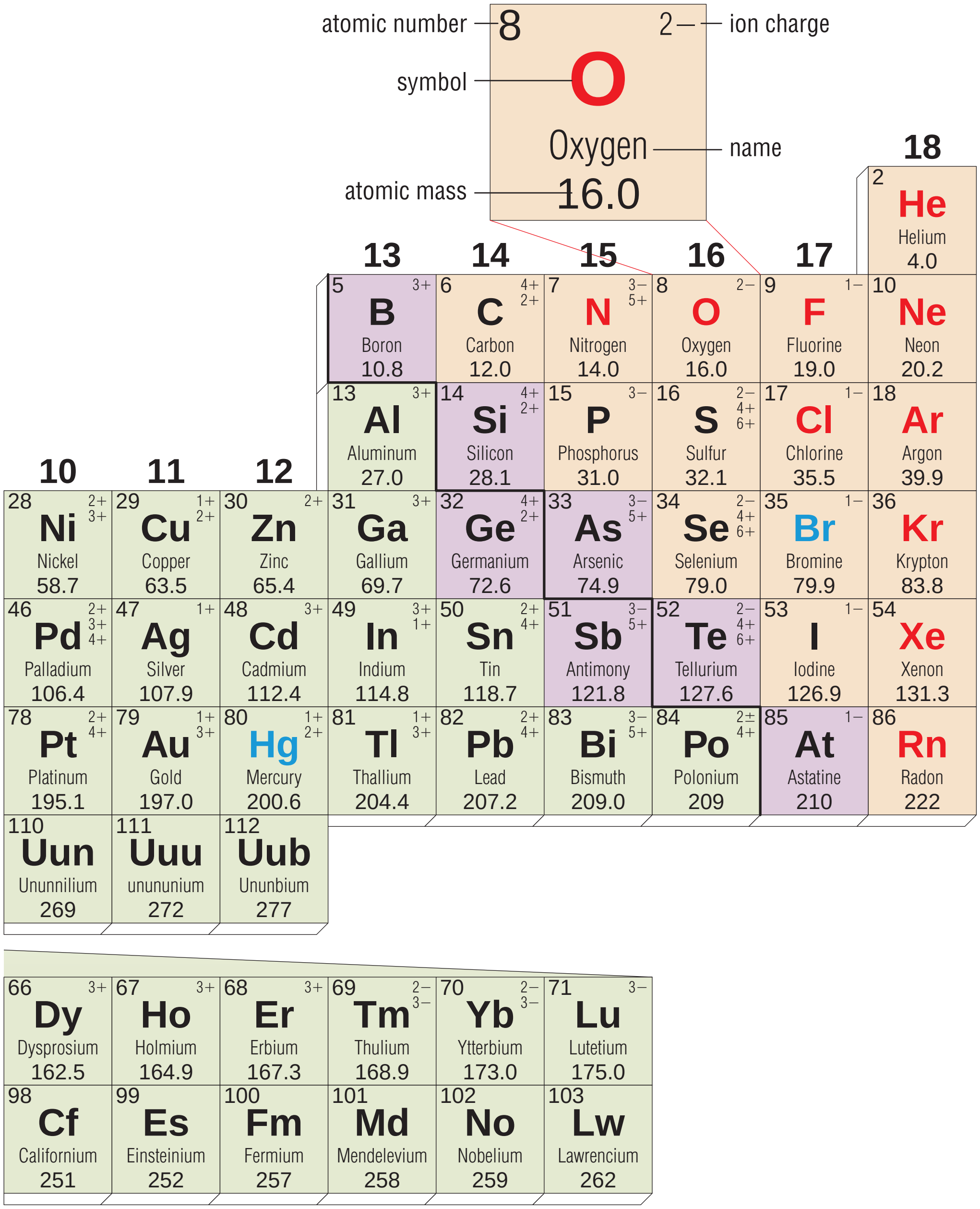


Figure 2.25 The periodic table. The element oxygen is shown as an example of the information that the periodic table provides for each element.

Today, more new elements are being discovered, but many of these are not stable. They have been created in laboratories with special equipment and have never been found in nature. Still, no matter how the elements are identified, they all have their place in the periodic table.

Understanding the Periodic Table

Notice that the periodic table is a series of boxes in rows and columns. Each horizontal row is called a **period** (numbered from 1 to 7). Each vertical column forms a **group**, or **family**, of elements (numbered from 1 to 18). These groups have similar chemical properties. Every box in the table contains several useful pieces of information.



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A Different Version of the Periodic Table

Scientists continue to organize the elements in different ways. One recent example is the three-dimensional periodic table shown here.

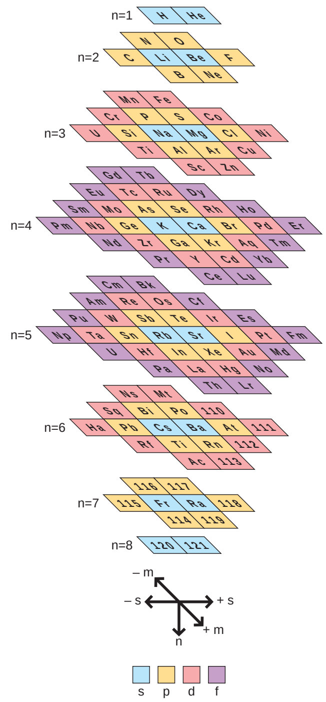


Figure 2.26 Not all scientists who contribute to the understanding of elements are recognized. Canadian Harriet Brooks is a case in point. One of her subjects of study was the radioactive element thorium. Brooks was able to measure the mass of what was thought to be a gas being given off by thorium. She showed that this "gas" was in fact a new element, and it was given the name radon.

Photo Miss Harriet Brooks, Nuclear Physicist, Montreal QC, 1898/Notman Photographic Archives/McCord Museum of Canadian History, Montreal/II-123880

Useful Information on Each Element

Element Symbol and Name

The large letter or letters in each box show the symbol for the element. In Figure 2.25, you can see that oxygen's symbol is O. For most elements, the symbol is an abbreviation derived from the element's modern chemical name. For example, the symbol for silicon is Si, and the symbol for manganese is Mn. However, there are exceptions. For example, the symbol for gold is Au, which is from *aurum,* the Latin word for gold. The symbol for iron is Fe, which is from *ferrum,* the Latin word for iron. The table below shows the word origin for several common elements.

Modern Name	Symbol	Latin Name
antimony	Sb	*stibium*
copper	Cu	*cuprum*
gold	Au	*aurum*
iron	Fe	*ferrum*
lead	Pb	*plumbum*
mercury	Hg	*hydrargyrum*
potassium	K	*kalium*
silver	Ag	*argentum*
sodium	Na	*natrium*
tin	Sn	*stannum*
tungsten	W	*wolfram*

Other Names for Elements

Not all elements are named for Latin words. Some elements are named after the location in which they were first discovered. For example, californium was discovered in 1950 at the University of California. Other elements are named after scientists who made important contributions to their field of study. For example, einsteinium, fermium, and curium are named after Albert Einstein, Enrico Fermi, and Marie Curie.

Atomic Number

The number above the element's symbol on the left is the **atomic number**. It shows how many protons are in the nucleus of one atom of the element. An oxygen atom, for example, always has eight protons. If you found six protons in an atom, the periodic table would show you that you were looking at carbon. Because atoms are neutral, the number of protons equals the number of electrons. Therefore, the atomic number also tells you how many electrons are in an atom of a particular element.

Notice that the atomic number increases by one for each element as you read across the periodic table from left to right.

Atomic Mass

The number below the element's name is the atomic mass. The atomic mass tells you the total mass of all the protons and neutrons in an atom. (Electrons are so tiny that they have very little effect on the total mass of the atom.) Recall that this is the average mass of the element's atoms. Not all atoms in an element have exactly the same mass: some have slightly higher values than others, and some have slightly lower values. This difference occurs because of the different number of neutrons from atom to atom. Atomic mass is measured by **atomic mass unit** (amu). One amu is defined as 1/12th the mass of a carbon-12 atom.

Associated with atomic mass is **mass number**. It represents the sum of the number of protons and neutrons in an atom. For example, the most common form of carbon atom has six protons and six neutrons. Its mass number is therefore equal to 12.

Not all carbon atoms are carbon-12, however. About 1% of carbon atoms have seven neutrons. The mass number of each of those atoms is 13. There is also one more naturally occurring form of carbon atom, and its mass number is 14. How would you find out how many neutrons it has? Subtracting the atomic number (6) from the mass number (14) shows you there are 8 neutrons in the nucleus of this type of carbon atom:

mass number (14) − atomic number (6) = number of neutrons (8)

Carbon-14 is present in nature in very low concentrations. That's good, because carbon-14 is *radioactive*, which means the atom is unstable and falls apart easily in a mini-nuclear reaction, releasing energy. Carbon-14 is present in small amounts in all living things. Scientists use it to find the age of biological materials, such as animal fossils. This technique is called carbon dating.

Element	Atomic Mass (amu)	Mass Number of Most Common Type of Atom of the Element	Mass Number of Second Most Common Type of Atom of the Element
hydrogen	1.0	1	2
carbon	12.0	12	13
bromine	79.9	79	81
iron	55.8	56	54
titanium	47.9	48	46
lead	207.2	208	206
uranium	238.0	238	235

SKILL PRACTICE

Using the Periodic Table

Use the periodic table to find out how many protons, electrons, and neutrons are in each of the following elements. The mass number is shown beside each element in parentheses. Make a table in your notebook to record your results.

a) vanadium (51)
b) nickel (58)
c) phosphorous (31)
d) bromine (79)
e) beryllium (9)
f) argon (40)
g) magnesium (24)
h) uranium (238)
i) silicon (28)
j) chromium (52)
k) titanium (48)

Activity B-3

Inquiry

Building a Periodic Table

The Question

How can you use a model to represent the patterns in the periodic table?

Materials & Equipment

- 24 assorted nuts and bolts in a bag
- 1 extra nut or bolt
- 2 large sheets of paper
- balance
- element cards
- graph paper

Procedure

Part 1—Classifying Nuts and Bolts

1. Your teacher will give you a bag that contains 24 nuts and bolts. Take the nuts and bolts out of the bag and examine them.
2. Your bag originally contained 25 nuts and bolts, but your teacher removed one of them. Determine whether a nut or a bolt was removed, and provide as much detail as you can about the missing piece.
3. Share your ideas with your class. How were your ideas similar to your classmates? How were they different?
4. Collect the missing nut or bolt from your teacher. How close was your description to the missing object?
5. In step 2, each group probably used a slightly different method of classifying their nuts and bolts to help them identify the missing one. For step 6, everyone will use the same classification.
6. On a large sheet of paper, make a grid with five equal-size columns and five equal-size rows. Make sure the boxes are large enough to hold your largest nut or bolt. Number the boxes 1 to 25 starting on the top left at number 1 and working across the row from left to right. The first box in the second row should be number 6.

Figure 2.27 Step 7

7. Place the smallest bolt at number 1 and the largest nut at number 25. Now organize the rest of your nuts and bolts on the grid.
8. Measure the mass of each nut and bolt and record that information on your grid.

Part 2—Classifying Elements

9 Your teacher will give you a card that describes an element. Find classmates who have element cards that describe elements with properties similar to yours.

10 Tell the class about the properties that the members of your group all share. If the class agrees with your grouping, your teacher will assign your group a number.

11 After everyone in the class has been assigned to groups, arrange all the students in the class in order of atomic mass.

12 Make another five-by-five grid, as you did in step 6. Fill it in using the order of the elements in the class. In your grid, include the atomic mass for each element.

Analyzing and Interpreting

13 Using the data you collected in part 1, make a graph of nut or bolt mass (responding or dependent variable) versus nut or bolt number (manipulated or independent variable). (The number of each nut or bolt is the number of the box in the grid where the nut or bolt was placed.)

14 What patterns do you notice in this graph? Record your observations.

15 Using the data on the elements from part 2, make a graph of atomic mass versus atomic number. What patterns do you notice in this graph? Record your observations.

16 Compare the two graphs you made. What similarities do you see?

17 What similar patterns do you see between the two grids you made in parts 1 and 2?

Forming Conclusions

TOOLBOX

18 Using the periodic table in Toolbox 12, compare your arrangement of elements with the arrangement of elements in the periodic table. Describe their similarities and their differences.

Applying and Connecting

As the infoBIT on page 127 says, different versions of the periodic table have been developed in the past and are still being developed today. Find examples of these other periodic tables and present your findings to the class.

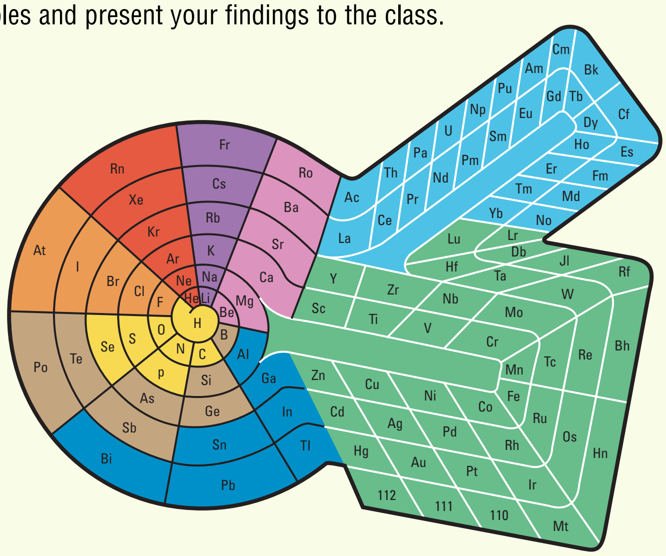


Figure 2.28 This is another version of the periodic table, created by Dr. Theodor Benfey, an American chemist.

Figure 2.29 Nickel is widely used in solution with other metals to create *alloys*. Some coins are made of copper-nickel alloys. Stainless steel is made of iron, nickel, and other elements.

Figure 2.30 Palladium is used in dental crowns, surgical instruments, and watch parts.

Figure 2.31 Platinum, highly valued as a precious metal, is more expensive than gold. It is also used in industry as a powder that enables chemical reactions to work better.

Patterns of Information in the Periodic Table

The periodic table contains a wealth of information related to the elements, in addition to their atomic number and atomic mass. By noticing where elements appear in the periodic table, you can tell something about their general nature.

Notice that a large part of the periodic table on pages 126–127 is green. All the elements in this area are metals. **Metals** are shiny, malleable, and ductile. They also conduct electricity. The elements in the orange area on the right are non-metals. **Non-metals** can be a solid or a gas. Solid non-metals are dull, brittle elements. Non-metals, except carbon, do not conduct electricity. Because they don't conduct electricity, they are called insulators. The diagonal purple row of elements between the metals and the non-metals contains elements called metalloids. **Metalloids** have both metallic and non-metallic properties.

Groups

Recall that Mendeleev arranged the periodic table to show a variety of patterns. The 18 columns in the table contain groups or families of elements with similar chemical properties.

These groups are numbered from 1 to 18 and are usually referred to by the first element in the column. For example, group 10 is the nickel group of elements because nickel is the first element at the top of that column. The other elements in that group are palladium and platinum. They have properties that are similar to those of nickel. There are a few exceptions to this pattern. Group 1 is divided into two parts—hydrogen and the alkali metals (see page 133). Hydrogen is considered to be a unique element, and in some periodic tables it is placed in a separate spot away from the other elements.

Periods

The rows in the periodic table, called periods, are numbered 1 to 7. The number of elements may vary from period to period. The first period has two elements. Periods 2 and 3 have eight elements, and periods 4 and 5 have 18 elements. You may have also noticed periods 6 and 7 have an additional 14 elements. These elements are placed separately at the bottom of the periodic table. This makes it easier to print a periodic table on a standard-sized page.

As you move from left to right across a period, you will notice that the properties of the elements change. Within the periods, there is a pattern. From left to right, the elements gradually change from metals to non-metals. So the first element in a period, on the far left, is a metal. The last element in a period, on the far right, is a non-metal. For example, if you look at period 4, you'll see that potassium (K) is a metal and krypton (Kr) is a non-metal. The most reactive metals start on the left. As you move right, the metals generally become less reactive.

Other Interesting Patterns

Group 1 elements, not including hydrogen, are called the **alkali metals**. These are the most reactive of the metals. They react when exposed to air or water. As you move down the group, starting with lithium, the reactivity increases. Group 2 elements are called the **alkaline-earth metals**. They react when exposed to air and water as well, but their reactivity is not as strong as that of the alkali metals.

Group 17 elements are called the **halogens**. They are the most reactive non-metals. For example, fluorine can etch glass, chlorine is commonly used to sterilize the water in swimming pools, and bromine gas is so corrosive it can burn skin. These elements are reactive and can combine with other elements to form new substances with useful properties. Sodium, for instance, can be highly reactive with fluorine, producing sodium fluoride—a chemical found in toothpaste.

Group 18 elements are the **noble gases**, the most stable and unreactive elements. In fact, it was long believed that noble gases could never combine with other elements. It wasn't until 1962 when that idea was proved incorrect. Canadian chemist Neil Bartlett and his colleagues at the University of British Columbia synthesized the first noble gas compound, combining xenon, platinum, and fluorine to create a new substance.

reSEARCH

Investigate an Element

Select an element from the periodic table and find as much information as you can about its properties and uses. Create a poster or Web page to illustrate your information. Begin your research at www.pearsoned.ca/scienceinaction.

SKILL PRACTICE

EXPLORING PATTERNS IN THE PERIODIC TABLE

TOOLBOX

Use the periodic table in Toolbox 12 to answer the following questions.

1 a) How many elements are gases at room temperature (20°C)? Write their chemical names and symbols.
   b) How many elements are liquids at room temperature (20°C)? Write their chemical names and symbols.

2 What element is found in group 2, period 3?

3 a) What is the symbol of the element with the atomic number 82?
   b) What is the atomic number of arsenic?

4 a) What is the symbol of the element with the atomic mass of 238?
   b) What is the atomic mass of silver?

5 Use the atomic number, atomic mass, and symbol of the elements to indicate the number of subatomic particles in an atom of the following elements:
   a) electrons in oxygen
   b) electrons in Li
   c) protons in Na
   d) protons in helium

6 Two of the most recent elements to be discovered are ununbium and ununquadrium. Ununbium has an atomic number of 112 and an atomic mass of 277. Ununquadrium has an atomic number of 114 and an atomic mass of 289. What do you think the atomic mass of the element with atomic number 113 will be?

Figure 2.32 High-energy subatomic particles leave telltale tracks in an experimental cloud chamber.

Check and Reflect

Key Concept Review

1. What is the difference between the atomic number and the atomic mass of an element?
2. If tin's mass number is 119 and its atomic number is 50, how many neutrons are in the nucleus of an atom of tin?
3. Correct the following statements about the periodic table.
   a) Neon has 11 protons.
   b) The symbol for sodium is So.
   c) Beryllium has 4 neutrons.
   d) Boron and aluminum are metals.
   e) Chlorine has 16 electrons.
4. Match the elements in the list below with one of the following two descriptions:
   i) shiny, ductile conductor of electricity OR
   ii) dull, brittle insulator
   a) P b) W c) Cu d) F e) Hg f) K
5. Match the term on the left with the description on the right.

a) alkali metal	i) a combination of two or more elements
b) halogen	ii) an unreactive non-metal
c) element	iii) very reactive metal
d) compound	iv) a pure substance of the same atoms
e) noble gas	v) very reactive non-metal

Connect Your Understanding

TOOLBOX

6. Use the periodic table in Toolbox 12 to answer the following questions:
   a) What two elements are liquids at room temperature?
   b) What element has the symbol K?
   c) What element has 50 protons?
   d) What element has a mass of 183.8 amu?
7. Hydrogen is considered to be a unique element. Describe three atomic properties that make it different from the other elements.
8. Why isn't atomic mass used to classify an element?

Extend Your Understanding

9. Three containers each hold a different "mystery" element. Four of their properties are shown below. Identify which element is (a) a non-metal, (b) an alkali metal, and (c) a noble gas.

	Colour	State at Room Temperature	Reactivity	Conductivity
Element X	green-yellow	gas	high	no
Element Y	colourless	gas	none	no
Element Z	silver-white	solid	high	yes

Careers and Profiles

Quality Control Analyst

Sona Arslan is a quality control analyst at a large pharmaceutical company.

A quality control analyst tests products to make sure that they meet manufacturing specifications before they are released to consumers. Quality control analysts use a variety of equipment during testing. For example, a quality control analyst testing medicines would use chromatographs, microscopes, lasers, pH meters, and other devices to test the properties of the substances. They also use many different computer applications to analyze the data. Sona Arslan is a quality control analyst for a major pharmaceutical company. Pharmaceutical companies make the wide range of medicines we use, from headache pills to chemotherapy treatments.

Q: Why did you choose the career of quality control analyst?

A: In high school, I liked and did well in chemistry, so I wanted to pursue a career in this field. Quality control analysts work in all types of industries. While at university, I became interested in working in the pharmaceutical industry. In 1998, after I graduated from university with an Honours B.Sc. in chemistry and physics, I obtained a one-year internship at Glaxo Wellcome Inc., one of the largest pharmaceutical manufacturing companies in the world. When I completed the internship, I was offered a position with the company to continue working as a quality control analyst.

Q: What types of skills are required in your work?

A: Some of the skills required are accuracy, attention to detail, organizational skills, and good computer, troubleshooting (problem-solving), and team-work skills.

Q: What do you enjoy most about your work?

A: I enjoy most the "hands on" aspect of my job, as well as the variety of work and challenges that are present. What I do on any given day depends on what test or tests I am working on. There is usually a lot of preparation work that is done before starting a test: glassware and reagents must be gathered, test solutions must be made, and instruments calibrated before testing can begin.

Q: Can you give an example of how a product is tested?

A: Here's what happens when we test an ointment. First, I conduct a physical examination to confirm the colour and consistency of the product. Next, I do a chromatography analysis to confirm that the ointment is homogeneous. This also confirms the identity and amount of the main active ingredient present in the product. Finally, I do a microscopic examination to make sure there is no foreign matter in the product. The test results are reviewed by a senior analyst and then signed off by a manager. The completed test results are sent to the Quality Assurance department. Staff there review the quality control test results before releasing the product for sale. If the sample fails the quality control test, an investigation is conducted to determine whether the failing result is related to analyst or instrument error, or to the product. If it is product related, the batch is rejected. According to Canadian law, no products can be released to market without first passing quality testing.

Q: What advice do you have for someone thinking about a career like yours?

A: You need a B.Sc., preferably in chemistry. It's also very helpful to obtain related work experience during the summer or through a co-op program.

1. Why do you think it's important for a quality control analyst to have a strong knowledge of the properties of matter?
2. What do you think quality control analysts would test for in the following industries?
   - candy making
   - soft drink production
   - synthetic fibre manufacturing (e.g., for clothing and furniture)
3. If you were a quality control analyst, what part of the job would you find most interesting?

Section Review

Assess Your Learning

Key Concept Review

1. What is considered to be one of the first series of events in the study of chemistry? Explain why this was an important event.
2. How did an early understanding of gases lead to a better understanding of the atom?
3. What properties could you use to distinguish metals from non-metals?
4. Explain how knowing the boiling point and melting point of a substance can help you identify it.
5. For each statement below, explain why you think it describes an element or a compound.
   a) An odourless, colourless gas produces water and carbon dioxide when it burns.
   b) A shiny, ductile solid cannot be broken into smaller components.
   c) An odourless, colourless liquid can be broken into two different gases when electricity is passed through it.
   d) A toxic, green gas is very reactive with other metals and some non-metals.
6. What is the difference between a group and a period in the periodic table?

Connect Your Understanding

7. Human history is divided into ages. How did an understanding of matter help humans move from the Stone Age to the Iron Age?
8. Describe the atomic model developed by each of the following people:
   a) Democritus
   b) Nagaoka
   c) Bohr
   d) Chadwick
9. The diagram in Figure 2.33 is a box from the periodic table. Label each item of information in the box. What does each item tell you about the element?
10. Copy the picture of the atom shown in Figure 2.34 into your notebook. Use the models of the atom developed by Ernest Rutherford and James Chadwick to label its parts.
11. While making a dessert in your kitchen, you realize that the salt, baking soda, and cornstarch are in unlabelled containers. What properties could you use to identify each substance? No tasting allowed!

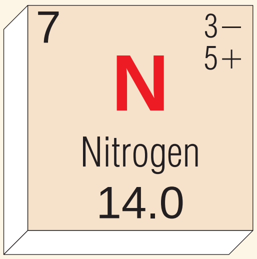


Figure 2.33 Question 9

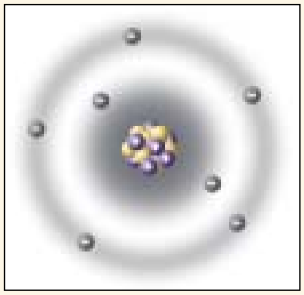
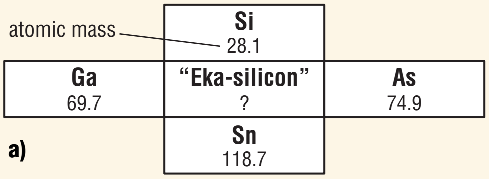


Figure 2.34 Question 10

Extend Your Understanding

12. Mendeleev believed that one of the gaps in his first periodic table would eventually be filled by an element he called *eka-silicon* (Figure 2.35a). Such an element had not yet been discovered. In 1871, he predicted what the properties of this undiscovered element would be. In 1886, he was proven correct.



b)

Some Properties of Selected Elements		
Element	**Colour**	**Atomic Mass**
Silicon	steel grey	28.1
Gallium	grey-black	69.7
Eka-silicon		
Arsenic	silver to grey-black	74.9
Tin	grey-white	118.7

Figure 2.35 Question 12

Use the information in Figure 2.35b to answer the following questions:

a) Which of the four elements in Figure 2.35b would you use to predict the properties of Mendeleev's new element? Explain your reasoning.

b) What atomic mass would you predict for *eka-silicon*?

c) What colour would you predict *eka-silicon* to be?

d) What do we now call *eka-silicon*?

e) Why do you think Mendeleev did not use the atomic number in his work?

Focus On — The Nature of Science

An idea, such as the description of the structure of an atom, develops through the contributions of many people over a long period of time. This is a common process for developing ideas in science. By sharing and collaborating with people all over the world, scientists make and investigate discoveries. Consider the following questions and, if possible, use examples from this section to support your answers.

1. What conditions or factors were necessary for ideas on the structure of the atom to be shared?

2. What is the value of sharing your discoveries with others?

3. Why would some people consider not sharing their discoveries with others?

3.0 Compounds form according to a set of rules.

Key Concepts

In this section, you will learn about the following key concepts:

- periodic table
- elements, compounds, and atomic theory
- chemical nomenclature

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between ionic and molecular compounds, and describe the properties of some common examples of each
- read and interpret chemical formulas for compounds of two elements, and give the IUPAC name and common name of these compounds
- identify/describe chemicals commonly found in the home, and write the chemical symbols
- identify examples of combining ratios/number of atoms per molecule found in some common materials, and use information on ion charges to predict combining ratios in ionic compounds of two elements
- assemble or draw simple models of molecular and ionic compounds

All the signs above tell you that this is where you can get gas for your car. If you were travelling in France, you would look for a sign that said "Gaz." If you were travelling in Britain, you would have to watch for a sign that said "Petrol." Even though Britain and Canada are both English-speaking countries, sometimes we use different words for the same things. For example, in England, potato chips are called "crisps" and the trunk of your car is called the "boot." If you travel to a non-English-speaking country, words can be even more confusing if you don't speak the local language.

Scientists studying the nature of matter encountered similar problems. At first, there was no common way of naming compounds. How could scientists understand each other's work if they weren't sure from the terminology what materials were being used? To help reduce the confusion, scientists have agreed on a common set of rules for naming compounds. Using these rules, a person can identify and describe any compound in the world—and be clearly understood by others. In this section, you will investigate how compounds are formed and how they are named.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Naming Compounds

Earlier in this unit, you learned how our understanding of the structure of the atom has gradually developed. At first, people thought the atom was the smallest particle possible (atom, you'll recall, comes from the Greek word *atomos*, meaning indivisible). Today we know that the atom is made of several much smaller particles.

infoBIT

How Big Are Atoms?
Five-hundred-million gold atoms lined up side-by-side would form a line as long as a $10 bill.

Combining Elements to Make Compounds

Look around your home and you'll be amazed at the variety of chemicals in your cupboards and on your shelves. In the bathroom, you'll find water, soap, shampoo, and toothpaste—all chemicals. In the basement or garage, you may find cleaning products, such as ammonia and bleach, and perhaps painting and gardening products. In your kitchen, you'll likely find table salt, baking soda, and baking powder. Each of these compounds has a chemical name and a **chemical formula**. The formula identifies which elements, and how much of each, are in the compound. So, for example, table salt's chemical name is sodium chloride and its formula is NaCl. Baking soda's chemical name is sodium bicarbonate and its chemical formula is $NaHCO_3$.

Figure 3.1 Most homes contain a range of chemical compounds, such as the ones shown here.

SKILL PRACTICE

Make a Model of an Atom

Your teacher will give you some of the following materials: paper, bingo chips, coins, Plasticine, and rubber magnetic strips. Your task is to choose an element from the first 18 in the periodic table and construct a model of what you think that element's atom would look like. Remember to consider the information you learned in subsection 2.1 about the atom and evolving ideas about its structure.

Your model should clearly show the structure of the atom and should include the correct number of protons, neutrons, and electrons.

When you have completed your model, show it to your class. Compare your model with other models.

Naming Chemical Compounds

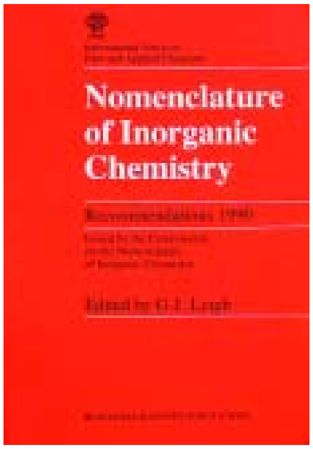


Figure 3.2 The IUPAC book contains the rules for naming chemical compounds.

Until the 18th century, no standardized system existed for naming chemicals. This created confusion because the names for chemical compounds varied from country to country and scientist to scientist. For example, hydrochloric acid and muriatic acid refer to the same thing. If you didn't know that, you might think they were two different chemicals. Today, some compounds are better known by their common name. Bleach, for instance, is almost always used instead of the chemical name aqueous sodium hypochlorite.

In 1787, a French chemist named Guyton de Morveau created a naming system, or nomenclature, for compounds. He decided to use the chemical name for each element in the compound, always putting the metal element first. For example, zinc and oxygen combine to form zinc oxide. Since 1920, the International Union of Pure and Applied Chemistry (IUPAC) has been the body responsible for agreeing on the appropriate name for every chemical compound discovered.

*QUICK*LAB

Common Chemicals in Your Home

Purpose

To learn about the chemical formulas of compounds by "buying" common household substances with "element money"

Procedure

1. Your teacher will give your group a selection of element cards and an information sheet. The cards are your element money. The information sheet tells you how to interpret the chemical formula for each item.
2. At the front of the class are several common items with labels. Each item can be purchased from the storekeeper (your teacher) with the correct amount of element money. Each group will have an opportunity to purchase an item.
3. You may purchase any of these items with the cards you have. For example, one of the components of toothpaste has the chemical formula NaF. If you want to buy some toothpaste, you need one sodium card (Na) and one fluorine card (F).
4. Note that each item has a value. Compounds made of two or more elements are more valuable than items made of one element.
5. When you have bought all your items, your group may trade any remaining cards with other groups.
6. Calculate the total value of the items you purchased.

Questions

7. What was the cost for each item you bought?
8. Were some materials easier to purchase than others? Explain your answer.
9. Describe any patterns you observed between the chemical formula and the "cost." (Hint: Using the periodic table might help you with your answer.)

Interpreting Chemical Names and Formulas from Compounds

If you know only the formula of a chemical compound, you can determine its chemical name. If you know only its name, you can determine its formula. Table salt's chemical name, sodium chloride, indicates that the compound is made of one atom of sodium and one atom of chlorine (Figure 3.3). Its chemical formula, NaCl, indicates this too.

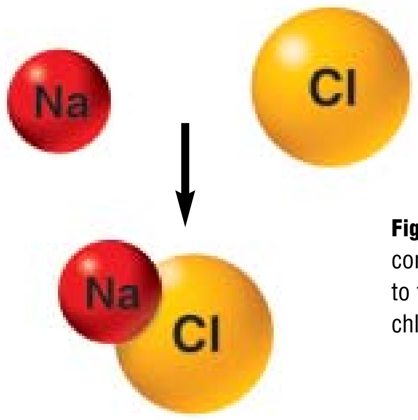


Figure 3.3 One sodium atom combines with one chlorine atom to form the compound sodium chloride, which we call table salt.

Now look at the formula for the compound water: H_2O. Notice that next to the H is a small 2 as a subscript. ("Sub" means below.) The 2 indicates that there are two atoms of hydrogen to go with every atom of oxygen in water. Figure 3.4 shows how the atoms in water are arranged. Subscript numbers in a chemical formula indicate the number of atoms of the elements that must combine to form the compound. No subscript number indicates that only one atom of that element is needed.

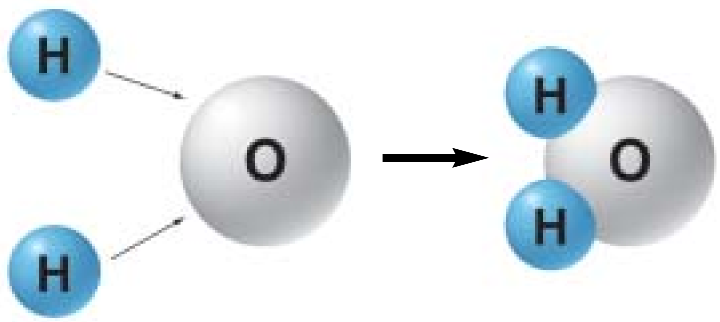


Figure 3.4 In water, two hydrogen atoms join with each oxygen atom.

Compound	Chemical Formula	Elements	No. of Atoms of Each	Total No. of Atoms
sodium chloride	NaCl	• sodium • chlorine	1 1	2
water	H_20	• hydrogen • oxygen	2 1	3

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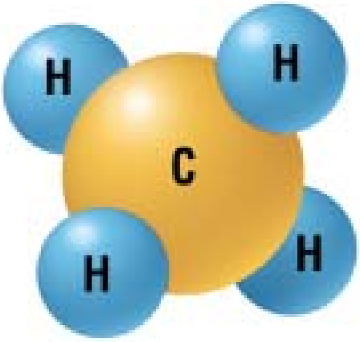
Chemical Formulas of Household Products

Many household chemicals have a common name rather than a chemical formula. Find the chemical formula for some of these household chemicals. Begin your search at www.pearsoned.ca/scienceinaction.

Indicating the Physical State of a Compound

Another common notation added to chemical compounds indicates the state of the chemical at room temperature. After the chemical formula, a subscript *s* for solid, *l* for liquid, or *g* for gas is shown in parentheses. For example, sodium chloride is written as $NaCl_{(s)}$, water is written as $H_2O_{(l)}$, and natural gas (methane) is written as $CH_{4(g)}$. For aqueous solutions (substances dissolved in water), a subscript *aq* in parentheses is added to the formula. So, if sodium chloride was dissolved in water, the resulting aqueous solution would be written as $NaCl_{(aq)}$.



$CH_{4(g)}$

Figure 3.5 In methane, four hydrogen atoms combine with one carbon atom.

SKILL PRACTICE

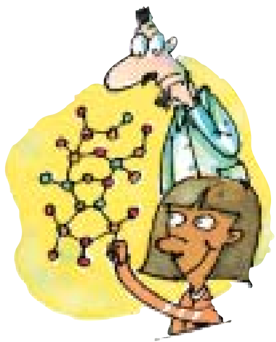
Working with Compounds

Referring to the compounds listed in the table below, complete the following.

- List the elements present in the compound.
- State the number of atoms of each element in the compound.
- In your notebook, draw what this compound would look like. Refer to Figures 3.3, 3.4, and 3.5 for your drawings. If time permits, create a model of each compound. Use materials of your own choosing.

Create a table like the one below to record your answers. Be sure to leave enough room to draw the compound in the far right column.

Compound	Elements in Compound	No. of Atoms in Each Element	Drawing of Compound
$CaO_{(s)}$			
$CaCl_{2(s)}$			
$Al_2O_{3(s)}$			
$Na_2O_{(s)}$			
$AlCl_{3(s)}$			
$KCl_{(s)}$			
$NaOH_{(s)}$			



Check and Reflect

Key Concept Review

1. What information can you determine from a chemical formula?
2. Identify the elements in each of the following compounds.
   a) $HF_{(g)}$
   b) $Li_2O_{(s)}$
   c) $K_3P_{(s)}$
   d) $Ni_2O_{3(s)}$
   e) $HgCl_{2(s)}$
3. How many atoms are indicated in the formula of each of the following compounds?
   a) Silver chloride—$AgCl_{(s)}$
   b) Calcium oxide—$CaO_{(s)}$
   c) Magnesium nitride—$Mg_3N_{2(s)}$
   d) Aluminum oxide—$Al_2O_{3(s)}$
   e) Scandium sulfide—$Sc_2S_{3(s)}$

Connect Your Understanding

4. Write the chemical formula for each of the following compounds:
   a) sodium sulfide, which has two atoms of sodium and one atom of sulfur
   b) aluminum fluoride, which has one atom of aluminum and three atoms of fluorine
   c) oxygen gas, which has two atoms of oxygen
   d) glucose, which has six carbon atoms, 12 hydrogen atoms, and six oxygen atoms

Extend Your Understanding

5. Acetylsalicylic acid, commonly called Aspirin, has the chemical formula $C_9H_8O_{4(s)}$. Urea, also called carbamide, has the formula $H_2NCONH_{2(s)}$. Compare and contrast the two formulas in terms of total elements and atoms.

3.2 Ionic Compounds


(a) (b) (c)

Figure 3.6 Sodium, shown in (a), is a metal. Sodium combines with chlorine gas in a violent reaction (b). The product is table salt, $NaCl_{(s)}$ (c).

Most people are familiar with common table salt and know that it is a white substance composed of tiny crystals. You might be surprised to learn that table salt is formed when a very reactive metal—sodium—is placed in a container with a poisonous, green non-metal—chlorine gas. When the two chemical elements are combined, the sodium metal explodes in a bright yellow flame. As the sodium burns, a white, coarse-grained powder is produced. That powder is table salt, or what you now know is sodium chloride ($NaCl_{(s)}$).

Sodium chloride is called an **ionic compound**. Ionic compounds are pure substances formed as a result of the attraction between particles of opposite charges, called ions. Table salt is formed from positively charged sodium ions and negatively charged chloride ions. Other properties of ionic compounds include their high melting point, good electrical conductivity, and distinct crystal shape.

All ionic compounds are solids at room temperature. In fact, table salt will not melt until it is heated to 801°C. When an ionic compound is melted or dissolved in water, it will conduct electricity. This property of ionic compounds led to the study of electrochemical cells (cells that either convert chemical energy into electrical energy or electrical energy into chemical energy). And that work in turn eventually led to the invention of batteries.

This new technology allowed scientists to investigate the structure of matter in greater depth.

How does an ionic compound actually form? When the ions are combined, they form a crystal.

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"Ion" Origin

The word "ion" comes from a Greek word meaning "to go" or "wander."

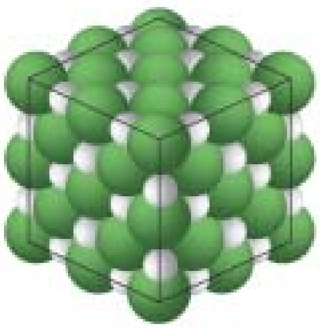

Figure 3.7 The crystals in this table salt are held together by ionic bonds.

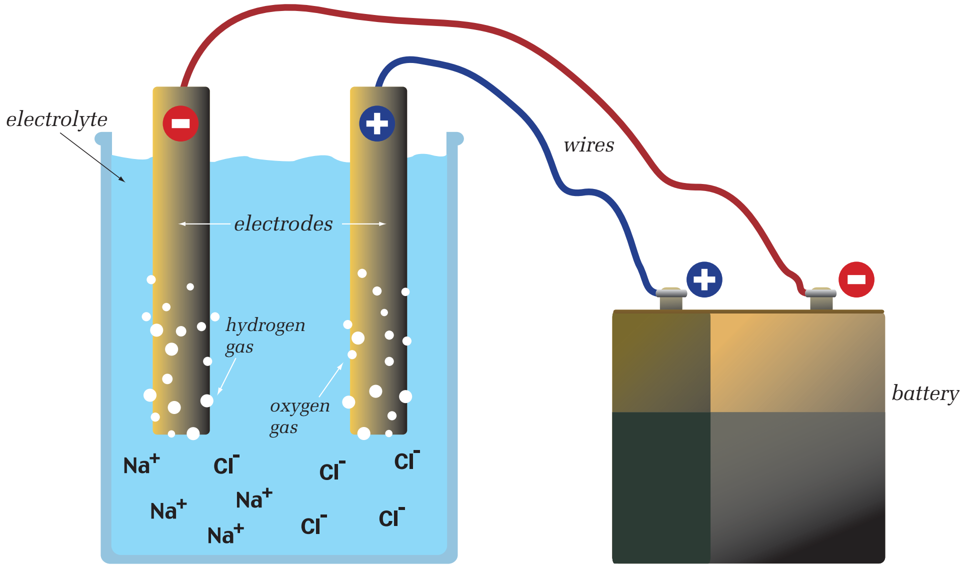

Figure 3.8 Two electrodes are placed in an electrolyte, water containing a little $NaCl_{(s)}$ forming $NaCl_{(aq)}$. The salt helps the electrical charge flow through the solution. At the negative electrode, positively charged hydrogen forms hydrogen gas. At the positive electrode, negatively charged oxygen forms oxygen gas. Chlorine gas may also be formed. In school laboratories, $Na_2SO_{4(s)}$ is used instead of $NaCl_{(s)}$.

QUICKLAB

Using Batteries to Investigate a Chemical Reaction

Purpose

To investigate the behaviour of ions

(Note: Your teacher may demonstrate this activity on the overhead projector.)

Procedure

1. Fill a Petri dish about two-thirds full with water. Add two to four drops of universal indicator.
2. Attach the end of one wire to the graphite at one end of a pencil. Attach the other wire to the second pencil in the same way. Make sure both ends of the pencils are sharpened so that the graphite is exposed. Attach the other ends of the wire to the battery.
3. Place the other sharpened ends of the pencils into the Petri dish, keeping the ends well apart. Record your observations.
4. Remove the pencils and place them in a safe spot.
5. Add several crystals of sodium sulfate to the Petri dish and stir until dissolved.
6. Repeat step 3. Do you observe any additional changes if you add a little more sodium sulfate?

Questions

7. What changes did you observe after the sodium sulfate was added to the Petri dish?
8. What evidence was there of a chemical change?
9. What do you think would happen if you added a non-ionic compound such as sugar to the Petri dish?

Materials & Equipment

- clear Petri dish
- water
- universal indicator
- 2 pencils sharpened at both ends
- 2 wires with alligator clips
- 9-V battery
- sodium sulfate ($Na_2SO_{4(s)}$)

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Ions and the Body

Metal ions such as Na^+, K^+, Mg^{2+}, Sn^{2+}, and Ca^{2+} are important in enabling our bodies to function properly. Find out the role of these ions in the human body. Begin your search at www.pearsoned.ca/scienceinaction.

When the ionic compound is dissolved in water, the metal and non-metal form an aqueous solution of **ions**. An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons. The table below shows some examples of ion charges for various elements.

Element	Ion Charge	Ion Notation
Hydrogen	1+	H^+
Lithium	1+	Li^+
Nitrogen	3−	N^{3-}
Oxygen	2−	O^{2-}
Fluorine	1−	F^-
Sodium	1+	Na^+
Magnesium	2+	Mg^{2+}
Aluminum	3+	Al^{3+}
Sulfur	2−	S^{2-}
Iron	2+ or 3+	Fe^{2+} or Fe^{3+}
Copper	1+ or 2+	Cu^+ or Cu^{2+}
Lead	2+ or 4+	Pb^{2+} or Pb^{4+}

Ion Charges

To indicate ions in written notation, a plus sign (+) or a minus sign (−) is placed to the upper right of the element symbol. This is a superscript position (*super-* means "above"). For example, a sodium ion is written as Na^+ and a chlorine ion as Cl^-.

Some ions can also form when certain atoms of elements combine. These ions are called **polyatomic ions** (*poly-* means "many"). Polyatomic ions are a group of atoms acting as one. For example, one atom of carbon and three atoms of oxygen form the polyatomic ion called carbonate or CO_3^{2-}. When carbonate reacts with calcium ions, the product is calcium carbonate, or limestone ($CaCO_{3(s)}$). Other examples of compounds with polyatomic ions include copper(II) sulfate ($CuSO_{4(s)}$) and sulfuric acid ($H_2SO_{4(aq)}$).

Naming Ionic Compounds

When naming an ionic compound, there are two rules to remember. First, the chemical name of the metal or positive ion goes first, followed by the name of the non-metal or negative ion. Second, the name of the non-metal negative ion changes its ending to *ide*. This is the reason that the chemical name for $NaCl_{(s)}$ is not sodium chlorine, but sodium chloride.

There is one exception to these naming rules. Where negative ions are polyatomic ions, the name remains unchanged. Limestone's chemical name therefore remains calcium carbonate.

You'll notice in the table above that iron, copper, and lead have more than one ion charge. Some elements have this property. To show clearly which ion is being used in a chemical name, a Roman numeral is added. For example, iron(II) oxide is a compound containing the Fe^{2+} ion. Iron(III) oxide contains the Fe^{3+} ion.

Using Ion Charges and Chemical Names to Write Formulas

Once you know the ion charge and the chemical name of a substance, you can determine its chemical formula. The following steps will help you write the formulas for ionic compounds.

Step 1 Print the metal element's symbol with its ion charge. Next to it, print the non-metal element's symbol with its ion charge.	Ca^{2+} Cl^{1-}
Step 2 Balance the ion charges. The positive ion charge must balance the negative ion charges. In our example, this means that there must be two chlorine atoms each with an ion charge of 1− to balance the 2+ ion charge of one calcium atom. Now you know how many atoms of each element you need to include in the formula.	Ca^{2+} Cl^{1-} Cl^{1-}
Step 3 Write the formula by indicating how many atoms of each element are in it, as shown. Do not include the ion charge in the formula. Place the number of atoms of each element in a subscript after the element's symbol. If there is only one atom, no number is used.	$CaCl_{2(s)}$

Ion Charges and the Periodic Table

Take a moment to look at the periodic table in section 2.3 and the common ion charge. Do you see a pattern? The first group of elements on the left side of the table is the alkali group of metals—lithium and sodium. They each have an ion charge of 1+. The halogens, on the right of the table—fluorine and chlorine—have an ion charge of 1−. Generally, all the elements in a group form ions with the same charge. This pattern is the most consistent at either end of the periodic table. Figure 3.9 illustrates the ion charges of the elements that follow this pattern the best.

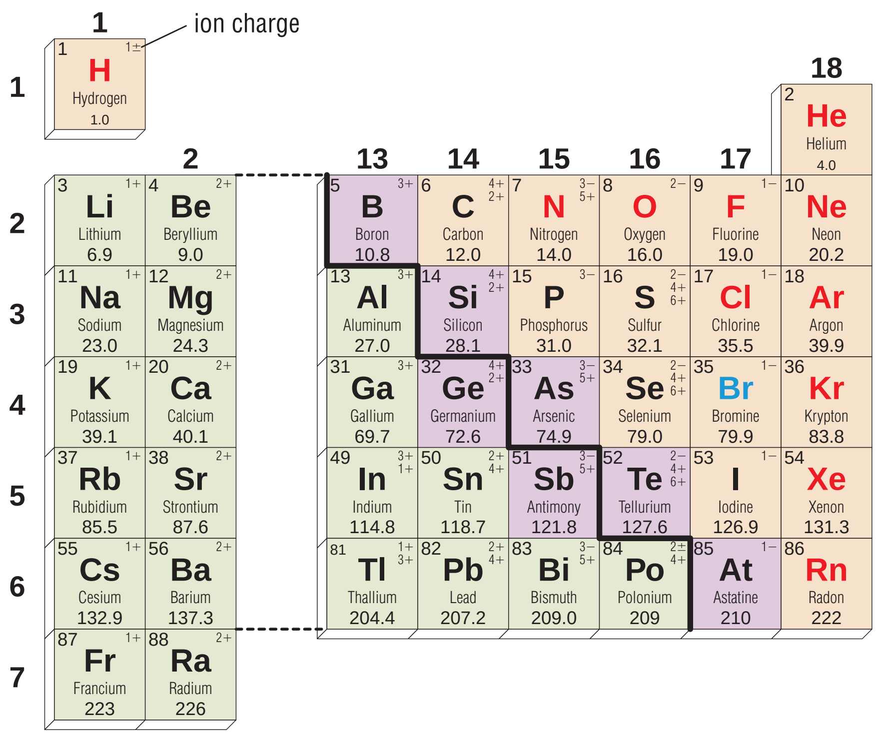


Figure 3.9 Ion charges of some of the groups in the periodic table

Activity B-4

Inquiry

Modelling Ionic Compounds

The Question

How can you create a model to illustrate an ionic compound?

Materials & Equipment

- marshmallows, marbles, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Figure 3.10 Step 4

Procedure

1. Working with a partner, select one metal and one non-metal element from the periodic table. Your task is to create a model illustrating the ionic compound that forms from combining these two elements. This type of ionic compound is called a binary compound because it consists of just two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model to show one formula unit.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional ionic compounds. Ensure that at least one of them is an example of a metal with multiple ion charges.
7. When you are finished, share your models with the class.

Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

Forming Conclusions

10. Describe how you created models that illustrate ionic compounds.

Check and Reflect

Key Concept Review

1. What is an ionic compound?
2. List three properties of all ionic compounds.
3. How is an ion formed?
4. What is the difference between Fe^{2+} and Fe^{3+} ?
5. If an element has more than one ionic charge, how is that piece of information represented in a chemical name?

Connect Your Understanding

6. Outline the steps for writing the chemical formula of an ionic compound.
7. Write the formula for the following compounds:
   a) sodium fluoride
   b) magnesium sulfide
   c) lithium oxide
   d) iron(III) chloride
   e) copper(II) phosphide
   f) magnesium iodide
   g) iron(II) phosphide
   h) aluminum nitride
8. Write the chemical name for the following formulas:
   a) $LiCl_{(s)}$
   b) $Ca_3P_{2(s)}$
   c) $AlBr_{3(s)}$
   d) $PbS_{2(s)}$
   e) $Fe_2O_{3(s)}$
   f) $Na_2O_{(s)}$
   g) $CaS_{(s)}$
   h) $CuSO_{4(s)}$

Extend Your Understanding

9. What ion charge patterns are there in the periodic table?

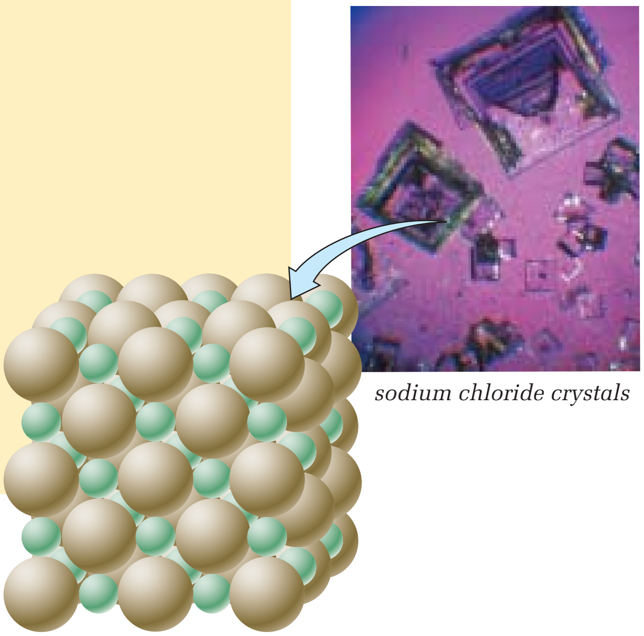


Figure 3.11 Each substance has a different crystal shape. Knowing the type of crystal a substance forms can help in identifying it. Pictured here are sodium chloride crystals.

*info***BIT**

Carbon Compounds

Scientists have discovered more than 10 million compounds. At least 9 million are molecular compounds containing the element carbon.

3.3 Molecular Compounds

When non-metals combine, a pure substance called a **molecule** or a **molecular compound** is formed. Molecular compounds differ from ionic compounds in several ways. They can be solids, liquids, or gases at room temperature. They tend to be insulators, or poor conductors of electricity. They also have relatively low melting and boiling points because the forces between the molecules are weak. Examples of molecular compounds include sugar, acetylene, and water.

Figure 3.12 Sugar ($C_{12}H_{22}O_{11(s)}$) is a common molecular compound.

*QUICK***LAB**

Ionic or Molecular Compound?

Purpose

To determine through experimentation whether a substance is an ionic compound or a molecular compound

Procedure

1. Set one of the 100-mL beakers in the dish or large bowl.
2. Using tongs, place several pieces of solid air freshener into the beaker.
3. Put the watch glass or Petri dish on top of the beaker and cover with ice.
4. Pour hot water into the dish to a depth of 2 cm. The water does not have to be boiling, but must be above 45°C (use the thermometer if necessary).
5. Record your observations every 5 min for 30 min.
6. In a second beaker containing water, place another piece of air freshener. Record your observations.
7. Test the conductivity of the air freshener.

Questions

8. From your observations, do you think the air freshener is an ionic compound or a molecular compound?
9. Did you collect any evidence that seemed to contradict the conclusion drawn in question 8?

Materials & Equipment

- two 100-mL beakers
- dish or large bowl
- tongs or forceps
- several small pieces of solid air freshener
- watch glass or Petri dish
- ice
- hot water
- thermometer
- pencil and notebook

Caution!
Handle the air freshener with tongs, not directly with your fingers. Do not directly inhale the vapour.

ACTIVITY B-5

Inquiry

MODELLING MOLECULAR COMPOUNDS

The Question

How can you create a model to illustrate a molecular compound?

Procedure

1. Working with a partner, select two non-metal elements from the periodic table. Your task is to create a model illustrating a molecular compound that forms from combining these two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional molecular compounds.
7. When you are finished, share your models with the class.

Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

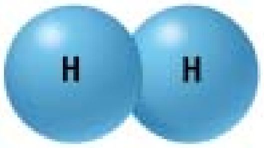
Forming Conclusions

10. Describe how you created models that illustrate molecular compounds.

Materials & Equipment

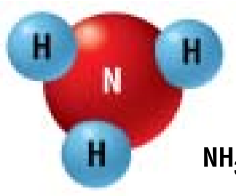
- marshmallows, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Figure 3.13 Step 4



$H_{2(g)}$

Figure 3.14 In a molecule of hydrogen gas, two hydrogen atoms combine to form the molecule. The formula is $H_{2(g)}$.



$NH_{3(g)}$

Figure 3.15 In a molecule of ammonia, each hydrogen atom is attached to the nitrogen atom. The formula is $NH_{3(g)}$.

Writing Formulas for Molecular Compounds

Writing formulas for molecular compounds is similar to writing formulas for ionic compounds, except that no ions are present and the ion charge is not used in the formulas. This makes it hard to predict how non-metals combine. However, the formulas still clearly show what elements are present, and how many of each type of atom make up the molecule. For example, hydrogen gas is usually found as H_2. Each molecule has two atoms of hydrogen connected to each other.

For ammonia ($NH_{3(g)}$), the situation is similar. Three hydrogen atoms combine with the nitrogen atom.

Naming of Molecular Compounds

Many molecular compounds are often known by their common names. Two compounds you have encountered in this section are water and ammonia. The names of these compounds do not give any indication of the elements they are made from. All molecular compounds, except those containing hydrogen, can be named using the following rules. Common names are used for molecular compounds containing hydrogen.

1. The first element in the compound uses the element name—just like ionic compounds.
2. The second element in the compound has the suffix 'ide'—just like ionic compounds.
3. When there is more than one atom in the formula, a prefix is used which specifies the number of atoms. Some prefixes are listed below.
4. An exception to rule 3 is when the first element has only one atom, the prefix *mono* is not used.

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Using the above rules, molecular compounds are named using this format:

Prefix + First Element **Prefix** + Second Element (with 'ide' ending)

Here are some examples: (Note that the coloured numbers in the formula correspond to the prefixes in the name.)

CO_2	carbon **di**oxide
N_2O	**di**nitrogen **mono**xide
N_2O_3	**di**nitrogen **tri**oxide
NF_3	**ni**trogen **tri**fluoride
CCl_4	carbon **tetra**chloride
PF_5	phosphorus **penta**fluoride

reSEARCH

Bonding Forces

Use your library and the Internet to find out about other types of forces that create bonds between atoms. Begin your research at www.pearsoned.ca/scienceinaction.

Comparing Ionic and Molecular Compounds

The table below and the one on the next page list the melting and boiling points for some common ionic and molecular compounds. By comparing the information in these tables, you will see several differences between the two types of compounds. For example, baking soda, an ionic compound, boils at 1550°C. Carbon dioxide, a molecular compound, boils at −78.5°C.

Figure 3.16 Examples of ionic compounds

Ionic Compound	Formula	Melting Point (°C)	Boiling Point (°C)
lye	$NaOH_{(s)}$	318°	1390°
silver nitrate	$AgNO_{3(s)}$	212°	440° (decomposes)
baking soda	$NaHCO_{3(s)}$	455°	1550°
salt	$NaCl_{(s)}$	801°	1413°

Molecular Compound	Formula	Melting Point (°C)	Boiling Point (°C)
carbon dioxide	$CO_{2(g)}$	(changes directly from solid to gas)	−79°
water	$H_2O_{(l)}$	0°	100°
sugar	$C_{12}H_{22}O_{11(s)}$	185°	(decomposes)
rubbing alcohol	$C_3H_8O_{(l)}$	−90°	82°

Figure 3.17 Examples of molecular compounds

Check and Reflect

Key Concept Review

1. Define a molecular compound and give an example of one.
2. List three properties of a molecular compound.
3. Draw a simple model to show a molecule for each of the following:
   a) chlorine gas ($Cl_{2(g)}$)
   b) phosphorus trichloride ($PCl_{3(g)}$)
   c) nitrogen monoxide ($NO_{(g)}$)
   d) iodine bromide ($IBr_{(g)}$)
4. Describe one test that can be performed to determine whether a substance is ionic.

Connect Your Understanding

5. Which of the following compounds are molecular?
   a) $H_2O_{(l)}$
   b) $NaCl_{(s)}$
   c) $NH_{3(g)}$
   d) $F_{2(g)}$
   e) $CuCl_{2(s)}$
   f) $CCl_{4(l)}$
6. Write the chemical formula for the following molecular compounds:
   a) dinitrogen trioxide
   b) sulfur trioxide
   c) carbon tetrachloride
   d) phosphorus pentachloride
   e) carbon disulfide

Extend Your Understanding

7. Create a Venn diagram that compares the properties of a molecular compound with those of an ionic compound.

SECTION REVIEW

Assess Your Learning

Key Concept Review

1. Explain the two rules to follow when naming an ionic compound.
2. For each substance below, name the elements and indicate the number of each kind of atom present in one formula unit.
   a) $HgF_{(s)}$
   b) $O_{2(g)}$
   c) $Na_2S_{(s)}$
   d) $B_2O_{3(s)}$
   e) $FeCl_{3(s)}$
3. When an ionic compound forms, what must be the sum of the ionic charges?
4. What kind of elements form molecular compounds?
5. Identify how many atoms of each element are present in the following compounds:
   a) glucose: $C_6H_{12}O_{6(s)}$
   b) ethanol: $C_2H_5OH_{(l)}$
   c) hydrogen peroxide: $H_2O_{2(l)}$
   d) rust remover: $H_3PO_{4(aq)}$
   e) fatty acid: $C_{17}H_{35}COOH_{(aq)}$
6. Which of the following compounds are ionic and which are molecular?
   a) $PbO_{(s)}$
   b) $Al_2S_{3(s)}$
   c) $F_{2(g)}$
   d) $H_2O_{(l)}$
   e) $NH_{3(g)}$
7. What is the formula for the ionic compounds with the following combinations of elements?
   a) potassium and bromine
   b) barium and oxygen
   c) aluminum and selenium
   d) calcium and nitrogen
   e) copper and phosphorous
8. Write the formula for the following molecular compounds:
   a) carbon monoxide
   b) carbon dioxide
   c) nitrogen dioxide
   d) dinitrogen monoxide
   e) disulfur dichloride

Connect Your Understanding

9. Describe a pattern of ion charges in the periodic table.
10. Write the formula for the following ionic compounds:
    a) magnesium bromide
    b) sodium phosphide
    c) lithium fluoride
    d) nickel(II) chloride
    e) lead(IV) nitride
    f) copper(I) sulfide
    g) silver oxide
    h) nickel(III) oxide

11. In terms of ion charges and chemical change, what is the difference between $CuF_{(s)}$ and $CuF_{2(s)}$?

12. Sketch simple models to show the following molecular compounds:
a) sulfur and oxygen (SO_2)
b) nitrogen and chlorine (NCl_3)
c) oxygen and bromine (OBr_2)
d) carbon and fluorine (CF_4)

Extend Your Understanding

13. Which of the following formulas is/are not correctly written?
a) Li_3O
b) CuO
c) Mg_3O_2
d) $HgCl_2$
e) FeCl

14. Using the periodic table, find the elements iron, mercury, and bromine. Make a chart to answer the following questions as related to each element.
a) Is it a metal or non-metal?
b) What is the common ion charge?
c) Will it conduct electricity?
d) What state will it be in at room temperature?
e) What state will it be in at room temperature if it combines with a non-metal?

15. An unknown ionic compound is formed with the formula $Z_2S_{3(s)}$.
a) What is the common ion charge of element Z?
b) What would be the new chemical formula of the unknown compound if the S (sulfur) was replaced with fluorine?
c) What would be one property of these two compounds?

Focus On THE NATURE OF SCIENCE

Scientific ideas can be difficult to represent in a way that is easily understandable. To help explain their ideas, scientists often use models. In this section, you investigated and developed models to explain how atoms form compounds. Answer the following questions, using examples from your work in this section to support your answers.

1. How can a model help explain your observations?

2. Can a model be used to predict future observations?

3. Why is it important to understand chemical symbols, and to ensure that everyone uses these symbols correctly?

4.0 Substances undergo a chemical change when they interact to produce different substances.

Key Concepts

In this section, you will learn about the following key concepts:

- endothermic and exothermic reactions
- reactants and products
- conservation of mass
- factors affecting reaction rates

Learning Outcomes

When you have completed this section, you will be able to:

- identify conditions under which properties of a material are changed, and critically evaluate if a new substance has been produced
- observe and describe evidence of chemical change in reactions between familiar materials
- distinguish between materials that react readily and those that do not
- observe and describe patterns of chemical change
- describe familiar chemical reactions, and represent these reactions by using word equations and chemical formulas and by constructing models of reactants and products

Fireworks burst into the night sky in brilliant patterns caused by chemical reactions. The different colours that we see result from reactions between different substances within the fireworks. For example, barium compounds create green fireworks, strontium compounds create red ones, copper creates blue ones and sodium yellow. Fireworks are also launched by the chemical reaction that results from the fuse being lighted. The heat of the fuse ignites the chemicals that propel the fireworks into the sky.

In this section, you will investigate a variety of chemical reactions and how different factors affect the rate of these reactions. Think about safety as you do each activity.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Chemical Reactions

At first it may seem that the launch of a space shuttle and the activation of air bags in a vehicle have very little in common. In fact, both of these events require a **chemical reaction** to work. A chemical reaction takes place when two or more substances combine to form new substances. A chemical change in a substance results from a chemical reaction.

The chemical reaction occurring in launching a space shuttle involves almost 1 500 000 L of liquid hydrogen and 545 000 L of liquid oxygen combining to form water. During this reaction, enough energy is released to put the shuttle into orbit around Earth. In a vehicle equipped with air bags, the chemical reaction occurs on a smaller scale, but the results are also dramatic. Air bags, packed inside the frame of a vehicle, contain the explosive chemical sodium azide ($NaN_{3(s)}$). When the vehicle is in a collision, the sodium azide reacts and forms large volumes of nitrogen gas and sodium. The sodium quickly reacts with another compound in the air bag to make less dangerous compounds. Fifty grams of sodium azide can produce 30 L of nitrogen gas in milliseconds—a reaction that releases a burst of energy. The nitrogen gas inflates the air bags instantly, cushioning the impact of the collision for the driver and front-seat passenger.

*info***BIT**

Dr. John Polanyi

In 1986, Canadian Dr. John Polanyi won the Nobel Prize in chemistry for his work investigating the properties of chemical reactions.

*QUICK***LAB**

ROCKET SCIENCE

Purpose

To use a chemical reaction to create a film canister rocket

Procedure

1. Half fill the film canister with water.
2. Place a quarter tablet of Alka-Seltzer in the canister and quickly snap on the lid.
3. Place the canister upside down on the ground and stand at least 5 m back. CAUTION: If the rocket does not launch after about 1 min, slowly approach it and kick it over with your foot. If the lid doesn't come off, carefully remove the lid, keeping the canister pointed **away** from everyone.
4. Record your observations.
5. Try changing the variables to make the rocket go as high as possible. For example, change the amount of water, the amount of Alka-Seltzer, or the position of the canister on the ground. Record your observations each time.

Questions

6. How did you make a film canister rocket?
7. Did a chemical reaction occur inside the film canister? Provide evidence to support your answer.
8. What combination of materials made the rocket go the highest?

Materials & Equipment

- plastic film canister with inside snapping lid
- water
- Alka-Seltzer tablet, cut into quarters
- pencil and notebook

Figure 4.1 The reactants potassium iodide and lead(II) nitrate are both clear. The chemical reaction that takes place when they are combined results in a colour change in the product.

The materials at the start of a reaction are called the **reactants**. Think of a campfire. The burning wood undergoes a combustion reaction. In this case, the reactants, or substances being combined in the reaction, are wood and oxygen. The new materials produced by the reaction are called **products**. In a campfire, the products are carbon dioxide and water, formed while energy is released.

This chemical reaction can be written as a chemical word equation, as shown below. Note that in such equations, the reactants always appear to the left of the arrow and the products to the right.

wood + oxygen ⟶ carbon dioxide + water + energy released

Plus signs separate the reactants from each other and the products from each other. The arrow indicates the direction in which the reaction is most likely to occur. When you take more advanced science courses, you will learn about situations where the reaction can occur in either direction.

Recall from section 1.3 that when a chemical reaction occurs, a new substance forms and evidence of the reaction may include one or more of the following:

- a colour change
- the formation of an odour
- the formation of a solid or a gas
- the release or absorption of heat

While colour change and formation of an odour are usually good indicators that a chemical reaction has taken place, care must be taken in interpreting some of the other types of evidence. For example, the formation of bubbles in a solution doesn't always mean that a new gas is being produced in a chemical reaction. The bubbles may simply mean that the solution has begun to boil. Evidence of heat being released or absorbed may also indicate a physical change rather than a chemical change. Some solids, for example, release heat when they are dissolved.

GIVE IT A TRY

IDENTIFY THE REACTION

Below are three different reactions. Identify the reactants and products for each reaction. Write out the chemical word equation.

Reaction 1. When hydrogen peroxide is left out in the sun, it changes to water and oxygen gas.

Reaction 2. A silver spoon is exposed to air. Over time, it turns a dark brown colour.

Reaction 3. Sodium and bromine react explosively to produce sodium bromide.

ACTIVITY B-6

Inquiry

OBSERVING CHEMICAL REACTIONS

The Question

How will different materials react with each other?

Materials & Equipment

- 3 test tubes
- test-tube holder
- 5% or 1.0 mol/L sulfuric acid
- magnesium ribbon
- matches
- splint
- 2% or 0.2 mol/L copper(II) sulfate
- steel wool
- stirring rod
- 3% or 0.2 mol/L iron(III) chloride
- 3% or 0.8 mol/L sodium hydroxide
- 5 g baking soda
- vinegar
- 500-mL beaker
- thermometer

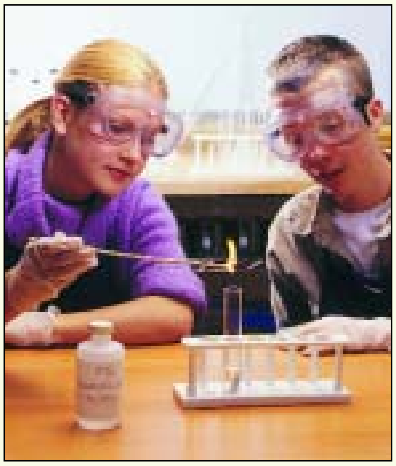


Figure 4.2 Step 4

Procedure

1 Before you start, your teacher will review the safety guidelines with you.

2 Draw a table in which to record your observations.

Reaction 1—Sulfuric acid and magnesium ribbon

3 Place a test tube in the test-tube holder. Pour the dilute sulfuric acid into the test tube to a depth of about 3 cm.

4 Add a 2-cm strip of magnesium ribbon to the dilute sulfuric acid in the test tube.

5 Light a splint and hold it so that the burning end is in the test tube. Make sure the test tube is pointing away from you and your classmates. Record your observations in the table.

Reaction 2—Copper(II) sulfate and steel wool

6 Place a clean test tube in the test-tube holder. Pour the copper(II) sulfate solution into the test tube to a depth of about 3 cm.

7 Add a small piece of steel wool to the copper(II) sulfate solution. You may need to use a stirring rod to push the steel wool down into the solution. Record your observations.

Reaction 3—Iron(III) chloride and sodium hydroxide

8 Place a clean test tube in the test-tube holder. Pour the iron(III) chloride solution into the test tube to a depth of about 3 cm.

9 Add a similar amount of the dilute sodium hydroxide solution to the test tube. Record your observations.

Reaction 4—Baking soda and vinegar

10 Pour 40 mL of vinegar into a 500-mL beaker. Measure and record the temperature of the vinegar.

11 Slowly add 5 g of baking soda to the vinegar. Measure and record the temperature.

Caution!
Be sure to wear your safety goggles, apron, and gloves. Iron(III) chloride is a strong irritant, and is corrosive and toxic. Sulfuric acid and sodium hydroxide are corrosive.

Analyzing and Interpreting

12 For each combination of materials you investigated, identify whether a chemical or physical change took place. Explain your answers.

13 For each chemical reaction, describe the evidence that you used to determine if new products were formed.

Forming Conclusions

14 Look back at the question at the beginning of this activity. Write a conclusion that answers that question by describing what you did, why you did it, and what you found.

reSEARCH

Changing Chemical Bonds

Endothermic and exothermic reactions involve the forming or breaking of chemical bonds. Find out how energy is used to form or break these bonds, and give examples. Begin your research at www.pearsoned.ca/scienceinaction.

Endothermic and Exothermic Reactions

A chemical reaction that releases heat energy is called an **exothermic reaction**. When you burn an object in the presence of oxygen, energy in the form of heat is given off. Heat is also emitted when your body metabolizes food.

A chemical reaction that absorbs heat energy is an **endothermic reaction**. If you observed the chemical reactions in Inquiry Activity B-6, you noticed that the temperature in the baking soda and vinegar reaction dropped during and just after the reaction. Chemical cold-packs found in first aid kits are another example of where an endothermic reaction occurs. The reactants in the cold-packs must be crushed together to start the reaction. As the chemical change occurs and new products form, energy is absorbed from the liquid in the bag, and the bag becomes very cold.

Chemical Changes Involving Oxygen

Chemical changes occur because some substances react with each other when they come into contact. Among the most common types of chemical reactions are those involving oxygen. Three examples of reactions in which oxygen reacts with other substances are combustion, corrosion, and cellular respiration.

Combustion is a chemical reaction that occurs when oxygen reacts with a substance to form a new substance and give off energy. Fire is a common example of a combustion reaction. In burning, wood reacts with oxygen to give off heat and light and produce carbon dioxide and water. Recall that earlier in this unit you read about the significance of early humans discovering how to start fires. Combustion could be considered the first chemical reaction used by humans. Today, it is still one of the most important chemical reactions we use.

Corrosion is the slow chemical change that occurs when oxygen in the air reacts with a metal. A common example of corrosion is rusting. Rusting occurs when iron reacts with oxygen to form iron oxide.

Cellular respiration is a chemical reaction that takes place in the cells in your body. Food (glucose) reacts with oxygen to produce energy, water, and carbon dioxide. Figure 4.4 shows the word equation for cellular respiration.

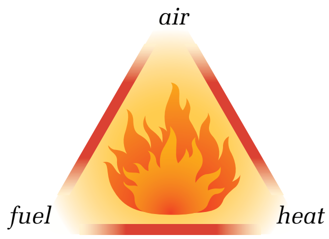


Figure 4.3 This fire triangle shows the three factors that keep a fire going. If any one of them is missing, the fire will not continue burning.

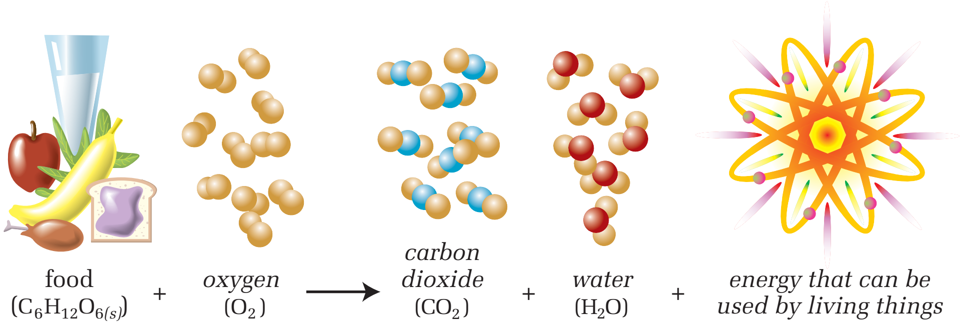


Figure 4.4 The word equation for cellular respiration

ACTIVITY B-7

Experiment **on your own**

REACTIONS FOR UPSET STOMACHS

Before You Start

Many different types of medications are available to soothe an upset stomach. A common one is antacid. Antacids can be solid tablets or liquids.

For this activity, you will use an Erlenmeyer flask containing 75 mL of dilute hydrochloric acid and 3 drops of methyl orange indicator. This is a model of an upset stomach. You will add antacids to the model stomach. When the orange colour disappears, the stomach is no longer upset. In this reaction, carbon dioxide gas is produced. To capture the gas, you can place a balloon over the flask.

In this activity, you will determine which antacid works best and the most effective way to take it. You may wish to use Toolbox 2 to help you plan your experiment.

Figure 4.5 Adding antacid to an Erlenmeyer flask containing hydrochloric acid

The Question

Which antacid medication works best? What is the most effective way to take it?

Design and Conduct Your Experiment

1. Write a hypothesis about the most effective method for taking antacid medication.
2. Decide what materials you will need to test your hypothesis.
3. Plan your procedure. Ask yourself questions such as:
   a) How will I determine which antacid is best?
   b) How will I determine what is the best way to take this antacid?
   c) What type of chart will I need to record data?
   d) Is the test I've designed fair? How do I know?
   e) What are the variables in my experiment? Which is the manipulated variable? Which is the responding variable? Which variables will I control?
   f) How long do I have to complete my experiment?
4. Write up your procedure. Show it to your teacher before continuing.
5. Carry out your experiment.
6. Compare your results with your hypothesis. Did your results support your hypothesis? If not, suggest possible reasons for this.
7. Share and compare your experimental plan and findings with your classmates. Did anyone plan an experiment exactly like yours or similar to yours? How do your results compare with theirs?

Check and Reflect

Key Concept Review

1. What is the difference between a chemical reaction and a physical change?

2. How are reactants different from products in a chemical reaction?

3. Describe three observations you might make when a chemical change occurs.

4. Chemical fire starter ignites as a result of from the following reaction:

$$2\ CH_3OH_{(l)} + 3\ O_{2(g)} \longrightarrow 2\ CO_{2(g)} + 4\ H_2O_{(g)}$$

a) What are the reactants?
b) What are the products?
c) What could be one observation you could make to conclude a chemical reaction has occurred?

5. What is the difference between an exothermic reaction and an endothermic reaction?

6. How are the reactions in the items shown in Figure 4.6 useful to humans?

Figure 4.6 Question 6

Connect Your Understanding

7. a) In what ways are combustion and corrosion similar?
b) In what ways are they different?

8. Write the chemical word equations for the following reactions:
a) Zinc and hydrochloric acid are added together. A bubbling reaction creates hydrogen gas and zinc chloride.
b) When sugar and sulfuric acid are combined, carbon, water, and sulfur dioxide are formed.
c) Rust is formed when iron reacts with oxygen.

9. Rewrite the following chemical reactions into chemical equations using the appropriate chemical formulas.
a) Magnesium and sulfur combine to form magnesium sulfide.
b) When calcium is added to chlorine gas, calcium chloride is formed.
c) Water is formed when hydrogen and oxygen are combined.

Extend Your Understanding

10. Create a step-by-step procedure describing how to write a chemical equation.

11. Compare and contrast combustion, corrosion, and cellular respiration.

4.2 Conservation of Mass in Chemical Reactions

In a chemical reaction, products are formed when the reactant (or reactants) undergoes a change. These products usually look very different from the reactants. However, the total mass of these products is always the same as the total mass of the reactants. This law is called the **conservation of mass**. It states that matter is not created or destroyed in a chemical reaction. For example, combining 24.3 g of magnesium and 32.1 g of sulfur creates a new substance called magnesium sulfide. The law of conservation of mass predicts that the mass of the product will be the sum of these two masses: 56.4 g. Careful experiments have been made on this and many other reactions. These experiments have been done in **closed systems**, where no additional material is allowed to enter or leave. The result? No exceptions to this law have ever been found in any chemical reaction.

$$\underset{24.3\text{ g}}{Mg_{(s)}} + \underset{32.1\text{ g}}{S_{(s)}} \longrightarrow \underset{56.4\text{ g}}{MgS_{(s)}}$$

$$\underset{\text{iron}}{Fe_{(s)}} + \underset{\text{sulfur}}{S_{(s)}} \longrightarrow \underset{\text{iron sulfide}}{FeS_{(s)}}$$

Figure 4.7 The total mass of the reactants and the total mass of the products are equal.

Some reactions may not seem to follow the principle of the conservation of mass. For example, adding 10 g of Alka-Seltzer to 100 g of water in a beaker causes carbon dioxide gas to be given off. When the reaction is complete, the mass of the products left in the beaker is only 106 g, not 110 g. This doesn't mean that mass was not conserved. The carbon dioxide gas was also one of the products of the reaction, but it escaped from the open beaker into the air. This is an example of an **open system**. If it had been trapped, it would have been found to have a mass of 4 g.

*info*BIT

Einstein, Matter, and Energy

In a nuclear reaction, some of the mass is converted to energy, as Albert Einstein expressed in his famous $E = mc^2$ relation.

*math*Link

Two reactants undergo a chemical reaction and produce one product. The mass of one of the reactants is 20 g and the mass of the product is 45 g. Write an algebraic equation representing this reaction, and solve the equation to find the mass of the second reactant.

Activity B-8

Inquiry

Conserving Mass

The Question

Does the mass of reactants and products change during a reaction?

Materials & Equipment

- balance
- 4 g baking soda
- 4 g calcium chloride
- large self-sealing plastic bag
- 5-mL measuring spoon
- 5 mL water
- 5 mL bromothymol blue
- film canister

Procedure

1 Put the baking soda and calcium chloride in the self-sealing plastic bag.

2 Put the water and bromothymol blue in the film canister.

3 Place the canister in an upright position in the bag. Carefully seal the bag. Measure and record the mass of the bag.

4 Predict what you think will happen when all the substances mix together. Record your prediction.

5 Without opening the bag, tip the canister over and allow the liquids and solids to mix. Record as many observations as you can while the reaction is occurring. Be sure to hold the bag to observe the temperature changes.

6 When the reaction is complete, measure and record the mass of the bag.

7 When you have finished the activity, clean up and return the materials as instructed by your teacher.

Caution!
If the bag seems ready to burst, open it up.

Analyzing and Interpreting

8 What evidence do you have that a chemical reaction occurred?

9 How did the mass before the reaction compare with the mass after the reaction?

10 Was the reaction exothermic, endothermic, or both?

Forming Conclusions

11 Use your observations and the data collected during this investigation to answer the question posed at the beginning of the activity.

Figure 4.8 Step 3

reSEARCH

Chemical Reaction Laws

In addition to the law of conservation of mass, two other laws apply to chemical reactions. Find out what the law of definite composition and the law of multiple proportions are. Begin your search at www.pearsoned.ca/scienceinaction.

CHECK AND REFLECT

Key Concept Review

1. Define the law of conservation of mass.
2. What is a closed system in terms of a chemical reaction? Give an example.
3. What is an open system in terms of a chemical reaction? Give an example.
4. If you were to compare (i) the mass of a car with a full tank of gas to (ii) the mass of the same car with an empty tank of gas *plus* the mass of the exhaust fumes produced while the car burned the gas, would mass (i) and mass (ii) be different or would they be equal? Explain your answer.

Connect Your Understanding

5. A solid mass of 25 g is mixed with 60 g of a solution. A chemical reaction takes place and a gas is produced. The final mass of the mixture is 75 g. What was the mass of gas released?
6. If 100 g of one substance reacts with 70 g of another substance, what will be the mass of the products after the reaction?
7. A student adds 15 g of baking soda to 10 g of acetic acid in a beaker. A chemical reaction occurs and a gas is given off. After the reaction, the mass of the products remaining in the beaker is 23 g. Has mass been conserved in this reaction? Explain your answer.

Extend Your Understanding

8. Select a chemical reaction you have read about or observed in this section. Use the chemical formulas of the reactants and products to prove the law of conservation of mass.
9. Does a glass of pop have a greater, smaller, or identical mass after it has sat out on the table overnight? Explain your answer.
10. Is Earth a closed system or an open system? Explain your answer.

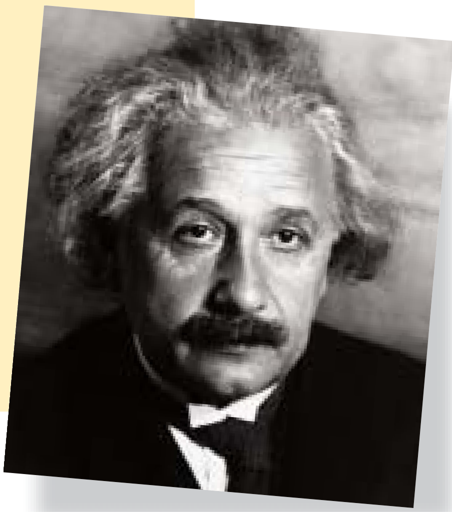


Figure 4.9 Albert Einstein was the first person to propose that in a nuclear reaction, some mass is converted into energy.

4.3 Factors Affecting the Rate of a Chemical Reaction

Figure 4.10 Chemicals can be used to change hair colour.

You may know someone who tried to change his or her hair colour, but the process didn't quite work out as planned. Colouring hair is the result of a chemical reaction. If the reaction is not controlled properly, unintended effects can occur, such as unexpected hair colours or burning of the scalp. Another common example of a chemical reaction is making a cake. It's important to use the right amount of each ingredient. If you add too much baking powder, for example, you can end up with a batter that rises more than it should.

It is important to understand how a chemical reaction works and the factors that affect the rate of the reaction. The four factors that can affect the rate of a chemical reaction are:
- the presence of a catalyst
- the concentration of the reactants
- the temperature of the reactants
- the surface area of the reactants

Catalysts

Catalysts are substances that help a reaction proceed faster. They are present with the reactants of a reaction, but they are not consumed during the reaction. Chemical reactions involving catalysts can be found in both living and non-living things. The most common example in living things is in your body. Many reactions, such as the breaking down of food, require a catalyst called an **enzyme**. Without enzymes, many reactions would require much higher temperatures—a situation that would be deadly to the human body.

Enzymes can help get rid of poisons in the body quickly. For example, one product of reactions in cells is hydrogen peroxide (H_2O_2). Hydrogen peroxide is poisonous. An enzyme called *catalase*, which is found in many different types of animal and plant cells, speeds up the breakdown of hydrogen peroxide into harmless oxygen and water. Figure 4.11 shows a model of how an enzyme like catalase functions.

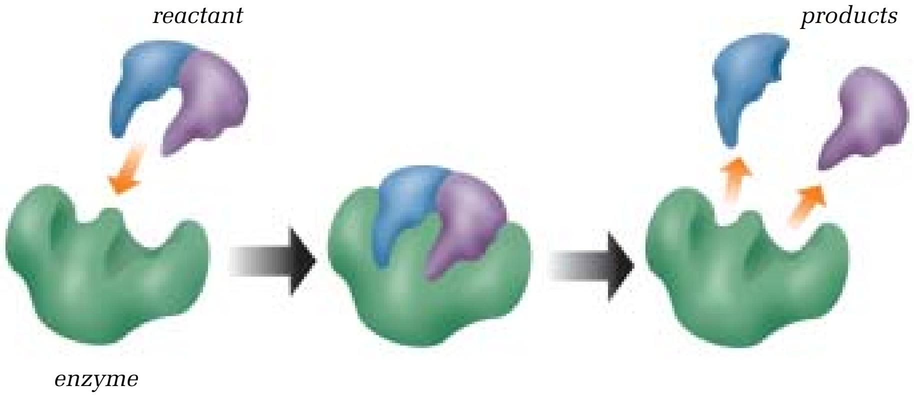


Figure 4.11 The shape of the enzyme molecule helps the reactant molecule break down.

QUICKLAB

Hydrogen Peroxide and the Catalyst Manganese(IV) Oxide

(Teacher Demonstration)

Like catalase, the catalyst manganese(IV) oxide ($MnO_{2(s)}$) also speeds up the reaction that breaks down hydrogen peroxide and produces a gas. To test if the gas is present, a glowing splint is placed in the test tube holding the reaction.

Purpose

To observe the effects of a catalyst on the rate of a chemical reaction

Procedure

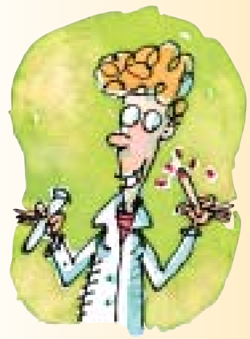
1. Pour hydrogen peroxide into a test tube to a depth of 4 cm. Wait 30 s.
2. Light a wooden splint. After 5 s, blow it out. Immediately hold the glowing splint in the test tube. Record your observations.
3. Add 1 g of the catalyst manganese(IV) oxide ($MnO_{2(s)}$) to the hydrogen peroxide in the test tube.
4. Observe the test tube for 30 s.
5. Light another wooden splint and blow it out after 5 s. Immediately place the glowing splint into the test tube. Record your observations.

Questions

6. Describe how the catalyst manganese(IV) oxide affects the rate of reaction in this demonstration.
7. What gas was given off by the reaction? What evidence do you have to support your answer?
8. If a piece of fresh liver is dropped into hydrogen peroxide, a similar reaction occurs. What can you infer about the chemicals found in liver?
9. If you were to cool the hydrogen peroxide before you added the catalyst, what do you think would happen to the rate of reaction? Explain your answer.

Materials & Equipment

- hydrogen peroxide
- test tube
- wooden splint
- matches
- manganese(IV) oxide



*info***BIT**

Fuel Cells

Fuel cells use a platinum catalyst to generate electricity from the reaction of hydrogen and oxygen. These cells can now be found in cars and other devices.

ACTIVITY B-9

Inquiry

RATES OF REACTION

The Question

What factors can be changed to increase the rate of a reaction?

Materials & Equipment

- graduated cylinder
- water
- 500-mL beaker
- 15-mL plastic measuring spoon
- copper(II) chloride
- stirring rod
- thermometer
- aluminum foil

Figure 4.12 Step 6

Procedure

Part 1—Investigating the Reaction

1. Using the graduated cylinder, measure 50 mL of water and place it in the beaker.
2. Measure 15 mL of copper(II) chloride.
3. Add the copper(II) chloride to the water and stir until the solid has dissolved. Record your observations of the solution.
4. Measure the temperature of the solution.
5. Crumple a piece of aluminum foil so that it will fit into the beaker. Using the stirring rod, push the aluminum foil into the solution. Observe and record any changes.
6. Record the temperature (in °C) every 30 s until the temperature begins to drop.

Part 2—Changing the Rate of the Reaction

7. In this part of the activity, you will design a procedure using only the materials you used in part 1. Your task is to create a reaction that will give you the highest temperature as quickly as possible.
8. Working with your lab partner, design your procedure and write it down. Remember that you will have to measure the temperature every 30 s as in step 6 in part 1.
9. Have your teacher approve your procedure.
10. Carry out your plan and record your results.

Analyzing and Interpreting

11. What evidence do you have that a chemical change occurred when aluminum was added to the copper(II) chloride?
12. Graph the temperatures you measured in part 1 against the time that you measured them. On the same graph, graph the temperatures you measured in part 2. Use a different colour for your second graph.
13. What products do you think were produced from the reaction?
14. What factors did you change to increase the rate of the reaction?
15. Was there a difference in the highest temperatures you measured in parts 1 and 2? Why do you think this occurred?
16. If the challenge was to create the lowest temperature possible, what factors would you change?

Forming Conclusions

17. Describe how you would create a reaction to get the highest temperature as quickly as possible, given the materials you used in this activity.

Other Factors Affecting the Rate of Reaction

A catalyst is one factor that can affect the rate of a reaction. Three other factors are concentration, temperature, and surface area.

Concentration

The greater the concentration of the reactants, the faster the reaction. The increased concentration of the reactants means that there are more atoms of each reactant available to react. For example, adding more aluminum to a copper(II) chloride solution will cause the reaction between the two substances to proceed faster.

Temperature

The temperature of the reactants can also affect the rate of a reaction. The more heat added to the reactants, the faster the reaction. The added heat causes the atoms of each reactant to move faster, which increases the chances of their colliding with each other. For example, if you were investigating the copper(II) chloride–aluminum reaction, you could heat the copper(II) chloride solution to make the reaction proceed more quickly.

Surface area

Increasing the surface area of the reactants is another factor that can increase the rate of a reaction. The greater surface area of the reactants means that more area is available for reaction. In the copper(II) chloride and aluminum example, cutting the aluminum foil into tiny pieces would increase the surface area, causing the reaction to proceed faster.

Figure 4.13 This grain elevator blew up when the extremely fine grain dust in the air was ignited accidentally. The fine dust means a large surface area of grain was available for the combustion reaction.

reSEARCH

Controlling Industrial Reactions

Find examples of industrial chemical reactions that require the rate of the reaction to be controlled. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is an enzyme?
2. Explain how an enzyme is different from other catalysts.
3. What are four factors that can affect the rate of reaction?
4. Give one example, not discussed in the book, of a reaction where the rate was increased because of changes in the four factors mentioned above.

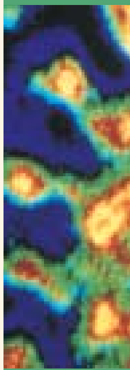
Connect Your Understanding

5. What is the purpose of storing food in a cooler with ice when you go camping or on a picnic? Explain your answer in terms of rate of chemical reaction.
6. Why does chewing your food make it easier to digest?
7. Why should batteries be stored in the fridge when they are not being used?
8. For each of the following reactions, how could the rate of chemical change be increased?
   a) a block of wood burns slowly
   b) an Alka-Seltzer tablet fizzes slightly
   c) ice-cold hydrochloric acid reacts slowly with powdered zinc

Extend Your Understanding

9. The catalyst manganese(IV) oxide is able to increase the rate at which hydrogen peroxide decomposes into oxygen and hydrogen. The enzyme catalase is found in animal livers and can perform the same function. If the hydrogen peroxide is heated to 60°C first, the catalase doesn't work. Why?
10. Plan and write a procedure to test how the concentration of yeast will affect the rising of bread.

Figure 4.14 Dyeing a shirt to create the varying colour tones shown here requires controlling the reaction rate of the various chemical dyes used.



Assess Your Learning

Key Concept Review

1. Define a chemical reaction and give an example.
2. Create a chemical word equation using the following: reactants, products, $\longrightarrow$
3. Which of the following observations would not be evidence of a chemical reaction?
   a) precipitate (solid) formed
   b) heat released
   c) substance melted
   d) colour changed
4. How does the fire triangle describe the chemical reaction called combustion?
5. Define the law of conservation of mass in your own words.
6. What is the difference between an open and a closed system?

Connect Your Understanding

7. Write the following reactions as chemical word equations.
   a) Calcium and water combine to form calcium hydroxide and hydrogen.
   b) Hydrogen gas and sulfur are products created when hydrogen sulfide decomposes or breaks down.
   c) Methane and oxygen react to produce carbon dioxide, water, and energy.
   d) If there is not enough air for all the methane to react in c), carbon and water are formed.
8. How can you determine if a reaction is exothermic?

Extend Your Understanding

9. A reaction occurs in a closed system. The mass of the products is 25 g. What was the mass of the reactants? How do you know?

Focus On THE NATURE OF SCIENCE

At the start of this unit, you were introduced to the idea that the goal of science was to develop knowledge about our natural world. This knowledge includes how substances interact to form new substances. Now that you are at the end of this unit, work with your partner or your class to consider the following questions.

1. Identify an example of two or more substances interacting to produce a change. How do you know a change has occurred?
2. Describe several chemical changes or reactions that you consider useful. What are some characteristics or properties of each of these reactions that make them useful?
3. Describe two chemical changes or reactions where it is important to control the rate of the reaction. Why is this important in each case?
4. Review your answers in Section 1.0, Focus on the Nature of Science. How has your understanding of matter and its interactions changed over time?

Key Concepts	Section Summaries
1.0 • Workplace Hazardous Materials Information System (WHMIS) and safety • substances and their properties • elements, compounds, and atomic theory	**1.0 Matter can be described and organized by its physical and chemical properties.** • Recognition of WHMIS symbols is important to lab safety. • Matter can be organized in different ways. One way is as solids, liquids, and gases. Another way is as mixtures and solutions. • Physical properties of matter such as colour, hardness, boiling point, and density are used to identify substances. Chemical properties describe how a substance interacts with other substances.
2.0 • substances and their properties • elements, compounds, and atomic theory • periodic table	**2.0 An understanding of the nature of matter has developed through observations over time.** • Human understanding of matter grew as people suggested explanations for their observations of the natural world. Theories were confirmed or rejected as people learned more about matter. • The Greek philosopher Democritus stated that matter was made up of tiny indivisible particles called *atomos*. This theory was not widely accepted for 2000 years. • Investigations by scientists, such as Robert Boyle, in the 1600s confirmed that matter is made up of tiny particles. Further investigation by researchers gradually developed the understanding we have today that matter is made up of atoms. Each atom has a nucleus containing protons and neutrons. Electrons orbit the nucleus. • Elements are pure substances made up of only one type of atom. The periodic table organizes the elements according to their atomic number and atomic mass. The atomic number is the number of protons in the nucleus. The atomic mass is the average mass of an atom of an element. • Patterns of information on the periodic table include groupings of metals, metalloids, and non-metals.
3.0 • periodic table • elements, compounds, and atomic theory • chemical nomenclature	**3.0 Compounds form according to a set of rules.** • Every chemical compound has a chemical formula and chemical name. The chemical formula identifies the elements in the compound and their proportions. • An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons from one atom to another. • Ionic compounds form between atoms of metals and non-metals. • Molecular compounds form between atoms of non-metals.
4.0 • endothermic and exothermic reactions • reactants and products • conservation of mass • factors affecting reaction rates	**4.0 Substances undergo a chemical change when they interact to produce different substances.** • A physical change may change the appearance or state of a substance but not its composition (e.g., melting). A chemical change results in the formation of one or more different substances. • Reactions involving oxygen are some of the most common types of chemical reactions. These include combustion, corrosion, and cellular respiration. • A chemical reaction occurs when substances called reactants interact to produce different substances called products. • According to the principle of the conservation of mass, the mass of the products in a chemical reaction equals the mass of the reactants. • An exothermic reaction gives off energy. An endothermic reaction takes in energy. • The rate of reaction can be affected by the addition of a catalyst, or an increase in the concentration, temperature, or surface area of the reactants.

Metal Contamination of the Environment

Equipment operators must wear special protective gear when cleaning up contaminated soil.

The Issue

Humans have many uses for metals. Copper for wire, aluminum for pop cans, and lead for batteries are just a few examples. Some metals, such as lead, are poisonous to humans if exposure occurs over a long period of time. This exposure may result from metals finding their way into the groundwater or from unsafe storage. In many cases, the people or companies responsible for the contamination are no longer present to take responsibility for the cleanup. The problem of metal contamination in the environment leads to several questions.

What should be done with contaminated soil?

When metals from factories, mines, and dumps contaminate soil, the area is closed to human access. This prevents immediate harm to people. However, the soil must be made safe for the future. There are two common options for cleaning up contaminated soil. The first option involves removing the top layer of contaminated soil. However, the contaminated soil must then be cleaned or stored in another area. The second option is to cover the contaminated soil with a thick layer of clean soil. In theory, the new layer seals the contaminated soil from the environment.

How much of the contaminated soil needs to be cleaned up?

Cleaning up a contaminated site is costly. Some people suggest that only toxic sites where people may live or work should be cleaned up. Others suggest that only areas where people live should be cleaned. To save money, only a partial cleanup of the workplace is necessary. Other people feel that all toxic areas should be cleaned, as it is hard to predict where people will live or work in the future.

Who should be responsible for the cleanup?

Cleaning a contaminated area may require removal of soil, buildings, and trees, and the addition of clean soil. This is an expensive process. Since many of these waste sites have been abandoned, it is difficult to determine who should be responsible for cleaning them up. All levels of government—municipal, provincial, and federal—have a role in determining how these sites should be rehabilitated.

Go Further

Now it's your turn. Look into the following resources to help you form your opinion.

- Look on the Web: Check the Internet for information on examples of metal contamination in Alberta and what is being done about them.
- Ask the Experts: Try to find an expert on metal contamination, such as a chemical engineer or an environmental geologist. Experts can be found in various places: city hall, universities, environmental consulting companies, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about metal contamination.

Analyze and Address the Issue

Summarize your opinion of what should be done about cleaning up contaminated soil and who should do it as one of the following:

- a newspaper article for your local or school newspaper
- a speech to be presented at a public forum on the issue

PROJECT

WHAT'S IN THE BOTTLE?

You can use the well in a spot plate for a micro-scale reaction.

Getting Started

There's a problem in the science lab. A bottle containing an unknown solution has been found. Because the contents are unknown, it is difficult to determine how to dispose of it.

Your Goal

In this activity, you will perform a variety of micro-scale reactions to gather information about how various solutions react. You will then use this information to identify an unknown sample.

What You Need to Know

Micro-scale reactions occur when very small amounts of reactants are used. Usually the reaction takes place in a small depression or well on a spot plate. By filling the well half full with one solution or solid reactant and then adding a second reactant, you can observe if a reaction has occurred.

The following observations can help you determine that a reaction has occurred:

• bubbles form or a gas is given off

• the colour changes

• a solid substance called a precipitate forms

If the spot plate is clear and colourless, you may need to put a piece of white paper under the plate. This will help you observe any reaction that occurs.

Steps to Success

Part 1—The Tests

1 Collect the necessary equipment for this activity:
- 1 spot plate
- bottles of solutions labelled A, B, C, D, E, F
- paper towel

2 Combine two solutions in all possible ways, using the table below as your guide.

3 Record your observations in a table like this one.

A	B	C	D	E	F	Unknown
A						
	B					
		C				
			D			
				E		
					F	
						Unknown

Part 2—The Identification of the Unknown

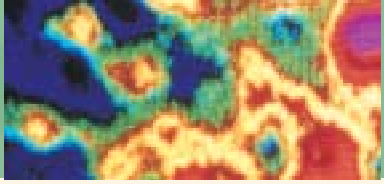
4 Your teacher will give you an unknown solution.

5 Using a clean spot plate, combine each of the known solutions with the unknown solution. Record your results in each case.

How Did It Go?

6 Using your data from part 1, determine what you think the unknown sample in the bottle is. Remember to support your answer with your data.

7 Write your conclusion in a short paragraph. Make sure it answers the following questions:
- What did you do in this activity?
- Why did you do this activity?
- What did you find?
- What is one new thing you learned?



UNIT REVIEW: MATTER AND CHEMICAL CHANGE

Unit Vocabulary

1. Define the following terms in full sentences using your own words.
   WHMIS
   matter
   elements
   periodic table
   atomic mass
   atomic number
   ion charge
   ionic compound
   molecular compound
   exothermic
   endothermic
   law of conservation of mass

Key Concept Review

1.0

2. Match the WHMIS symbol to the following descriptions.


(i)


(ii)


(iii)


(iv)


(v)


(vi)


(vii)


(viii)

   a) poisonous and infectious causing other toxic effects
   b) corrosive material
   c) dangerously reactive material
   d) flammable and combustible material
   e) oxidizing material
   f) biohazardous infectious material
   g) poisonous and infectious causing immediate and serious toxic effects
   h) compressed gas

3. If you had to describe an unknown green solid, what properties could you use?

4. What is the difference between a physical change and a chemical change?

5. Create a chart or picture to illustrate the differences among a pure substance, a mechanical mixture, and a solution. Include examples in your chart or picture.

2.0

6. Why must copper be heated before it can be made into something?

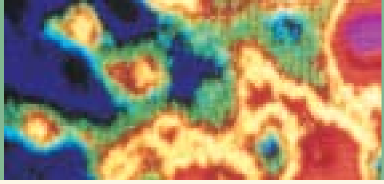
7. What was Ernest Rutherford's contribution to the understanding of the atom?

8. How are metals and non-metals organized in the periodic table?

9. What is the difference between a family and a period in the periodic table?

3.0

10. a) Explain what "ion charge" means.
    b) How can the ion charge be used to determine the chemical formula of compounds?



11. Name the elements in the substances below.
    a) $LiCl_{(s)}$
    b) $Al_2S_{3(s)}$
    c) $AgF_{(s)}$
    d) $ZnO_{(s)}$
    e) $Br_{2(l)}$

12. Which of the following compounds are ionic and which are molecular?
    a) beryllium oxide
    b) lithium phosphide
    c) water
    d) sodium fluoride
    e) carbon dioxide
    f) copper(I) chloride

13. Write the chemical formula for each compound in question 12.

4.0

14. Rewrite the chemical reactions below as word equations.
    a) A solid piece of sodium metal is placed in water, and it reacts explosively to form sodium hydroxide and hydrogen gas.
    b) Hydrogen peroxide is placed in sunlight and reacts slowly to form oxygen and water.
    c) Iron(II) chloride is formed when iron and chlorine gas are combined.
    d) When aluminum is exposed to oxygen, aluminum oxide forms.

15. For each reaction in question 14, suggest a different method for increasing the rate of reaction.

16. How is cellular respiration similar to combustion? How is it different?

17. Is there a difference between a catalyst and an enzyme? Explain your answer.

Connect Your Understanding

18. What contribution to the field of chemistry was made by:
    a) alchemists
    b) Robert Boyle
    c) John Dalton
    d) J.J. Thomson

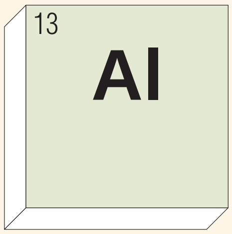
19. Compare Democritus's understanding of the atom with Niels Bohr's understanding.

20. Why was Dmitri Mendeleev's periodic table accepted as a useful way to organize the elements?

21. Explain how J.J. Thomson's "raisin bun model" of the atom is different from Niels Bohr's model of the atom.

22. Describe two patterns found in the periodic table.

23. Below is a box from the periodic table that is missing information. Copy the box into your notebook and fill in the missing information.



24. Copy the following table into your notebook. Use the periodic table to fill in the blanks.

Element	Mass Number	Protons	Electrons	Neutrons
H	1			
	166	82		
Ca	41			
Ag	109			
U	238			
	4			2
	21		10	

25. Write the name for the following formulas, including the correct Roman numerals where necessary:
  a) $MgBr_{2(s)}$
  b) $Ba_3N_{2(s)}$
  c) $FeP_{(s)}$
  d) $PbI_{4(s)}$
  e) $Cu_2S_{(s)}$
26. Why do we use kindling (small sticks of wood) to help start a fire?

Extend Your Understanding

27. How were the first "chemists" in the Stone Age different from "chemists" in the Iron Age?
28. Give three examples of how an understanding of the properties of a type of matter has benefited humans.
29. How can the periodic table be used to determine the ion charge of elements?
30. What is the chemical symbol of the element that has 14 neutrons in its nucleus?

Practise Your Skills

31. Create a mnemonic or "safety slogan" that can be used to remind people of the proper techniques for handling and disposing of laboratory materials.
32. In the following reactions, calculate the mass of the unknown product.
  a) How much water is produced when a spark creates an explosive reaction between 4 g of hydrogen and 32 g of oxygen?
  b) In a 100-g beaker, a student added 25 g of lead(II) nitrate to 15 g of sodium iodide. In her notebook, she recorded the mass of reactants as 40 g. During the chemical rection between the two materials in the beaker, the student noted a colour change but no gases being given off. When she weighed the products of the reaction, she found the total mass to be 140 g. Did this reaction conserve mass? Explain your answer.

Self Assessment

33. Scientific investigations usually require many people to work together as a team. Why is collaboration an important part of scientific work?
34. In this unit, you investigated many different questions and issues related to chemistry. Describe one idea that you would like to find out more about. Explain why you want to learn more about it.

Focus On — The Nature of Science

In this unit, you investigated the nature of science related to matter and chemical change. Consider the following questions.

35. Scientific knowledge results from the shared work of many people over time. Describe the development of an idea in this unit that resulted from the work of many people over time.
36. Was an alchemist really a scientist? Explain your answer.
37. It is often said that science cannot provide complete answers to all questions. Describe a situation in this unit where you felt this statement was true.
38. Reread the three questions on page 91 about the nature of science related to matter and chemical change. Use a creative way to demonstrate your understanding of these questions.

UNIT

C

Environmental Chemistry

In this unit, you will cover the following sections:

1.0

The environment is made up of chemicals that can support or harm living things.

1.1 Chemicals in the Environment

1.2 Acids and Bases

1.3 Common Substances Essential to Living Things

1.4 How Organisms Take in Substances

2.0

The quantity of chemicals in the environment can be monitored.

2.1 Monitoring Water Quality

2.2 Monitoring Air Quality

2.3 Monitoring the Atmosphere

3.0

Potentially harmful substances are spread and concentrated in the environment in various ways.

3.1 Transport of Materials Through Air, Soil, and Water

3.2 Changing the Concentration of Harmful Chemicals in the Environment

3.3 Hazardous Chemicals Affect Living Things

3.4 Hazardous Household Chemicals

Exploring

Willow bark contains salicylic acid.

First Nations people relied on plants for both food and medicine.

Many people use an extract made from the purple coneflower *(Echinacea purpurea)* to help stimulate their immune systems. Echinacea is a traditional medicine in North America.

Medicine from the Environment

When you look at a willow like the one in the photo, you probably just see a tree or a bush. But when a pharmaceutical chemist looks at a willow, she sees an important chemical—salicylic acid. Chemists recognize that the environment is made up of chemicals. Some of these chemicals can interact to cure sickness and improve health in organisms.

First Nations people made use of chemicals in their environment for food and medicine. For example, they recognized the benefits of drinking willow bark tea. In Europe as well, willow bark had been used since at least 400 B.C. At that time, Hippocrates—now known as the Father of Medicine—had recommended it to treat pain and fever. The active ingredient in willow bark was identified in the 1800s as salicylic acid. In 1898, the Bayer company in Germany used a synthetic version of this chemical, called acetylsalicylic acid, to develop a new medicine under the brand name Aspirin.

Aspirin is just one of many medicines we use today that were originally derived from naturally occurring chemicals in the environment. Identifying plants that might provide such chemicals is challenging for scientists. The knowledge of local people helps them select the plants to test. Once the plants are collected, their chemical composition must be analyzed. Plants may be made up of hundreds of different chemicals. When a potentially useful chemical is found, it must be tested for safety and effectiveness.

QUICKLAB

Testing Health Products

Willow bark tea had an unpleasant side effect—it severely irritated the stomach and mouth. One of the tests that was done during the development of the commercial medicine was an acidity test. From other science classes, recall that litmus paper turns red in an acid and blue in a base. If there is no colour change, the test substance is said to be neutral. You will learn more about acids and bases as you work through this unit.

Purpose

To test some health products to determine if they are acidic, basic, or neutral

Procedure

1. Use the medicine dropper to place 5 drops of Aspirin suspension in a clean spot plate.
2. If you are using neutral litmus paper, dip one end of a small piece into the suspension in the spot plate. Record the results.
3. If you are using red and blue litmus paper, do step 2 first with red litmus paper. Then repeat step 2 using blue litmus paper.
4. Repeat steps 1 to 3 for each of the other suspensions. Make sure to use a clean medicine dropper and spot plate each time.

Questions

5. Which suspensions were acidic, basic, or neutral?
6. How do you know in each case?

Materials & Equipment

- Aspirin suspension
- echinacea suspension
- vitamin C suspension
- antacid (e.g., Tums) suspension
- litmus paper
- spot plate
- medicine dropper

Focus On — Social and Environmental Context

While studying this unit, you will be asked to organize your thoughts about the chemical nature of the environment. As you work through the unit, think about the following questions:

1. **What chemicals do we find in the local and global environments?**
2. **How do changes in the concentration and distribution of these chemicals affect living things?**
3. **How can we assess the impact of our use of chemicals on the environment?**

The answers to these and other questions about environmental chemistry will help you understand the role of science and technology in monitoring and maintaining the environment.

1.0 The environment is made up of chemicals that can support or harm living things.

Key Concepts

In this section, you will learn about the following key concepts:

- chemicals essential to life
- organic and inorganic material
- acids and bases
- ingestion and absorption of materials
- substrates and nutrients

Learning Outcomes

When you have completed this section, you will be able to:

- describe processes by which chemicals are introduced into the environment
- identify acids, bases, and neutral substances based on measurement of their pH
- describe the effects of acids and bases
- identify common organic and inorganic substances that are essential to living things
- describe organic matter synthesized by organisms
- describe the uptake of materials by living things
- identify substrates and nutrient sources for living things in a variety of environments
- identify questions about the safe release of substances into the environment

Water is one of the chemicals that is essential for life. You can live only a few days without it. Life-supporting substances dissolve in water and are transported to all parts of your body. Water carries waste materials to your kidneys for removal.

A waterfall like the one shown here creates a large surface area exposed to the air. Gases such as oxygen that make up part of the air dissolve in the water. Aquatic plants, animals, and micro-organisms absorb the dissolved oxygen and use it to release energy through cellular respiration.

In this section, you will learn about chemicals in the environment. You will learn about natural and human processes that change the chemical composition of the environment. And you will learn how organisms use chemicals and are affected by them. You will investigate two important types of chemicals: acids and bases.

For Web links relating to 1.0, visit www.pearsoned.ca/scienceinaction

1.1 Chemicals in the Environment

Trees, mountains, the air we breathe, our own bodies—everything that makes up the environment is made of chemicals. All living things are made of chemicals and depend on chemicals to survive. Without carbon dioxide and water, green plants could not produce sugar for food. Without oxygen, plants and animals could not carry out cellular respiration. These are just a few of the chemicals that support living things.

Not all chemicals that form the environment support living things. For example, forest fires and volcanoes both release large quantities of chemicals such as carbon dioxide, sulfur dioxide, and ash. Even though these substances are produced naturally, they can be harmful to living things. Human activities can also cause chemical changes in the environment. We benefit from products such as gasoline, electricity, and pesticides, but by using them, we may be harming both the living and non-living environment.

*info***BIT**

Volcanoes

Volcanoes release 130 million tonnes of carbon dioxide into Earth's atmosphere every year.

GIVE IT A **TRY**

CHEMICALS IN THE ENVIRONMENT

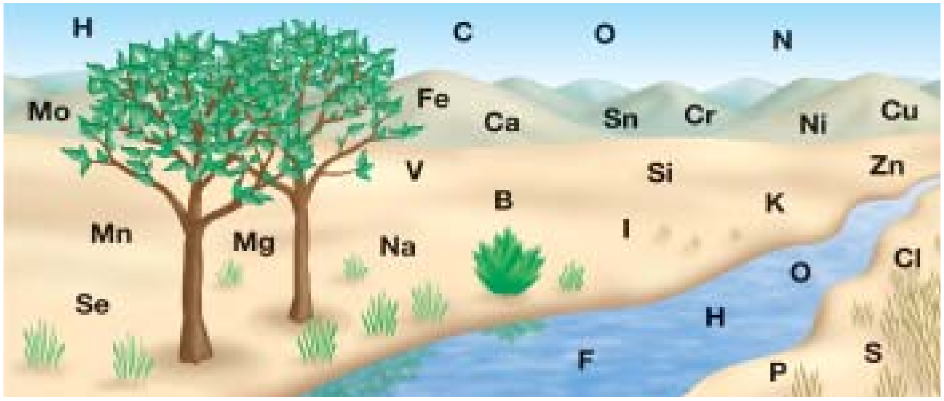


Figure 1.1 Chemicals occur naturally everywhere.

Figure 1.1 is designed to give you an impression of the many elements that are important to life on Earth. These elements combine in different ways to form chemical compounds. **Elements** are pure substances that cannot be broken down into other substances.

TOOLBOX

- Select one of the symbols for the elements shown in Figure 1.1. Using the periodic table in Toolbox 12, record the name of the element.
- Use books, magazines, interviews, or electronic sources to find out how plants and animals use the element. Hint: An element may be used on its own or be part of a compound.
- If possible, also identify any beneficial and harmful effects of the element on living things, including humans.
- Record your findings on a poster.

The Nitrogen Cycle

All chemical compounds are made up of elements. Recall that **elements** are pure substances that cannot be broken down into other substances. Also recall that some elements, such as oxygen and carbon, are always moving through ecosystems. They form chemical compounds that are used and reused by living things. Similarly, the chemical compound water changes state as it moves through ecosystems. The repeating changes of these elements and water as they move through ecosystems is called a cycle. The element nitrogen also cycles in this way.

Nitrogen Fixation

Nitrogen is important for living things. For example, plants require nitrogen to make substances necessary for life. However, plants can use nitrogen only when it is combined with other elements, such as hydrogen and oxygen. Air is about 78% nitrogen in the form of nitrogen gas ($N_{2(g)}$). But plants can't use this "free" nitrogen directly. It has to be "fixed" in compounds with other elements. **Nitrogen fixation** is the process of changing free nitrogen so that the nitrogen atoms can combine with other elements to form compounds that organisms can use.

Certain types of bacteria do most of the nitrogen fixation in the soil. Some of these bacteria are located in the root nodules of specific types of plants, such as beans, clover, and alfalfa (Figure 1.2). The bacteria in these nodules are able to separate the two nitrogen atoms that form nitrogen gas (free nitrogen). Once separated, the nitrogen atoms can form compounds with other elements, such as hydrogen and oxygen. Lightning also converts nitrogen in the air to nitrogen compounds that plants can use.

Steps in the Cycle

Figure 1.2 The bumps on the roots of this alfalfa plant are called "nodules." Bacteria in these nodules are able to fix nitrogen in the soil so other plants can use the nitrogen.

After nitrogen fixation occurs, plants use the nitrogen-containing compounds. Animals then eat the plants. Their bodies use the nitrogen in the compounds to make more complex substances, such as proteins. Decomposers break down these large nitrogen-containing molecules in dead organisms and animal waste into simpler nitrogen compounds in the soil. The nitrogen can move from organisms and back to the soil several times. Eventually some nitrogen-containing compounds are broken down further by other bacteria in the soil. This nitrogen is released back into the air as free nitrogen, and the cycle begins again.

Figure 1.3 shows the nitrogen cycle. However, the concentration of usable nitrogen is not the same everywhere. This is similar to water. The total amount of water on Earth does not change, but too little water in some places causes droughts, and too much water causes floods. The concentration of usable nitrogen varies because it can be removed from the local environment in different ways. Conversion to free nitrogen by bacteria is one way. Another way is by water carrying dissolved nitrogen compounds away or deep into the soil so that they are unavailable to plants. Nitrogen is also lost in an area when plants are harvested. If soil lacks nitrogen, farmers plant nitrogen-fixing plants such as clover and alfalfa or add fertilizers to increase the amount of nitrogen.

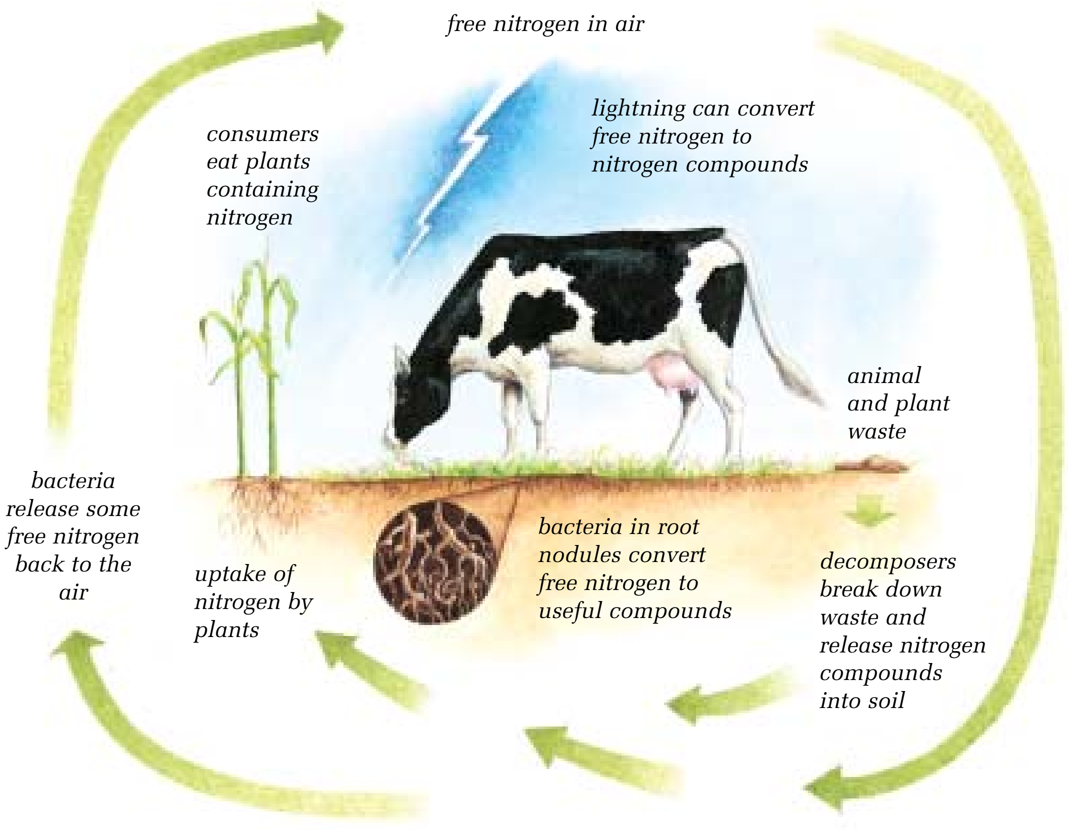


Figure 1.3 The nitrogen cycle. Nitrogen moves from the air into the soil. Bacteria "fix" some of the nitrogen so it can be used by plants, while some is released to the air. This "fixed" nitrogen is taken in by plants, which may be eaten by animals. Plant and animal waste return nitrogen to the soil. The nitrogen may then be reused by plants or released to the air.

Processes and Activities That Affect Environmental Chemicals

The nitrogen cycle is one example of how environmental chemicals change. Other processes and activities can also cause changes in the environment. Think about how you use and change chemicals.

Your body can be compared to a vehicle. You give it food as "fuel" and air rich in oxygen. It uses the chemicals in the food and the oxygen in the air in the process of cellular respiration to give you energy. One of the products you release in this process is carbon dioxide. When you travel in the family car or truck, the vehicle burns a fuel such as gasoline or propane. Oxygen from the air is required for that reaction. Along with the energy produced in this combustion reaction, gases such as water vapour, carbon dioxide, carbon monoxide, and nitrogen oxides are released into the atmosphere.

Cellular respiration is a natural process—a basic process that exists in nature. The nitrogen cycle is another natural process. Driving your car or truck is a human activity—an activity that humans design and carry out. Both natural processes and human activities may change chemicals in the environment. The chemicals formed by human activities are of special interest to many people who are concerned about pollution. **Pollution** is any change in the environment that produces a condition that is harmful to living things. For example, smog caused by vehicle exhaust emissions is pollution because it makes it hard for people and other animals to breathe. Forest fires produce similar chemical pollution.

Human Activities

Human activities release chemicals into the air, water, and soil every day. Growing crops, disposing of solid waste, treating wastewater, manufacturing products, and driving vehicles are all examples of ways that we change the concentration of some chemicals in the environment. Many of these chemicals can be broken down through natural processes. Other chemicals cannot be broken down easily, and can cause long-term problems. Sometimes the use of chemicals becomes an issue. An **issue** is any subject of importance about which people have strong, conflicting points of view.

Figure 1.4 This fertilizer contains the three elements nitrogen (15%), phosphorus (30%), and potassium (15%).

Agricultural Activities

Farmers must have an understanding of chemistry to produce good crops. They have to know what chemicals to add to soil to improve plant growth and what chemicals to treat plants with to protect them from pests.

A **fertilizer** is a substance that enriches soil so that plants will grow better. For example, potassium is essential to plant growth. If a soil is low in potassium, plants cannot grow well in it. The soil must be enriched by adding a potassium fertilizer.

Fertilizers are described by the major nutrient elements they contain. These elements are nitrogen, phosphorus, and potassium. Figure 1.4 shows a typical fertilizer label. The three numbers 15–30–15 on the label indicate that this fertilizer contains 15% nitrogen compounds, 30% phosphorus compounds, and 15% potassium compounds. Some fertilizers have a fourth number and the letter "S" on the label to indicate that they contain sulfur as a major ingredient.

Fertilizers may come from natural sources or synthetic chemicals. They are added to the soil to help plant growth, but they must be applied carefully. It doesn't matter whether a fertilizer comes from a natural or a synthetic source—too much can damage organisms. Too much fertilizer may even damage the crop it's supposed to help. If fertilizer enters ponds, streams, lakes, or rivers, it may damage those ecosystems by changing the concentration of chemicals. You will learn more about the effects of fertilizers on water systems later in this unit.

Farmers also use their understanding of chemistry to apply pesticides safely. **Pesticides** are chemicals used to kill pests. A **pest** is an organism that harms people, crops, or structures. Pesticides are grouped according to the pest that they kill. Herbicides kill or control weeds. Insecticides kill or control insects. Fungicides kill fungi.

Figure 1.5 Some types of insects damage or destroy food crops. The bertha armyworm shown here is a major pest of canola.

It is estimated that at least 50% of the world's food production would be lost to pests if pesticides were not used. However, improper application of pesticides can be harmful to people and other non-pest organisms. Pesticides can also create other problems.

Some pesticides are not selective—they kill both pest and non-pest species. For example, the bertha armyworm shown in Figure 1.5 is a pest of canola. Spraying for the armyworm may kill bees, which are important for pollinating canola and other crops. Another problem occurs with pesticides that stay in the environment for a long time. For example, DDT lasts from 2 to 15 years. It is not approved for use in North America, but it is still used in some parts of the world to kill mosquitoes that carry the disease malaria. Some pests become resistant to pesticides, so new pesticides must be developed to control them.

Solid Wastes

Chemicals may be introduced into the environment when we dispose of solid waste or wastewater. Solid waste includes the garbage that is collected from households, industrial plants, commercial buildings, institutions, and construction and demolition sites. It includes large items, such as machinery, all the way down to small items, such as the caps on plastic drink bottles.

Some solid waste can be reused or recycled, but most of it is placed in landfill sites, like the one in Figure 1.6. Some hazardous wastes are burned in special plants called incinerators, which burn at very high temperatures. Emissions from incinerators may contribute to air pollution.

Sanitary landfill sites are specially built to prevent waste chemicals from moving into the soil. As rainwater or groundwater moves through solid waste, it can dissolve or corrode some items. Sanitary landfills use plastic liners and compacted clay to prevent these solutions from entering the soil and the groundwater.

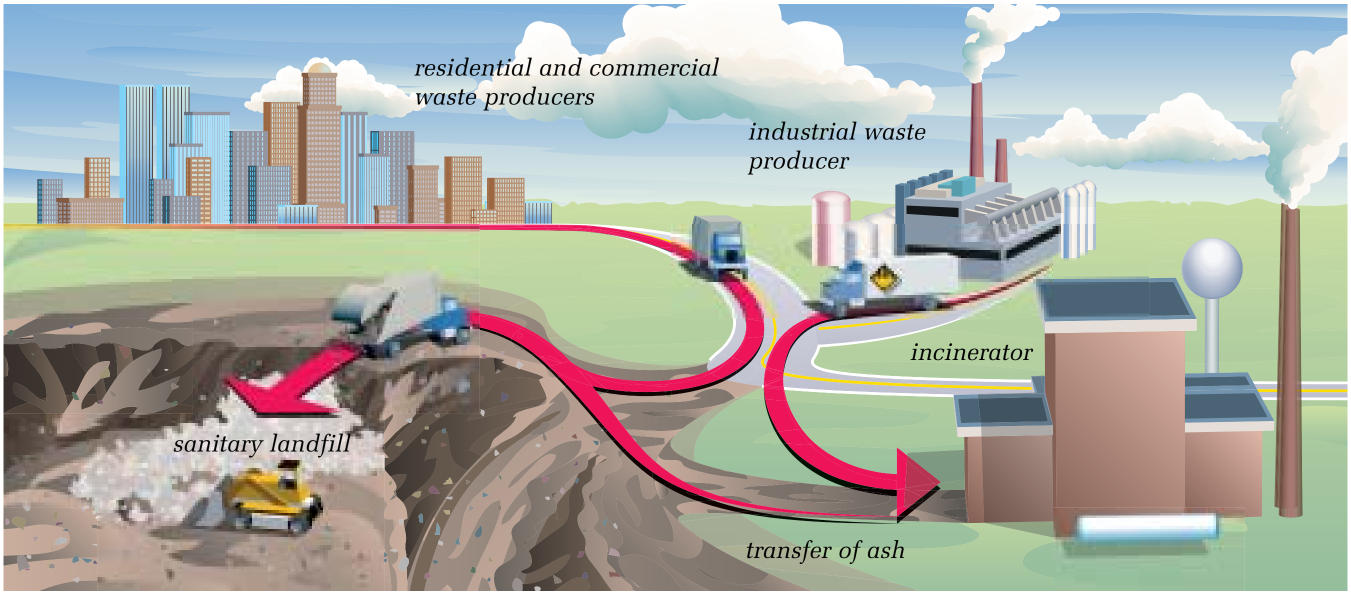


Figure 1.6 In a sanitary landfill, wastes are spread and compacted by bulldozers before they are covered by a layer of soil.

Figure 1.7 The soap and dirt from this car flow into the storm drains in the street. From there, the water flows into local rivers or lakes.

Wastewater

Wastewater containing dissolved and undissolved materials from your kitchen, bathroom, and laundry is called **sewage**. Sewage moves through pipes into a septic tank in rural areas or to a sewage treatment plant in towns and cities. A **septic tank** is an underground container where bacteria break down the organic materials before they are moved out to the soil. A **sewage treatment plant** treats wastes from homes, businesses, industries, and institutions. It may also treat water from street drains. Treated wastewater or **effluent** is released into rivers or lakes. It may contain nitrogen and phosphorus from the breakdown of sewage during treatment.

If the municipal sewage system cannot handle a large quantity of rain water from street drains, that water may go directly into a river or lake through large pipes called **storm sewers**. Water from storm sewers contains chemicals washed off the street, such as oil or other fluids that have leaked from vehicles, and salt from snow-clearing operations.

Fuel Combustion

Coal, oil, and natural gas are called **fossil fuels** because they formed from dead plants and animals. They are called hydrocarbons because they are mainly made up of the elements hydrogen and carbon. They may also contain oxygen, nitrogen, and sulfur. Fossil fuels may contain traces of other elements such as mercury and lead.

When fossil fuels are burned in homes, vehicles, and industrial plants, they produce large amounts of carbon dioxide and water vapour. The general reaction equation for this combustion reaction is:

$$\text{hydrocarbon} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

The combustion of fossil fuels may also release pollutants such as sulfur dioxide, nitrogen oxides, and traces of mercury and lead into the air.

The equations below show what happens in the combustion of methane (in natural gas) and propane. Propane is used in barbecues, vehicles, and some home appliances.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

methane + oxygen ⟶ carbon dioxide + water vapour + energy

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

propane + oxygen ⟶ carbon dioxide + water vapour + energy

As consumers, we are most familiar with the fuels from crude oil and natural gas, which we use in our homes and vehicles. At one time, coal was also used in homes as a heating fuel. Today it is used mainly for electrical generation.

ACTIVITY C-1

Decision Making

VIEWPOINTS ON ELECTRIC POWER

The Issue

Alberta needs more power for its growing economy and increasing population. How can scientific questions be used to help people decide how this power should be generated?

Background Information

1 At large electric power plants, turbines (large wheels) turn coils of wires or magnets in a generator to produce electricity. Hydro-electric plants use falling water to turn the turbines, and wind-powered plants use windmills. Where falling water or wind are not available, water is converted to steam by burning a fossil fuel such as coal, natural gas, or oil. The steam turns the turbine.

2 Consider the following viewpoints:

a) "Alberta has a lot of low-sulfur coal. Natural gas is in much more limited supply. If we use natural gas to produce electricity, we won't have as much available for making plastics. Let's use the coal to produce inexpensive electricity."

b) "Natural gas is the cleanest burning fuel. We will have fewer environmental problems in the future if we build plants that burn natural gas."

c) "Burning fossil fuels produces harmful chemicals such as sulfur dioxide, nitrogen oxides, and mercury. I like the idea of using windmills to generate electricity. It might be less efficient than burning coal or natural gas, but it is the most environmentally friendly method."

d) "Any method is fine as long as the amount of harmful substances released from the electrical plants into the atmosphere does not exceed the government standards."

Analyze and Evaluate

TOOLBOX

3 What viewpoint is expressed by each speaker in step 2? (Use Toolbox 4, to help you identify viewpoints. You may find more than one viewpoint per speaker.)

4 Imagine that you can talk to the speakers. List five questions you might ask them. Compare your questions to those asked by your classmates.

5 Science attempts to understand and explain the natural world. Identify any two of your questions that might be answered by scientific knowledge or processes. Explain why you chose these questions.

6 Technology involves the designing and building of things that satisfy human needs and wants. Identify one question that might be answered by technological knowledge or technological development. Explain why you chose this question.

Figure 1.8 Sheerness Generating Station, east of Drumheller, uses coal to generate electricity.

reSEARCH

Electricity Generation in Alberta

Research one way that electricity is generated in Alberta. Explain the electricity generation process you chose. In a T-chart, list its advantages and disadvantages. Begin your information search at www.pearsoned.ca/scienceinaction.

Industrial Processes

Industrial processes such as electrical power generation, mineral processing, and fertilizer production may release chemicals into the air. A common industrial process in Alberta is natural gas processing. Natural gas is composed of compounds such as methane, ethane, propane, and butane. It also contains nitrogen gas, carbon dioxide, hydrogen sulfide, helium, and traces of metals such as mercury.

Natural gas is processed to separate its components for different uses. Methane, propane, and butane are all derived from natural gas and are used primarily for heating. Ethane is used in plastics such as polyethylene.

Natural gas is also processed to eliminate unwanted substances such as hydrogen sulfide, a poisonous chemical. Natural gas that contains hydrogen sulfide is called **"sour" gas**. If no hydrogen sulfide is present, the gas is considered "sweet."

The process for removing hydrogen sulfide produces sulfur dioxide gas and pure sulfur. Since the 1970s, natural gas processing plants in Alberta have been required by law to restrict their sulfur dioxide emissions. They now recover more than 99% of the pure sulfur for use in manufacturing sulfuric acid. Sulfuric acid is used in making fertilizers, steel, synthetic fibres, and paints.

Check and Reflect

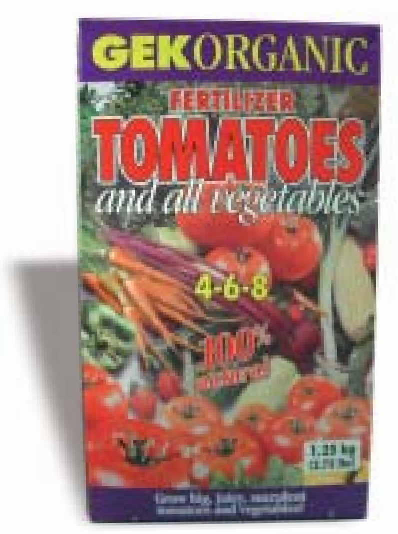


Figure 1.9 Fertilizer label for question 3

Key Concept Review

1. What role do decomposers play in the nitrogen cycle?
2. What is pollution? Give three examples of chemical pollution.
3. What do the numbers on the fertilizer label in Figure 1.9 indicate?
4. Define the term "herbicide."
5. How do sanitary landfill sites prevent chemicals from moving into the groundwater?

Connect Your Understanding

6. Describe two ways that nitrogen is removed from an ecosystem.
7. What pollutants are released from fossil fuel combustion?
8. Why do farmers use fertilizers?
9. Why does sewage need to be treated?

Extend Your Understanding

10. Suggest two ways that you could reduce your need for a fuel-burning vehicle.
11. Identify two issues related to human activities that change chemicals in the environment. For each one, explain why it is considered to be an issue.

1.2 Acids and Bases

In earlier studies, you may have learned that acid rain can be harmful to both the living and non-living environment. An **acid** is a compound that dissolves in water to form a solution with a pH lower than 7. The **pH** number of a solution indicates its acidity. It is a measure of the concentration of hydrogen ions in a solution.

Industrial processes and fuel combustion produce large quantities of carbon dioxide, sulfur dioxide, and nitrogen oxides. In the air, these chemicals dissolve in water droplets to form acids. Sulfur dioxide combines with water to form sulfuric acid. Nitrogen oxides combine with water to form nitric acid. Carbon dioxide dissolves in water to form carbonic acid. All these droplets then fall as acid rain. Acid rain is a concern around the world for several reasons. It can cause lakes and streams to become acidic, which harms the organisms that live in them. It can increase the rate at which buildings and monuments deteriorate.

Acid rain is harmful to the environment, but acids can also be beneficial. Vinegar, for example, is a dilute solution of acetic acid. Lemon juice contains citric acid. Some types of plants, such as blueberries, grow better in acid soils.

A **base** is a compound that dissolves in water to form a solution with a pH higher than 7. Hair conditioner is a base, as are many household products.

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Natural Acid

The sting of the bite from a red ant is partly caused by formic acid. At one time, the bodies of red ants were used to produce large quantities of formic acid for use in dyeing wool and tanning leather. Today synthetic formic acid is used.

pH Scale

Acidity is measured according to the pH scale. Most solutions have a pH in the range of 0 to 14. A solution with a pH of 0 is very acidic. For example, battery acid has a pH of about 0.5. A solution with a pH of 14 is very basic or alkaline. For example, household ammonia has a pH of about 12.6. A pH of 7 means that a solution is **neutral**—it's neither an acid nor a base.

The difference between one number and the next on the pH scale represents a 10-fold difference. For example, a solution with a pH of 3 is 10 times more acidic than a solution with a pH of 4. Similarly a solution with a pH of 9 is 10 times more basic than a solution with a pH of 8.

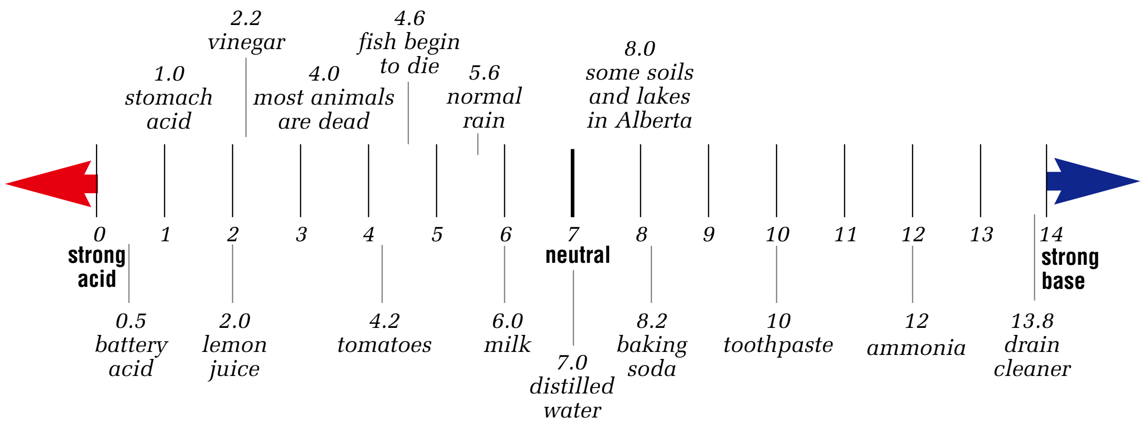

Figure 1.10 This figure shows the pH measurements of some common household products and some environmental situations.

Activity C-2

Inquiry

Measuring Acids and Bases

Materials & Equipment

- pH meter, chemical indicators, or pH paper
- distilled water
- small beakers
- materials to be tested (e.g., local water, pure water, rain or melted snow, household ammonia, vinegar, lemon juice, antacid tablet dissolved in water, baking soda solution, carbonated drink, fruit juices)
- 5-mL measuring spoon

Caution!
Acids and bases can burn the skin and eyes. If any of the ingredients spill, wash immediately with cold water. Never mix substances (unless you are told to) since they may react and produce dangerous chemicals.

Caution!
Make sure the room is well ventilated when you test ammonia.

Before You Start

In this activity, you may use either a pH meter, chemical indicators, or pH paper to determine the pH of substances. The pH meter shows the pH of the substance being tested. For chemical indicators and pH paper, a colour guide will help you measure the pH of acids and bases.

The Question

What are the pHs of some common substances?

Procedure

1. Place 10 mL of each solution in separate beakers.
2. If you are using a pH meter, rinse the meter's probe with distilled water. Submerge the tip of the probe in one of the solutions. Read and record the pH. Repeat for each solution.
3. If you are using a chemical indicator, place several drops of the chemical indicator in each solution. Observe and record the colour. Use the colour guide to determine the pH. Record the pH.
4. For pH paper, use a clean strip for each solution. Dip the end of the pH paper into the solution. After about 2 s, remove the paper. Compare the colour of the wet end of the paper with the colour guide. Record the pH.

Figure 1.11 You can use a pH meter, chemical indicators, or pH paper for this activity.

Analyzing and Interpreting

5. Which is the manipulated variable and which is the responding variable in this activity?
6. Describe how you determined the pHs of the substances tested.

Forming Conclusions

7. a) Which solutions were acids? How do you know?
   b) Which solutions were bases? How do you know?
   c) Which ones were neutral? How do you know?

MEASURING pH

You can use a pH meter or acid-base indicators to measure pH. A pH meter consists of a probe attached to a meter. To test a fluid, you submerge the tip of the probe in it, and the meter indicates the fluid's pH.

Acid-base indicators are substances that can change colour when they are placed in solutions. For example, blue litmus paper turns red in an acid, and red litmus paper turns blue in a base. A universal indicator is a mixture of indicators that change colour over a wide pH range. The pH of a clear fluid can be identified by the colour of the fluid after several drops of the indicator have been added. To determine the pH, you need to use a colour chart to compare the colour of the test fluid with that of a known standard.

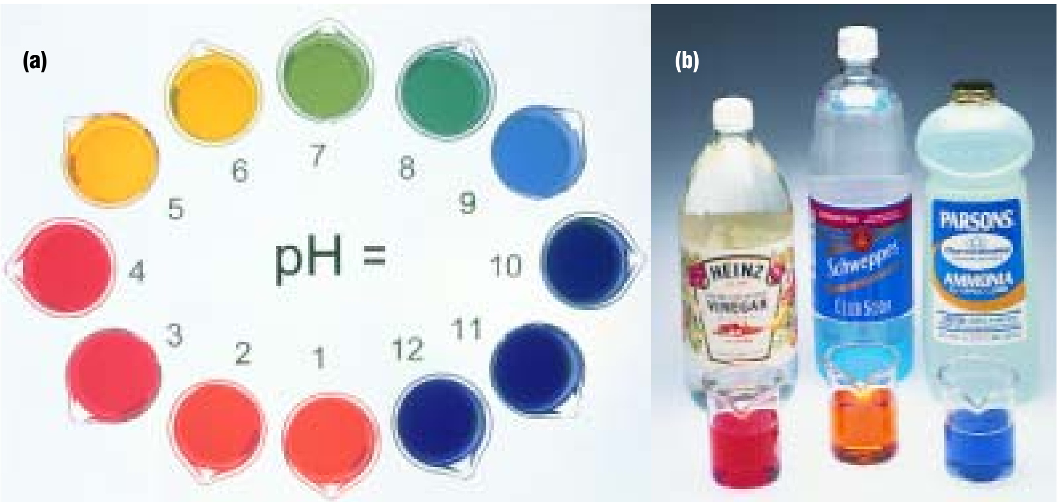

Figure 1.12 (a) You can determine the pH of a solution with a universal indicator by comparing the colour of the solution with a colour chart. (b) Compare the colour of these solutions with the standard ones shown in (a) to determine the pH of each of these common household solutions.

NEUTRALIZATION

If you have an upset stomach, you might take an antacid to help you feel better. An antacid is a mild base that reacts with the acid in your stomach to neutralize it. The base in the antacid and the acid in your stomach react to form compounds that are less upsetting to your stomach. This acid-base reaction is called **neutralization**. The neutralization reaction produces water and a compound called a **salt**. For example, what we call table salt can be produced by combining hydrochloric acid with sodium hydroxide solution, a base. Here is the equation for that neutralization reaction:

$$\mathrm{HCl}_{(aq)} + \mathrm{NaOH}_{(aq)} \longrightarrow \mathrm{NaCl}_{(s)} + \mathrm{H_2O}_{(l)}$$

$$\text{acid} + \text{base} \longrightarrow \text{salt} + \text{water}$$

Earlier in this subsection, you learned that a neutral solution is one with a pH of 7—it's neither acidic nor basic. That means that it doesn't have the properties of acids or bases, which sometimes can be harmful to humans and the environment. For example, if a strong base spills from a tanker truck, a weak acid can be used to neutralize it.

ACTIVITY C-3

Inquiry

NEUTRALIZING ACID

The Question

What effect does adding a base to an acid have on the pH of a solution?

The Hypothesis

Reword the question in the form of a hypothesis.

Materials & Equipment

- baking powder
- water
- graduated cylinder
- 2 50-mL beakers
- vinegar
- pH meter, chemical indicators, or pH paper
- 2-mL measuring spoon

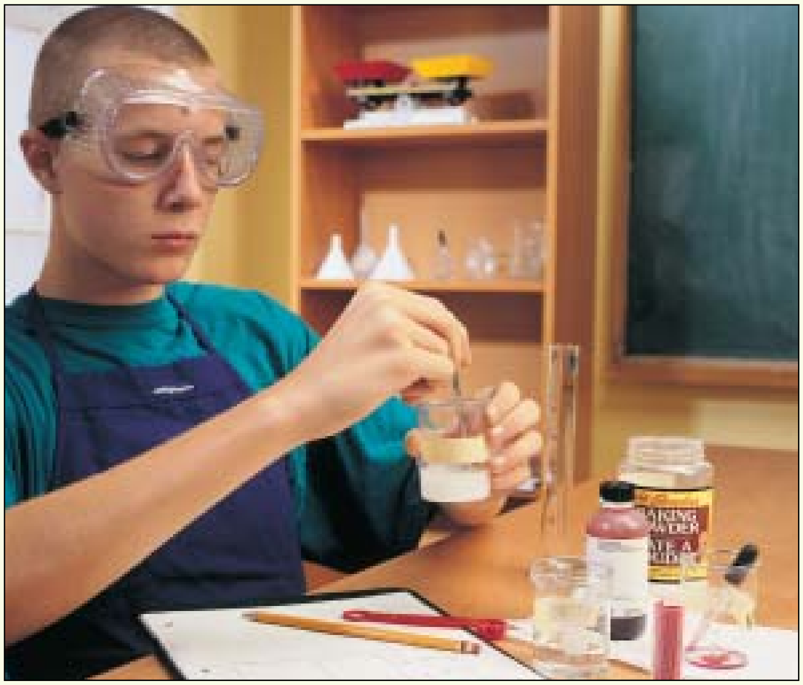

Figure 1.13 Step 3

Procedure

1. Place 2 mL of baking powder in 30 mL of water in a 50-mL beaker. Test and record the pH of the baking powder–water mixture.
2. Place 10 mL of vinegar in another 50-mL beaker. Test and record the pH of the vinegar.
3. Stir the baking powder mixture. Slowly stir 10 mL of this mixture into the vinegar in the beaker. Measure and record the pH of the vinegar–baking powder mixture.

Analyzing and Interpreting

4. Was the pH of the vinegar–baking powder mixture different from the pH of the vinegar alone? Explain your answer.
5. What evidence was there that a chemical reaction took place?
6. Was your hypothesis correct? Why or why not?

Forming Conclusions

7. Describe the effect that adding a base to an acid has on the pH of the solution.

Extending

Design and carry out an experiment to determine how adding water to a solution affects its pH.

Neutralizing the Effects of Acid Rain

At the beginning of this subsection, you read about the formation of acid rain. Ordinary rainwater is naturally slightly acidic. The raindrops dissolve carbon dioxide from the air to form very weak carbonic acid, which has a pH of about 5.6. In some areas of Canada, mainly in central Canada, acid rain has a pH as low as 3. In earlier studies, you may have learned about the effects of acid rain on living things and buildings. Many lakes in Ontario and Quebec became so acidic that organisms could no longer survive in them.

Acidic lakes are sometimes treated with lime (calcium hydroxide) to neutralize them. The lime is mixed with water so that it dissolves. A chemical reaction takes place between this limewater, which is a base, and the dilute sulfuric acid of the lake's water. The reaction produces calcium sulfate (a salt) and water. If all the acid and all the base are used up, the solution becomes neutral. The equation for that reaction is:

$$Ca(OH)_{2(aq)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(s)} + 2H_2O_{(l)}$$

calcium hydroxide + sulfuric acid ⟶ calcium sulfate + water

You will learn more about the effects of acids and bases on living things as you work through this unit.

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Acid Effects in the Canadian Shield

The Canadian Shield is a large horseshoe-shaped area of ancient rocks around Hudson Bay. It covers much of eastern and central Canada. Using books or electronic resources, explain in a paragraph why the water bodies on the Canadian Shield are so sensitive to acidic deposition. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Define the terms "neutral solution," "acid," and "base."
2. State whether each sentence below refers to an acid, a base, or a neutral solution.
   a) Solution A turns blue litmus paper red.
   b) Solution B has a pH of 10.
   c) Pure water has a pH of 7.
   d) Solution C neutralizes an acid.

Connect Your Understanding

3. a) List three human activities that release chemicals that produce acid rain.
   b) Identify the chemicals that are released and the acids they form.
4. What is the scientific meaning of the following sentence? *Lemon juice is an acid.*
5. You have been asked to determine the pH of a solution. Explain why using a pH meter or a universal indicator is better than using litmus paper.

Extend Your Understanding

6. Predict what the chemical products will be if sulfuric acid ($H_2SO_{4(aq)}$) and sodium hydroxide ($NaOH_{(aq)}$) are mixed together.
7. Suppose that there is a small lake on property that you own. The pH of the water in the lake has increased to 8.1 because of human activities.
   a) How could you make the water neutral?
   b) What environmental changes might you expect following the neutralization of the lake water?

1.3 Common Substances Essential to Living Things

Figure 1.14 Composition of the human body: water, proteins, fats, sugars, starch, DNA, minerals, vitamins, salts, acids, and bases

Our bodies need about 25 elements for normal growth. The chemical symbols for these elements are shown in Figure 1.1 at the beginning of subsection 1.1. Carbon (C), oxygen (O), and hydrogen (H) are the most common chemical elements in living things. Together, they make up the complex molecules that form sugar, starch, fat, oil, wax, and proteins. Because these complex molecules contain carbon, they are called **organic compounds**. Fossil fuels (petroleum, natural gas, and coal) are examples of substances that contain many different organic compounds. Substances that do not contain carbon are called **inorganic compounds**. Baking soda and the mineral quartz are examples of inorganic compounds.

Organic molecules can be very large and complex. On Earth, these molecules far outnumber inorganic molecules.

GIVE IT A **TRY**

Organic or Inorganic?

Draw a table with two columns. List the following items in the left column: oxygen, distilled water, sugar, motor oil, hydrochloric acid, rust, vitamin C, glass, fat, rubber.

In the right column, identify each item as organic or inorganic.

Macronutrients

All living things need nutrients to survive. **Nutrients** are elements and compounds that organisms need for living, growing, and reproducing. Plants obtain the nutrients carbon, hydrogen, and oxygen from air and water. They obtain nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur from the soil. These nine elements are all essential for the normal growth of plants. Because they are needed in relatively large amounts, they are called **macronutrients** ("macro-" means large or large scale). In earlier science classes, you learned about the importance of carbon, hydrogen, and oxygen for living things. You will learn more about them throughout this unit. The table below summarizes the role of the six other macronutrients in the growth and development of plants and humans.

Elements such as selenium are also essential for plant and animal growth and development. However, they are needed in only minor or trace amounts, so they are called **micronutrients** ("micro-" means very small or small scale).

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Elements in the Human Body

Just six elements—oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus—make up 99% of the human body.

Nutrient	In plants, it's important in:	In humans, it's important in:
Nitrogen (N)	• Composition of proteins and chlorophyll • Leaf and stem growth	• Composition of proteins and nucleic acids found in all cells • Growth and repair of tissues
Phosphorus (P)	• Root and flower growth • Cellular respiration and photosynthesis	• Composition of bones, teeth, and DNA • Many metabolic reactions
Potassium (K)	• Stimulation of early growth • Starch and protein production and sugar movement • Disease resistance • Chlorophyll production and tuber formation	• Muscle contraction and nerve impulses
Magnesium (Mg)	• Composition of chlorophyll structure • Photosynthesis	• Composition of bones and teeth • Absorption of calcium and potassium
Calcium (Ca)	• Cell wall structure • Cell division	• Composition of bones and teeth • Blood clotting • Muscle and nerve function
Sulfur (S)	• Production of fruits and grains	• Protein synthesis • Enzyme activation • Detoxification

Maintaining the Right Level of Nutrients

Figure 1.15 Knowledge of how elements are used by plants can help farmers diagnose problems like those shown here.

Knowing how plants use elements can help farmers diagnose deficiencies and excesses of nutrients in the soil. Consider this scenario. A farmer has noticed that his crops are not growing as well as they have in past years. The lower leaves on the plants are showing a distinct yellow striping, and the plants are not as tall as they should be. The farmer has been applying large amounts of phosphorus and potassium fertilizer, expecting to get high yields from the crops.

Soil tests show low levels of magnesium and high levels of potassium. The farmer knows that high levels of potassium can interfere with the absorption of magnesium by the plant. One solution is to stop applying potassium fertilizer, since the soil has an adequate supply already, and apply a fertilizer containing magnesium.

Optimum Amounts

In the early 1980s, a reservoir was built in California to control the flow of irrigation water to farms. Shortly after the reservoir was built, many fish in the reservoir died. Birds living on or near the reservoir were also dying or producing abnormal chicks. Tests showed that the surviving fish contained a high level of selenium. Birds' eggs from the area contained eight times more selenium than similar eggs 10 km away. The selenium was traced back to soils around the reservoir.

The micronutrient selenium is an element that is required in trace amounts in your diet. Too much of it can cause harmful health effects, like those that affected the wildlife around the California reservoir. But too little selenium can also be harmful to your health. If plants are deficient in selenium, the animals that eat them will also have a deficiency of selenium. Scientific studies have shown that selenium deficiency in humans can be linked to diseases such as cancer and heart disease. Selenium, along with vitamin E, helps to protect cell membranes from damage caused by hydrogen peroxide, a poison that is produced in some chemical reactions in cells.

Selenium, like most other substances, should be available in our diets in **optimum amounts**. The optimum amount of a substance is the amount that provides an organism with the best health. For humans, at least 70 μg (micrograms) of selenium per day is recommended.

Figure 1.16 The far right is the foot of a healthy pig. The other two feet belong to pigs that have ingested too much selenium.

Types of Organic Molecules

Most chemicals in humans and other living things are organic compounds. Four important classes of organic compounds are: carbohydrates, lipids, proteins, and nucleic acids.

Figure 1.17 Carbohydrates are a major part of our diet.

Carbohydrates

When we eat food such as pasta, rice, potatoes, fruits, and bread, we are eating carbohydrates. **Carbohydrates** are organic molecules made up of atoms of carbon, hydrogen, and oxygen. These atoms can form simple molecules, such as sugar, or large, complex molecules, such as starch, cellulose, and glycogen.

Glucose is the simple sugar made by green plants in photosynthesis. The atoms in a molecule of glucose usually join together to form a six-sided figure as shown in Figure 1.18(a). Complex carbohydrates such as cellulose, starch, and glycogen are composed of many glucose molecules joined together, as shown in Figure 1.18(b).

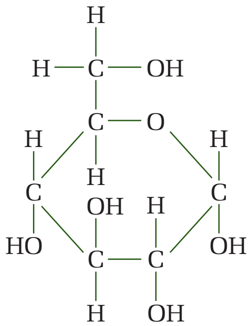


Figure 1.18(a) A glucose molecule has the formula $C_6H_{12}O_6$.

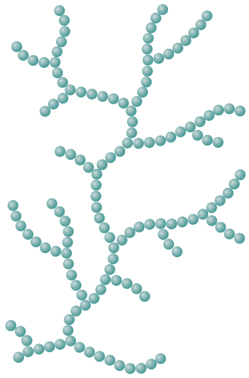


Figure 1.18(b) A glycogen molecule is made up of connected glucose molecules. Each circle represents a glucose molecule.

Lipids

Fats, oils, and waxes are **lipids**—compounds composed of many carbon, hydrogen, and oxygen atoms. Both animals and plants produce lipids. For example, our skin produces oils, and our bodies store food in the form of fat. Plant products such as canola seeds, corn, peanuts, soybeans, walnuts, and cashews contain large amounts of oils.

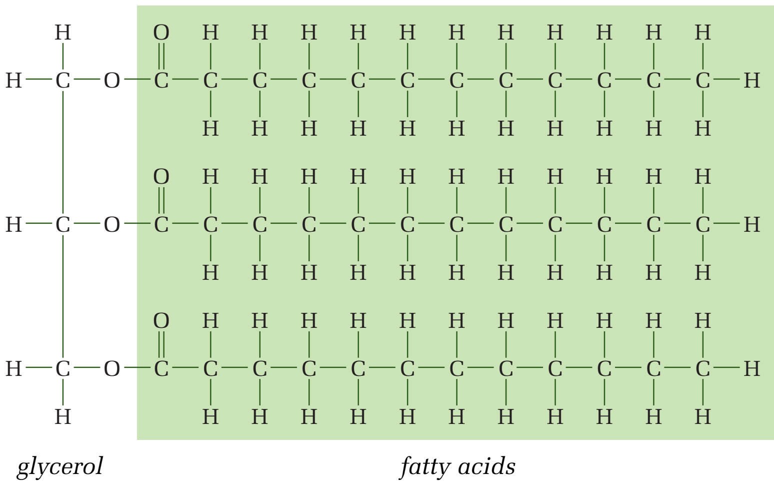


Figure 1.19 A fat molecule is made up of three chains of fatty acids connected to one molecule of a compound called glycerol.

Activity C-4

Inquiry

Testing for Organic Molecules

The Question

How can indicators be used to test for the presence of different organic molecules?

Materials & Equipment

- substances to be tested (glucose/dextrose solution, corn starch mixed in water, vegetable oil, gelatin solution)
- water
- Benedict's solution
- Biuret solution
- iodine solution
- spot plate
- brown paper
- medicine droppers
- test tubes
- hot water bath
- stir sticks
- test tube containing unknown substance(s)

Figure 1.20 Step 6

Caution!
Benedict's solution, Biuret solution, and iodine solution are hazardous, corrosive substances that can stain your clothes and skin. Handle them carefully.

Caution!
Hot water scalds and hot surfaces burn.

Procedure

1. In this activity, you will be testing for different types of organic molecules. This table shows the indicators you will use.

Substance	Test
Glucose	Benedict's solution turns from blue to yellow-orange-red
Starch	Iodine solution turns from red-brown to blue-black
Fat/Oil	Fats and oils leave a spot on brown paper that light can pass through
Protein	Biuret solution turns from blue to purple or mauve

2. Copy the table below in your notebook for recording your observations.

	Final Colours Using Indicators			Light Transmittal Through Brown Paper
Substance Tested	Benedict's Solution	Iodine Solution	Biuret Solution	
Glucose				
Corn Starch				
Vegetable Oil				
Gelatin				
Unknown				

3. Label the test tubes with the names of the substances you are testing.

Testing for Glucose

4 Place a small amount of each substance to be tested in separate test tubes.

5 Place a small amount of water in a test tube.

6 Add 10 drops of Benedict's solution to each test tube. Heat the tubes in a hot water bath for about 2 min. Record your observations.

Testing for Starch

7 Place several drops of each substance to be tested and water into separate places on the spot plate.

8 Place a drop of iodine solution on each substance. Record your observations.

Testing for Lipids

9 Divide a piece of brown paper into five sections. Label each section with the name of the substance to be tested on it: one section for water, one for glucose, etc. Using a clean medicine dropper each time, place a drop of each substance on the appropriate spot on the brown paper.

10 Leave the paper for 5 to 10 min in a vertical position. After the time is up, look through the paper by holding it up to the light.

Testing for Proteins

11 Place several drops of each substance and an equal number of drops of water into separate places on a clean spot plate.

12 Add three drops of Biuret solution to each of them. Record your observations.

Testing an Unknown Sample

13 Use appropriate materials and equipment to test an unknown sample for the presence of glucose, starch, lipids, and proteins.

14 Wash your hands after you have completed all the tests and cleaned up your equipment. Follow your teacher's instructions for disposing of all the substances you have used.

Analyzing and Interpreting

15 Which substances contained each of the following molecules? In each case, how did you know?

a) glucose

b) starch

c) lipids

d) proteins

16 What organic substance or substances were in the unknown sample?

Forming Conclusions

17 Describe how you determined what organic substance or substances were in your unknown sample. Use your data to support your conclusions.

Figure 1.21 Fish is an excellent source of protein. Sometimes it is eaten raw as sushi or sashimi. Both are Japanese dishes.

Proteins and Amino Acids

Foods such as meat, fish, eggs, and dairy products add **proteins** to our diet. Proteins have many functions. They are used by organisms for growth and repair, and as a source of energy. They are the main component of **enzymes**. Recall that enzymes are catalysts that control chemical reactions in organisms.

A protein is an organic compound made up of units called **amino acids**. Figure 1.22 shows the structure of an amino acid. The way amino acids form proteins is similar to the way glucose units join together to form complex carbohydrates such as starch.

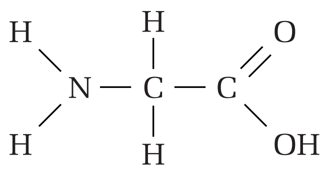


Figure 1.22 This diagram shows the structure of the amino acid glycine. Each amino acid has a central carbon atom. Amino acids also include nitrogen, hydrogen, and oxygen atoms, along with more carbon atoms. Some also contain sulfur.

Each protein has its own number and arrangement of amino acids. In general, a protein contains between 40 and 500 amino acid units. Insulin, for example, contains 51 amino acid units arranged in two chains, as shown in Figure 1.23. Twenty different kinds of amino acids are common in protein molecules. Green plants convert glucose into amino acids.

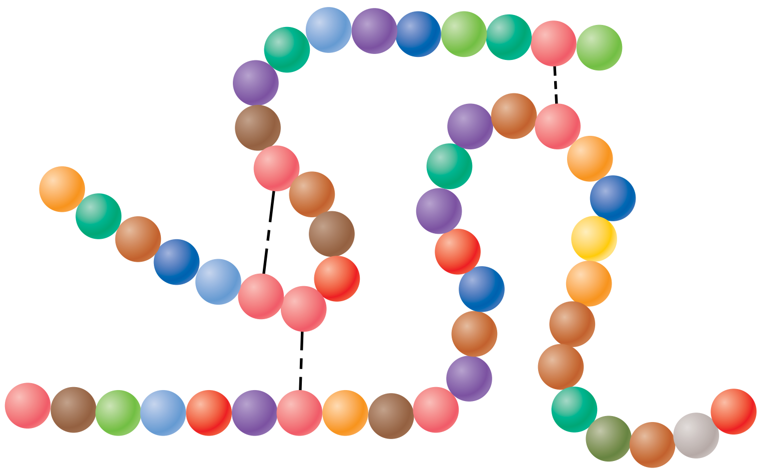


Figure 1.23 An insulin molecule. Each circle represents an amino acid unit. Different colours represent different amino acids.

Nucleic Acids

Nucleic acids are the largest and most complicated molecules found in living things. All cells contain two important nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA and RNA are made up of three substances: phosphates, a simple sugar called ribose, and nitrogen-containing molecules. Nucleic acids play a major role in heredity and in controlling a cell's activities.

Figure 1.24 The structure of DNA. DNA transfers information about an organism's body from one generation to the next.

> **reSEARCH**
>
> **Organic or Inorganic?**
>
> Find out whether the following substances are organic or inorganic: gasoline, nitrogen gas, canola oil, vinyl, hydrogen sulfide, protein. For each one, write out the chemical formulas for its compounds. Describe how the substance is used. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Define the term "organic compound." Give two examples of these compounds.
2. List four elements that are macronutrients for plants. Explain their importance in plants and in humans.
3. What is a micronutrient? Give one example.
4. What elements are found in the following compounds?
   a) carbohydrates
   b) proteins
   c) lipids
   d) nucleic acids

Connect Your Understanding

5. Imagine that your favourite house plant is growing well but it is not flowering. A friend suggests that your plant may be lacking phosphorus. Is that a possibility? Explain your answer.
6. Explain the term "optimum amount" using one of the following as an example: potassium for plants or selenium for animals.
7. Which term in each of the following groups of four terms includes the other three?
   a) carbohydrate, glycogen, starch, glucose
   b) sugar, DNA, phosphate, nitrogen-containing base
   c) fats, waxes, oils, lipids

Extend Your Understanding

8. Suppose you are a farmer and your crop is not growing as well as it has in the past. You notice that the lower leaves of the plants are turning yellow. Recall that chlorophyll gives leaves their green colour and is important in photosynthesis. Use the table on page 197 to help you answer the following questions.
   a) What nutrient deficiencies might be causing this problem?
   b) What would be your next step to solve the problem?
9. A sample solution was sent to a laboratory for examination. When Benedict's solution was added, and the sample was heated, a red precipitate formed. When Biuret solution was added, the sample remained blue. What substance was identified in the solution?

1.4 How Organisms Take in Substances

Figure 1.25 Inorganic chemicals from the environment are taken up by producers which then provide food for consumers.

*info***BIT**

Eating Elements

In 1295, when Marco Polo was on the way to China, some of his pack animals became sick and died. The ones that did not become sick were the ones that came from the area through which they were passing. It is now thought that the local pack animals avoided those plants that had accumulated selenium from the soil. The other animals ate the selenium-rich plants and died from selenium poisoning.

Plants and animals rely on the environment for the substances they need to live. Plants take in inorganic compounds to make organic compounds. Consumers must rely on organic compounds made by plants for their energy, growth, and repair. Consumers obtain these compounds by either eating plants or eating other organisms that eat plants.

When organisms take in the chemicals they need, they may also be taking in other substances. Sometimes, these are harmless. For example, when you drink pop, you are taking in water, which you need, but you are also taking in the flavouring and colouring in the pop. You don't need them and they are harmless. Sometimes the other substances may be harmful. For example, a lake beside a coal-fired generating plant may contain high levels of mercury. If you ate fish caught near the plant, you would take in this harmful substance.

Uptake of Substances by Plants

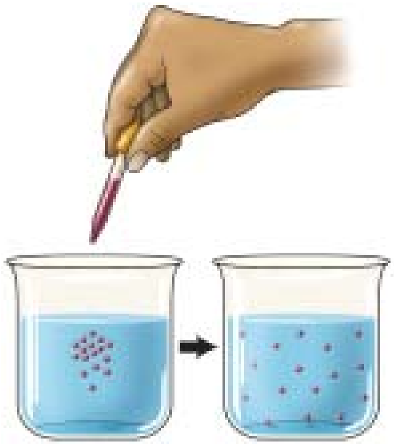


Figure 1.26 Diffusion is a process in which substances dissolved in water move from an area of higher concentration to one of lower concentration.

Nutrients enter the roots of plants either passively or actively. Passive uptake does not require the plant to use any energy. It occurs through a process called **diffusion**. Diffusion is the movement of molecules from an area of higher concentration to one of lower concentration. Figure 1.26 shows diffusion occurring in a solution of food colouring and water. The food colouring gradually moves from the more concentrated area where it enters the water until it is spread evenly throughout the water.

Similarly, some nutrients move into the roots of plants by diffusion.

They move from the area of higher concentration outside the roots to the area of lower concentration within the roots. The movement continues until the concentration of nutrients is the same both inside and outside the plant roots. You can think of diffusion as an evening out or balancing of the concentration of a substance in solution. No energy is required for this process because the molecules naturally diffuse to the areas of lower concentration.

Osmosis

Water moves into plant roots by a special type of diffusion called **osmosis**. In the process of osmosis, water moves through the walls of the plant's roots from an area where there are more water molecules to an area where there are fewer water molecules. As the plant uses water for its growth and maintenance, it draws water up from the roots. As the number of water molecules within the roots decreases, more water molecules move into the roots from the surrounding soil. Figure 1.27(a) shows this movement.

Active Transport

Plants need high concentrations of some nutrients in their roots. The concentrations of these nutrients may be higher in the roots than in the water in the surrounding soil. To maintain these high concentrations, plants must move some nutrients from the soil, an area of lower concentration, into their roots. To move nutrients in this direction, plants use a process called **active transport**. In active transport, plants must use energy to move the molecules of nutrients in the direction opposite to diffusion. This energy is used by specific molecules in the root cells that transport the nutrient molecules into the plant roots. Figure 1.27(b) shows the movement in active transport.

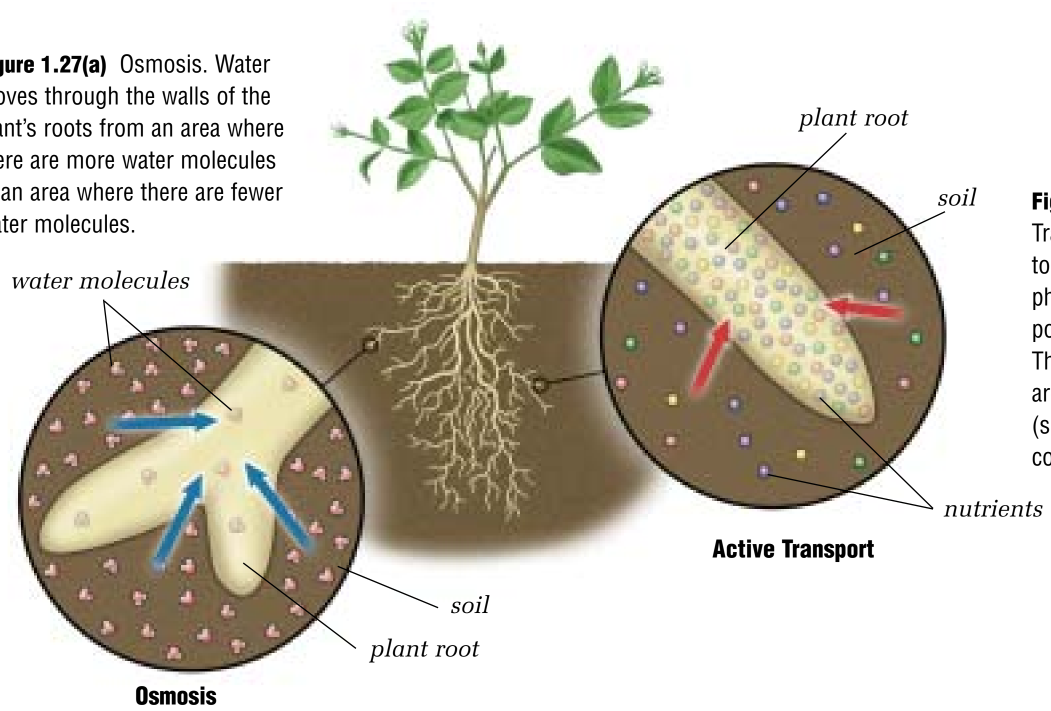


Figure 1.27(a) Osmosis. Water moves through the walls of the plant's roots from an area where there are more water molecules to an area where there are fewer water molecules.

Figure 1.27(b) Active Transport. Plants use energy to transport nitrogen, phosphorus, sulfur, and potassium into their roots. The nutrients move from an area of lower concentration (soil) to one of higher concentration (roots).

INGESTION AND ABSORPTION OF MATERIALS BY ANIMALS

Humans and other animals obtain the 25 elements our bodies need for normal growth and function from the air we breathe and the food we eat.

The process of taking food into our bodies is called **ingestion**. Every time you drink or eat, you are ingesting food. Most of the ingested food must be broken down into smaller particles so our bodies can absorb the nutrients from it.

Humans and other animals break down food mechanically and chemically. An example of mechanical breakdown is chewing food. Chemical breakdown occurs in the mouth, stomach, and small intestine with the help of enzymes that speed up the chemical reactions. The breakdown or digestion of large organic molecules occurs by a process called **hydrolysis**. “Hydro” refers to water and “lysis” means breakdown. A substance that is broken down by hydrolysis has been **hydrolyzed**. For example, when you eat potatoes, the large starch molecules are hydrolyzed into double sugars called maltose, and then into single sugars called glucose. This reaction can be written in the following way.

$$C_{12}H_{22}O_{11(aq)} + H_2O_{(l)} \longrightarrow 2\ C_6H_{12}O_{6(aq)}$$
$$\text{maltose} + \text{water} \longrightarrow \text{glucose}$$

Nutrients such as glucose and amino acids are absorbed through cell membranes and into the bloodstream. The blood carries them to cells throughout the body where they are either used or stored.

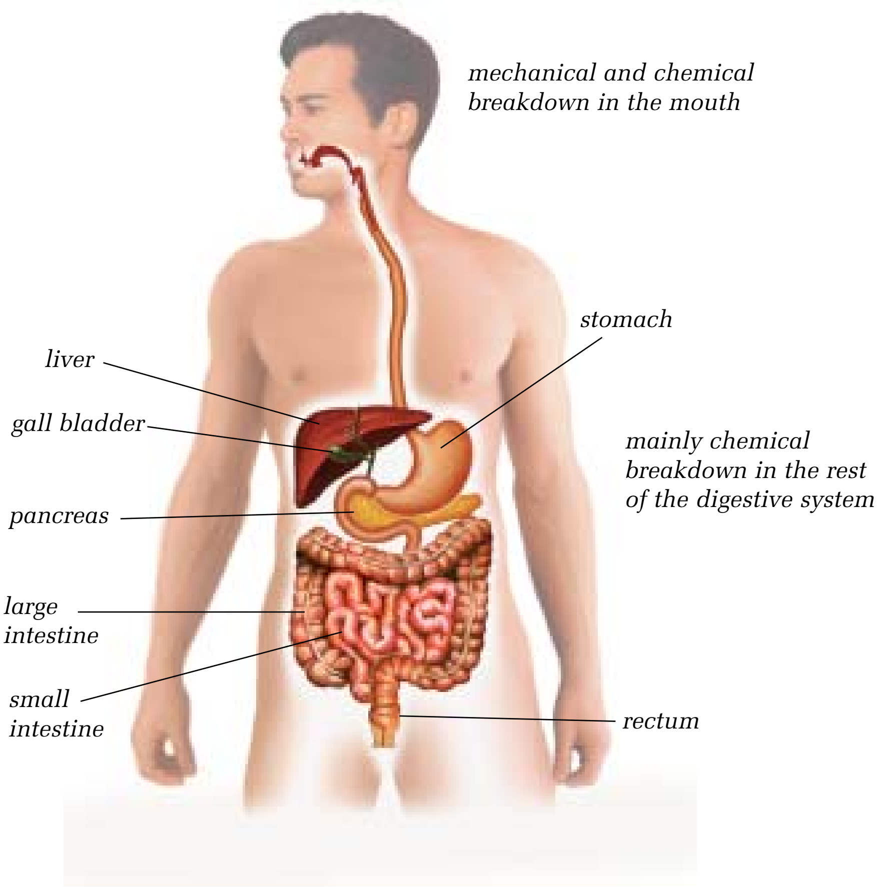


Figure 1.28 The food you ingest is broken down mechanically and chemically in your digestive system.

Activity C-5

Inquiry

Breakdown of Starch by Hydrolysis

Before You Start

Large starch molecules are formed by many glucose molecules joined together. The bonds that join the glucose molecules can be broken in several ways. Two ways are:

- heating at high temperatures
- using enzymes in the digestive tract as catalysts in the hydrolysis of the starch

The Question

Which of the following processes breaks down starch more quickly: heating or using enzymes?

The Hypothesis

TOOLBOX

Restate the question in the form of a hypothesis.

Materials & Equipment

- corn starch suspension
- iodine solution
- digestive enzyme suspension
- hot plate
- 2 beakers
- spot plate
- stir stick
- graduated cylinder
- eye dropper

Procedure

1. Place 4 drops of starch suspension in a spot plate. Add 1 drop of iodine solution. Record your results.
2. Label two beakers with the numbers 1 and 2. Place 50 mL of starch suspension into each beaker.
3. Place beaker 1 on a hot plate. Boil and stir the contents for 5 min.
4. Place 4 drops from beaker 1 in the spot plate, and test for the presence of starch. Record your observations.
5. If you observe a positive starch test, repeat steps 3 and 4 two more times. Do not repeat these steps more than twice.
6. In beaker 2, add 10 mL of digestive enzyme suspension to the starch suspension, and stir for 5 s.
7. Place 4 drops from beaker 2 in the spot plate and test for the presence of starch. Record your observations.
8. Follow your teacher's instructions for disposing of all the substances you have used.

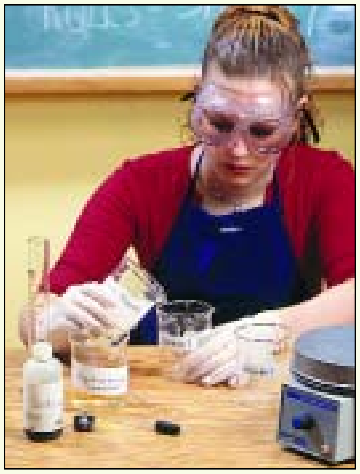


Figure 1.29 Both beakers contain starch suspension.

Caution!
Hot surfaces burn. Leave beaker 1 on the hot plate to cool.

Analyzing and Interpreting

9. What are the manipulated and responding variables in this investigation?
10. Explain why no starch was present in one of the beakers.
11. Was your hypothesis correct? Explain why or why not.

Forming Conclusions

12. Which process broke down the starch more quickly? Support your answer with your data.

Applying and Connecting

Corn starch is hydrolyzed to produce various kinds of corn syrup, which are used for making products such as candy and chewing gum.

Extending

Design and carry out an experiment to show how the temperature of an enzyme suspension affects the rate of hydrolysis of starch.

Taking in Nutrients in Different Environments

Organisms inhabit almost all parts of Earth—from the icy Arctic to tropical jungles, and from mountain slopes to deep under the ocean. Where organisms live affects how and when they can obtain nutrients. For example, plants living in the north can obtain nutrients only during a short growing season. Plants in the desert often have methods to limit the growth of other plants around them. This reduces the competition for the limited nutrients available. Figure 1.30 shows examples of the nutrient sources for organisms in a variety of environments.

Figure 1.30 Life in a variety of environments

Figure 1.30(a) Anemones are animals that live attached to rocks in the ocean. They capture food with their tentacles.

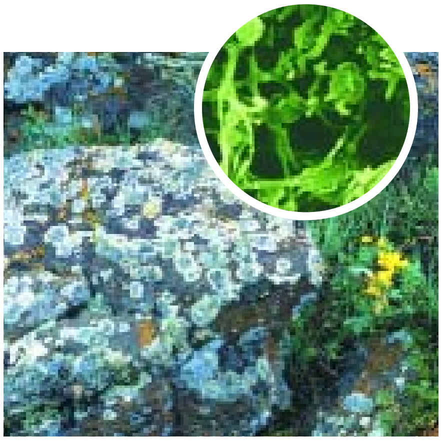


Figure 1.30(b) Lichens are often the first organisms to colonize an area. They have been found in cold, dry valleys in Antarctica, as well as on bare rocks high in the mountains. Lichens are made up of fungi and algae living together.

Figure 1.30(c) Bread mould is a fungus that secretes digestive enzymes. The enzymes help break down the bread into small molecules that can be absorbed into the fungal cells.

Figure 1.30(d) Desert soil does not hold water and contains little organic material. Plants and animals in deserts are adapted to going for long periods without water.

Figure 1.30(e) Decaying plant and animal materials enrich the soil in grasslands.

Figure 1.30(f) The treeless, flat areas of the north are called *tundra*. Only a few centimetres of the ground thaw in the tundra in the summer. Plants must grow and reproduce quickly when the temperature is favourable and nutrients are available.

Substrates

A **substrate** is the material on which an organism moves or lives. Some organisms are attached to their substrate. For example, the sea anemone in Figure 1.30(a) attaches itself to rocks in intertidal zones, where the water is very turbulent. It obtains its nutrients by capturing food with its tentacles. Other organisms obtain nutrients from their substrate. For example, the bread mould shown in Figure 1.30(c) breaks down the molecules of its substrate, the bread, to obtain nutrients.

You may be surprised by the substrates on which some organisms are able to live. If you have ever hiked high in the mountains in early summer, you probably saw snow still remaining from the winter. Sometimes this snow is red and smells like watermelons. In the early 1800s, observers thought that iron from a meteorite must have been responsible for the red snow. Soon after, a biologist observed single-cell algae in the coloured snow. These algae manage to survive on a substrate that is near freezing, poor in nutrients, and often acidic. The red pigment masks the green chloroplasts that enable the algae to carry out photosynthesis.

reSEARCH

Nutrients and Substrates

Choose one of the environments shown in Figure 1.30 and find out about the organisms that live there. Describe the nutrients they obtain from their environment and how they take them in. Identify the substrates on which they live. Prepare a poster or electronic presentation to summarize your research. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Define the following terms:
   a) diffusion
   b) osmosis
   c) active transport
2. What is the substrate for the lichen in Figure 1.30(b)?
3. What happens to food when you ingest it?
4. What effect do hydrolysis enzymes have on the rate at which large organic molecules break down?

Connect Your Understanding

5. Plants take in water from the soil. Why does the water move from the soil into a plant's roots?
6. a) How is the process of diffusion similar to active transport?
   b) How are the two processes different?
7. Why are the algae that live on snow able to survive high in the Rockies in early summer?

Extend Your Understanding

8. a) Write a hypothesis for an experiment to show the effect of temperature on the rate of diffusion.
   b) Identify the manipulated and responding variables.
   c) Write the procedure for the experiment.

Careers and Profiles

Chemical Researcher and Theoretical Chemist

On a hot summer day in the Rocky Mountains, bark beetles were crawling all over the screen door of a trailer where chemicals were stored. Dr. Hal Wieser, Dr. William Laidlaw, and their graduate students were surprised to see the beetles, but they could guess why they were there. One of the chemicals, a pheromone, is used in traps to attract bark beetles—it must have escaped from its container inside the trailer.

Figure 1.31(a) A female bark beetle and her eggs in the inner bark of a lodgepole pine.

Bark beetles are small brown-black insects that burrow into the bark of mature or injured trees. Unfortunately, the beetles carry a fungus with them that causes the trees to die. One of the techniques for controlling the beetles involves trapping them, using pheromones as bait. Once trapped the insects are killed.

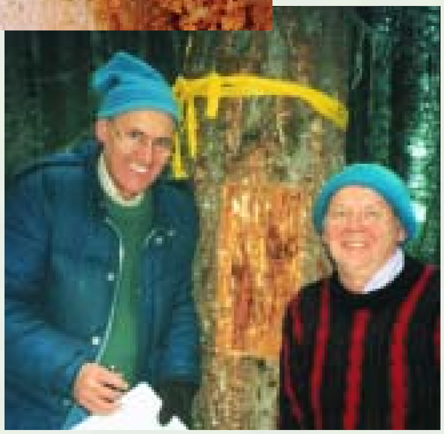


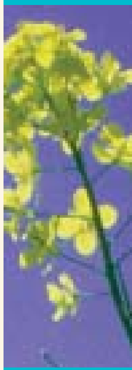
Figure 1.31(b) Dr. Hal Wieser (left) and Dr. William Laidlaw at work in the forest.

The beetles detect the pheromones with their antennae much the way you detect different smells with your nose. Each species of insect is attracted to different pheromones with different chemical structures. By using pheromones, foresters and forest researchers can target only those insects that must be controlled. This avoids the problem that often arises with widespread spraying of insecticides—both non-targeted and targeted species are killed.

Many people with a variety of skills work together to help protect forests from insects that can kill trees. Dr. Wieser is a research chemist working at the University of Calgary. He became interested in pheromones when he was trying to establish a link between the sense of smell and the shapes of molecules. Dr. Laidlaw is a theoretical chemist interested in the computer modelling of beetle behaviour. For their experiments, they often work with people who know about the biology of the beetle and people who know about forests and timber resources.

1. Why do you think scientists often work together?
2. Think about projects on which you've worked with other students. What advice would you give on how to work well with others on projects?

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. Define the term "macronutrient" and give three examples.
2. List two roles of potassium in plants and two roles in humans.
3. Identify two elements that are known to enhance plant growth but that limit growth if too little or too much is available.
4. What is a sanitary landfill site?

Connect Your Understanding

5. Use an example to help explain what a neutralization reaction is.
6. Explain the difference between organic and inorganic compounds. Give one example of each.
7. Match the organic molecules with the elements that compose them.

carbohydrates	C, H, N, O
proteins	C, H, O
nucleic acids	C, H, O, N, P

8. a) What do the numbers 10-0-0 on a fertilizer label mean?
   b) What type of growth does this fertilizer promote?
9. a) Why do farmers use pesticides?
   b) Why do some people want farmers to use lower amounts of pesticides?

Extend Your Understanding

10. What types of organic molecules make up a hamburger? In your answer, name the part of the hamburger that includes each type of compound. Include the bun, the meat patty, and everything on the burger.
11. What could you do at home to help minimize the environmental damage caused by pollution from gas and oil processing?

Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

In this section, you looked at chemicals in the environment that support or harm organisms. Science can play a role in helping people understand the impact of the human use of chemicals on the natural world. Technology can help reduce or control this impact. Consider the following questions, and use examples from this section to support your answers.

1. Identify three examples of human impact on the chemical composition of the environment. For each example, explain how science can help us understand these impacts.
2. Describe an example of how science and technology can be used to reduce the impact that humans have on ecosystems.

2.0 The quantity of chemicals in the environment can be monitored.

Key Concepts

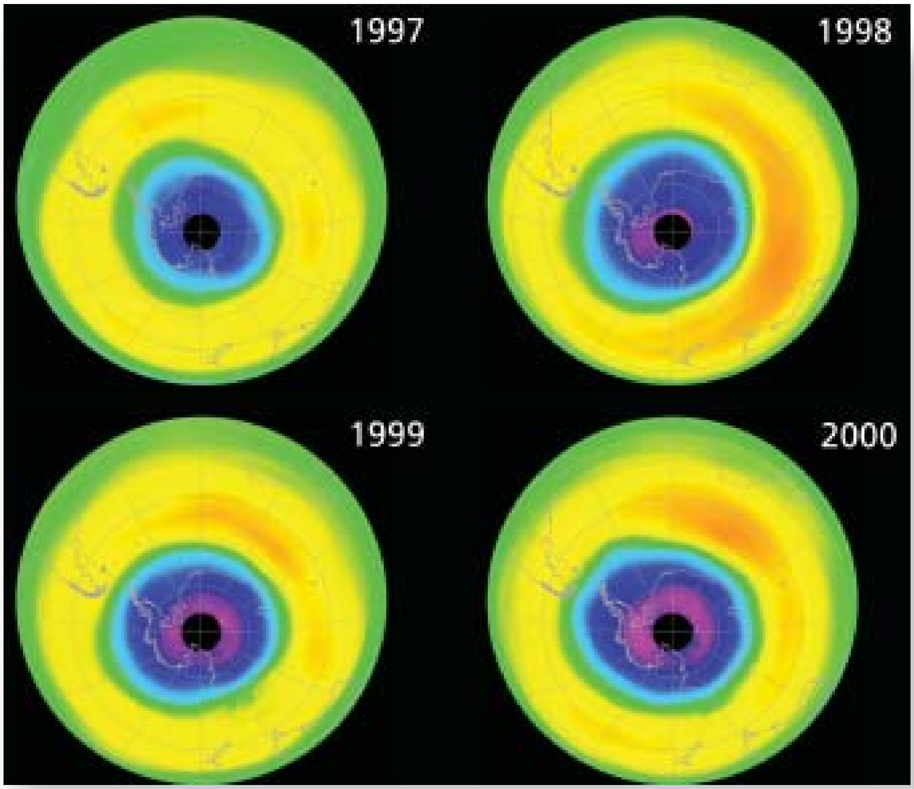
In this section you will learn about the following key concepts:

- air and water quality
- concentration and dispersal
- uncertainties in environmental monitoring and in assessing toxicity and risk

Learning Outcomes

When you have completed this section, you will be able to:

- describe and illustrate the use of biological monitoring as a method of determining environmental quality
- identify chemical factors in the environment that might affect the health and distribution of living things
- apply and interpret measures of chemical concentration in parts per million, billion, or trillion



The hole in the **ozone layer** over the Antarctic concerns many scientists. Ozone ($O_{3(g)}$) forms a layer that shields Earth from much of the damaging ultraviolet (UV) radiation from the Sun. Some UV radiation passes through this shield normally, but now more is getting through. Experts predict more skin damage and cancers in humans, as well as effects on other organisms. The ozone layer is 15 to 50 km above Earth's surface, but ozone also exists at ground level. This ground-level ozone can cause health problems.

The photo of the hole in the ozone shown here was taken from a satellite. Photos such as these are important in **monitoring** the ozone layer. Monitoring means keeping track of something for a specific purpose. At ground level, scientists use sampling and other techniques to monitor the ozone levels in the air. In this section, you will learn about the different chemicals that must be monitored so we can protect water and air quality. You will also learn about chemicals monitored in the atmosphere to protect life on Earth.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 Monitoring Water Quality

Figure 2.1 Would you swim in this water?

If you wanted to jump into a lake for a swim, you probably would not choose a lake like the one in Figure 2.1. And you would not be the only one put off by the lake's appearance. Studies show that when lake transparency decreases, property values of cottages and homes around the lake decrease as well.

Lakes may become cloudy in summer because of excessive algal growth. This reduces the oxygen content in the lake, which affects the types of organisms that can live there. Insects and fish that live in water like this are different from the ones that live in a clear lake. Trout, for example, are one of the first fish to die when the concentration of dissolved oxygen decreases.

Clarity is not a good indicator of water quality. Clear water can sometimes be harmful to humans and other organisms. For example, lakes affected by acid rain are crystal clear and lifeless.

Water quality is determined according to what the water is used for. Both provincial and federal governments set guidelines for water quality in five categories of water use:

- human drinking water
- recreation such as swimming
- livestock drinking water
- irrigation
- protection of aquatic life

The guidelines are designed to protect humans, animals, crops, and other organisms that live in or near water systems. Scientists and technicians make sure that these guidelines are being met by monitoring water quality, using both biological and chemical indicators.

*info***BIT**

Safe and Unsafe

The insecticide pyrethrum is produced from plants such as chrysanthemums. It is used to eliminate pests such as aphids. Pyrethrum is safe for mammals, including humans. However, it is very poisonous to fish and other aquatic life, so it should not be used near ponds or other bodies of water.

Biological Indicators

Scientists use organisms that live in water to help determine water quality. These indicator organisms include fish, plants, worms, insects, plankton (microscopic algae and tiny animals), protozoa, bacteria, and viruses.

Microbiological Indicators

Microscopic organisms such as bacteria can cause serious health problems if they are present in large enough numbers. Small samples of water are taken frequently from water sources that people use. These samples are processed to determine the numbers and types of microscopic organisms, such as harmful bacteria (e.g., some strains of *Escherichia coli*). If the count is too high, additional water treatment may be necessary.

Aquatic Invertebrates

Water with a large number of harmful bacteria can cause illness. Other biological indicators of water quality do not cause illness themselves but can show the effects of pollution, which may indicate unsafe water. Aquatic invertebrates are one group of indicator organisms. **Invertebrates** are animals without backbones. Those that live in water include insects, crustaceans (such as shrimp), worms, and mollusks (such as clams). They are used for monitoring because different invertebrates prefer different living conditions. For example, the organisms living in a stagnant pond are different from those living in a pond with a higher concentration of dissolved oxygen. Water temperature and pH can also affect the types of organisms found in an area.

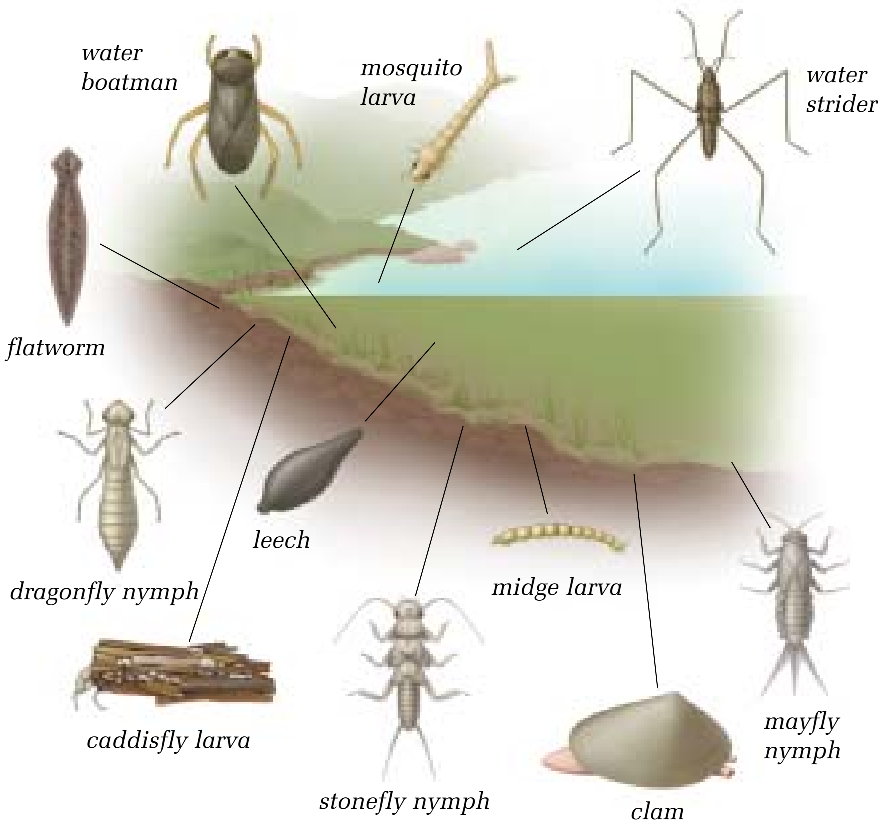


Figure 2.2 Examples of the many different kinds of aquatic invertebrates

QUICKLAB

Identifying Aquatic Invertebrates

Purpose

To identify aquatic invertebrates used in biological monitoring of water quality. You will apply your knowledge of invertebrates later in this unit to help assess water quality.

Procedure

1. Place the invertebrate with some water in a clear container such as a Petri dish, watch glass, or microscope slide.
2. Using a magnifying glass or dissecting microscope, observe the organism's features such as legs/no legs, gills/no gills on abdomen, wings/no wings. Use Figure 2.2 to help you identify the invertebrates in your sample. Record your identification. If you are unable to identify the organism, draw a diagram of it. Record as many different organisms as you can.
3. Wash your hands with soap when you are finished.

Questions

4. How many different types of invertebrates were you able to identify?
5. Work with the rest of the class to identify those organisms that you and other students were not able to identify.

Materials & Equipment

- water sample from pond or stream containing invertebrates
- magnifying glass or dissecting microscope
- medicine droppers
- spoon
- watch glass, Petri dish, or microscope slide

Aquatic Environments

If the pH of the water in an aquatic environment is below 5.0, you will not find many fish there, especially young ones. Some insects such as mayflies are also very sensitive to acidic environments and environments that have little dissolved oxygen. The diversity of all organisms decreases as acidity increases and dissolved oxygen decreases. For example, few insects and many worms may mean that the water contains little dissolved oxygen. Recall from earlier studies that diversity refers to the number of different species in an ecosystem.

A pond that supports a wide variety of organisms probably has good water quality for allowing organisms to survive. However, it cannot be considered safe for humans to drink until it is tested to make sure.

Chemical Factors That Affect Organisms

Pure water is made up of only $H_2O_{(l)}$ molecules, but water in the environment is never completely pure. It can contain many different organic and inorganic compounds. The concentration of these compounds affects water quality. The following are most commonly monitored as indicators of water quality:

- dissolved oxygen
- acidity
- heavy metals
- plant nutrients such as nitrogen and phosphorus
- pesticides
- salts such as sodium chloride and magnesium sulfate

Measuring Chemicals in the Environment

The concentration of chemicals in the environment is usually measured in **parts per million** (ppm) or milligrams per litre (mg/L). For example, the human nose can detect chlorine in water at a concentration of 1 ppm of chlorine. That means that there is 1 part chlorine for every 1 million parts of the chlorine/water solution. One part per million means that one unit of an element or chemical can be found in one million units of solution.

Here is an example to help you better understand parts per million as a unit of measurement. Suppose you put 999 mL of water in a large beaker or bucket, add 1 mL of food colouring, and stir to make a solution. The concentration of food colouring in the container is 1 mL of food colouring per 1000 mL of solution, or you can say, 1 part food colouring per 1000 parts solution.

Figure 2.3 The beaker above has 1 part food colouring for every 100 parts of solution. The other beaker below has 100 ppm.

Now you will make a very dilute solution using the solution you just made. Pour 999 mL of water into another large container. Add 1 mL of the mixture from the first container. This contains 0.001 mL of food colouring. Stir. The concentration in the second container is therefore 0.001 mL of food colouring per 1000 mL of solution, or 0.001 parts food colouring per 1000 parts solution. To express this as parts per million, write:

0.001 parts per 1000 parts = x parts per 1 000 000 parts

where x is the number of parts per million parts of solution.

Write this statement as a ratio.

$$0.001 : 1000 = x : 1\,000\,000$$

Write each ratio as a fraction.

$$\frac{0.001}{1000} = \frac{x}{1\,000\,000}$$

Multiply each side of this equation by 1 000 000 to clear the fractions.

$$\frac{0.001}{1000} \times 1\,000\,000 = \frac{x}{1\,000\,000} \times 1\,000\,000$$

$$1 = x$$

The concentration of food colouring in the diluted solution in the second container is now 1 part per million parts solution, or 1 ppm.

Sometimes you may encounter even lower concentrations of chemicals in parts per billion (ppb) and parts per trillion (ppt). Here's an example to show the difference between these measurements:

- 1 drop of food colouring in a half-full bathtub is about 1 ppm
- 1 drop of food colouring in a full swimming pool is about 1 ppb
- 1 drop of food colouring in the amount of water needed to fill 1000 swimming pools is about 1 ppt

Measuring parts per trillion of anything is difficult and requires special, costly equipment. Only extremely hazardous substances are measured to this level of concentration. For example, the average concentration of polychlorinated biphenyls (PCBs) in the Great Lakes has been measured at 4 ppt. These manufactured oils are used in electrical equipment. They persist in the environment and accumulate in the body tissues of animals.

SKILL **PRACTICE**

PARTS PER MILLION

Try these examples for practice using parts per million as a unit of measure.

Suppose you make a food colouring solution by putting 99 mL of water in a beaker and adding 1 mL of food colouring. The concentration of food colouring in this beaker is 1 part food colouring per 100 parts solution.

- Calculate this concentration in parts per million.

You then add 1 mL of this solution to 99 mL of water in a second beaker. This creates a concentration of 0.01 parts of food colouring per 100 parts of solution.

- Calculate this concentration in parts per million.

Now suppose you take 1 mL of the solution in the second beaker and add it to 99 mL of water in a third beaker.

- What is the concentration of food colouring in this solution in parts per million?

DISSOLVED OXYGEN

Imagine white-water rafting down a roaring river. As the water churns over and around rocks, oxygen from the air is dissolving into it. Dissolved oxygen is essential for the health of aquatic life such as fish, insects, and micro-organisms. The level of dissolved oxygen in water depends on:

- temperature
- turbulence due to wind or the speed of moving water
- the amount of photosynthesis by plants and algae in the water
- the number of organisms using up the oxygen

Five milligrams per litre (equal to 5 ppm) of dissolved oxygen will support most organisms that live in lakes and streams. The following table gives examples of levels of dissolved oxygen needed by aquatic invertebrates.

Dissolved oxygen (ppm or mg/L)	Invertebrates
8	Large numbers of diverse invertebrates
6	Mayflies, stoneflies, and beetles begin to disappear
4	Freshwater shrimp, midge larvae, and worms can survive
2	Midge larvae and some worms can survive

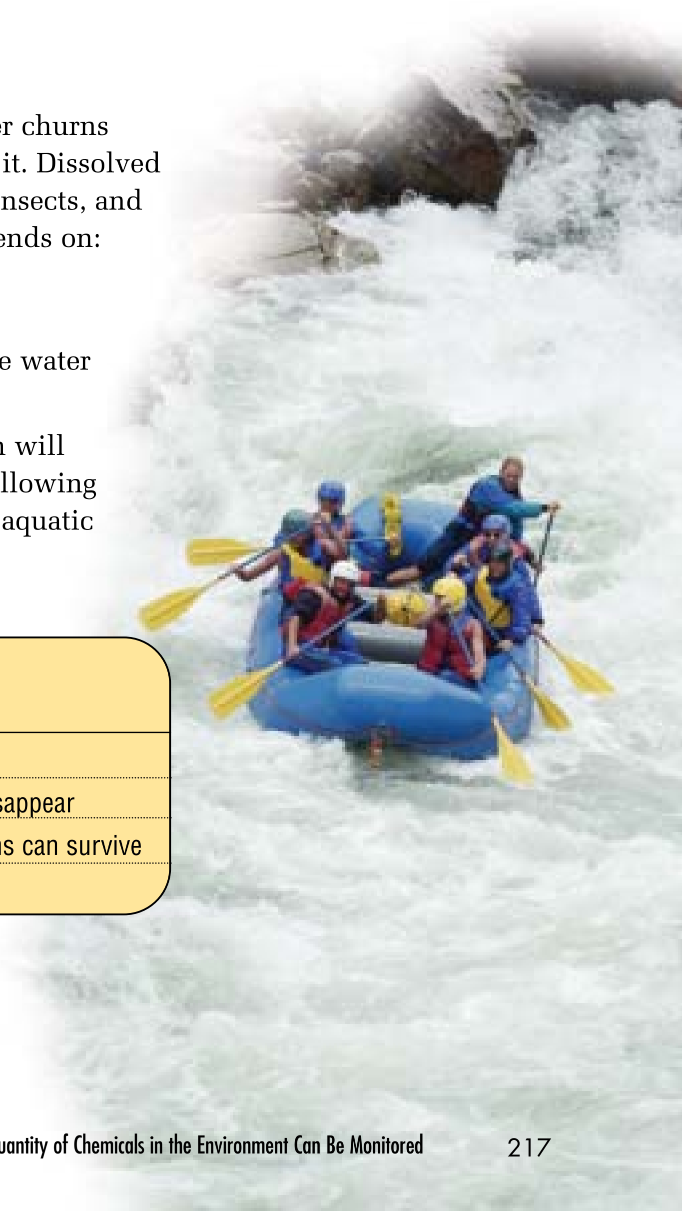


Figure 2.4 Rapids expose more water surface to the air than smooth river flow does. The turbulence allows more oxygen from the air to dissolve in the water.

ACTIVITY C-6

Inquiry

How Does Oxygen Get into the Water?

Before You Start

In this activity, you will use an indicator to determine the amount of dissolved oxygen in a water sample. The indicator changes colour according to the amount of oxygen present.

Materials & Equipment

- 100 mL boiled, then cooled water
- dissolved oxygen measuring kit
- 2 small beakers
- small jar with tight-fitting lid (e.g., baby food jar)

Figure 2.5 Step 2

The Question

What is the effect of turbulence on the amount of dissolved oxygen in water?

The Hypothesis

Reword the question in the form of a hypothesis.

Procedure

1. Pour 50 mL of the boiled, cooled water into a small beaker.
2. Following the directions on the dissolved oxygen kit, measure the amount of dissolved oxygen in your sample in milligrams per litre. Record your measurement.
3. Pour the remaining 50 mL of the boiled, cooled water into a jar with a tight-fitting lid. (The jar should be big enough so that a large amount of air remains after the water sample is placed in it.)
4. Shake the jar vigorously for 1 min.
5. Open and close the jar and repeat step 4 two more times.
6. Following the directions on the dissolved oxygen kit, measure the amount of dissolved oxygen in the shaken sample in milligrams per litre. Record your measurement.

Analyzing and Interpreting

7. Why did you have to use water that had been boiled and then cooled for this activity?
8. Would the amount of dissolved oxygen in the shaken water sample change if the water was boiled and then cooled again? Explain your answer.
9. What was the manipulated variable in this experiment? What was the responding variable?

Forming Conclusions

10. Use your observations to explain the effect of turbulence on the amount of dissolved oxygen in the water.

Applying and Connecting

The bubbles you see breaking the surface in an aquarium are produced by a device called an aerator. An aerator bubbles air through the water in the aquarium to replace the dissolved oxygen that has been used up by fish and other organisms.

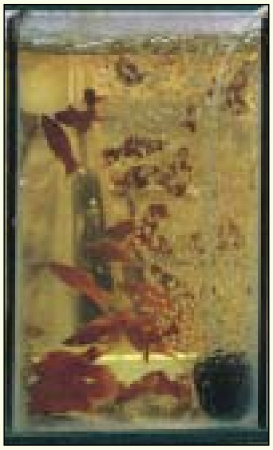


Figure 2.6 An aerator in an aquarium

Extending

Design an experiment that shows the effect of temperature on the concentration of dissolved oxygen in water.

Phosphorus and Nitrogen Content

Most aquatic organisms are sensitive to changes in the amount of dissolved oxygen in the water in which they live. One factor that can affect dissolved oxygen is an increase in phosphorus and nitrogen in the water. Phosphorus and nitrogen are important to all living things, but too high a concentration in water can cause problems.

Large amounts of phosphorus and nitrogen can enter water systems in different ways. Sewage outfalls and runoff from fertilized fields are two possible sources. Higher concentrations of these nutrients in water cause increased growth of algae and green plants. As more algae and plants grow, more die. This dead organic matter becomes food for bacteria that decompose it. With more food available, the bacteria increase in number and use up the dissolved oxygen in the water. When the dissolved oxygen content decreases, many fish and aquatic insects cannot survive. Figure 2.7 shows the effects of increased amounts of phosphorus and nitrogen on a lake.

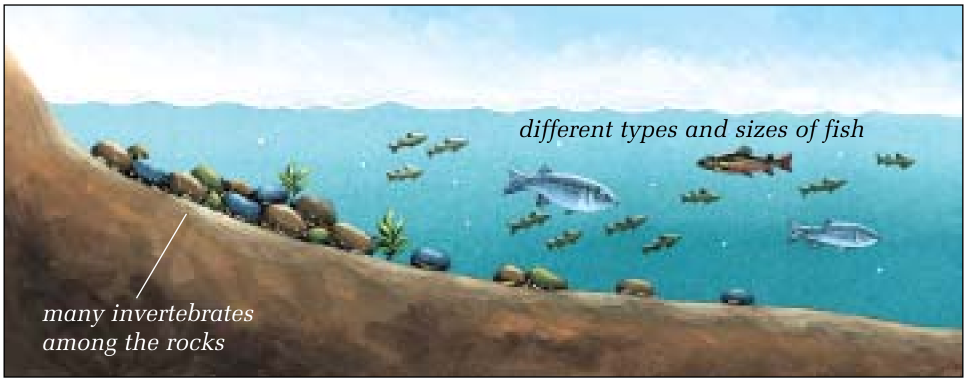


Figure 2.7(a) A "clean" lake contains a wide variety of organisms. These include fish and invertebrates such as mayfly nymphs, stonefly nymphs, midge larvae, and worms. The white dots represent the numbers of bacteria.

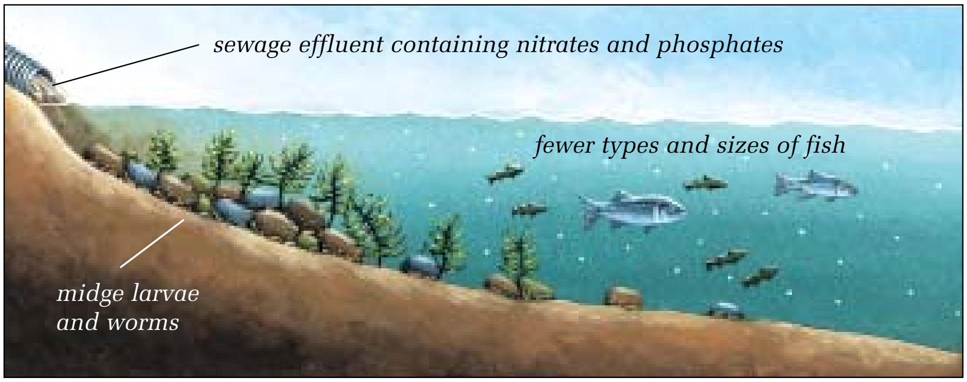


Figure 2.7(b) Added plant nutrients from treated sewage or runoff from fields causes increased growth of algae and plants. Fewer fish and invertebrates can live in these conditions.

Figure 2.7(c) Some plants die. Bacteria help to decompose them. With more food available, the population of bacteria increases. They need oxygen to survive, so they use up much of the dissolved oxygen in the water. The lake is no longer a place where fish and many insects can live.

QUICKLAB

PHOSPHORUS AND "FOGGY" WATER

Phosphorus commonly combines with oxygen to form compounds called phosphates. These compounds in fertilizers and sewage can pollute water systems. Magnesium sulfate dissolves in water and reacts with phosphates to form magnesium phosphate. This process occurs best in a solution that is basic. Magnesium phosphate does not dissolve in water so it forms a precipitate, causing the water to appear cloudy. You can use magnesium sulfate to test water samples for the presence of phosphorus.

Purpose

To detect phosphorus in water

Procedure

1. Place 15 mL of each water sample in a different test tube. Add 20–30 drops of dilute ammonium hydroxide to each water sample to make the solution basic.
2. Carefully add 2 mL of magnesium sulfate solution to each sample. Let the test tubes stand for 2 to 3 min. Record your observations.
3. Follow your teacher's instructions for disposing of chemicals.

Questions

4. In which samples did you detect phosphorus?
5. Where do you think the phosphorus came from in these samples?

Materials & Equipment

- water samples (e.g., tap water, water from a local pond, water containing fertilizer, water containing a phosphate detergent)
- test tubes
- dilute ammonium hydroxide solution
- magnesium sulfate solution
- medicine dropper
- small graduated cylinder

Caution!
Ammonium hydroxide can burn your skin and eyes. Make sure the room is well ventilated when you work with ammonia compounds.

ACIDITY

Earlier in this unit, you learned that normal rain and snow have a pH of 5.6 because carbon dioxide from the air dissolved in them to form weak carbonic acid. Precipitation with a pH lower than 5.6 is considered acid rain or snow. When this acid precipitation falls on water systems, it affects the acidity of the water. As the acidity increases, the diversity of plants and animals that live in this water decreases. Most fish disappear if the water's pH falls to 4.5.

Acidic deposition is a major problem wherever the soil and water lack natural bases to neutralize acidic precipitation. The Canadian Shield in northern and eastern Canada is an example of an affected area. The thin soils and the chemical composition of the rocks there are not able to neutralize the acid. As a result, forests and lakes have been damaged.

In areas where acid precipitation is a problem, acidic deposits build up in ice and snow in the winter. In spring, when the ice and snow melt, the acid meltwater flows into aquatic systems. This quickly creates a concentration of acid that can dramatically lower the pH of the water in a pond, slough, lake, or river for a short period of time. This is known as **spring acid shock**. It can seriously affect the eggs of aquatic organisms, as well as the young offspring of spring-spawning fish.

Pesticides

In section 1.0, you learned about the importance of pesticides, and some of the risks connected with their use.

Some pesticides have had longer-term harmful effects because they remained in the environment after they were no longer needed. Today most pesticides are designed to last only one growing season. They are broken down by bacteria so that they are no longer toxic.

However, even these shorter-lasting pesticides may cause pesticide-resistant pests to develop. For example, insects reproduce rapidly, so many generations can be exposed to an insecticide in one season. Some of these insects may be resistant to the insecticide. If they survive and reproduce, the whole population could become insecticide-resistant. When this happens, new insecticides must be developed, which introduces other chemicals into the environment.

In some cases, shorter-lasting pesticides may not disappear entirely from the environment. Although they break down in soil and water, they remain in the tissues of some organisms.

The large numbers of pesticides being used today are also creating another problem. Scientists are finding that water samples may contain very low concentrations of many different pesticides. One pesticide at a very low concentration might not be harmful. However, several pesticides together might mix to form a much more **toxic** or poisonous substance. Scientists are researching ways to predict the toxicity of combinations of substances in bodies of water. **Toxicity** describes how poisonous a substance is.

Figure 2.8 Ladybugs can be used to control aphids because they eat large quantities of them. Spraying plants with insecticide to kill aphids may also kill ladybugs.

Measuring Toxicity

Toxins or poisons are substances that produce serious health problems or death when introduced into an organism. In order to compare toxins, scientists use a measurement called **LD50**. "LD" stands for "lethal dose" and the "50" represents 50%. LD50 is the amount of a substance that causes 50% of a group of test animals to die if they are given a specified dose of the substance all at once.

Different types of chemicals can affect organisms in different ways. For example, one chemical may damage the liver; another may cause brain damage. It is difficult to compare the toxicity of different chemicals if you consider these effects only. However, all toxic chemicals will cause death in some organisms if given in large enough doses. LD50 testing allows scientists to compare toxicity because they are comparing the dosage that will produce the same outcome: death.

LD50 testing is usually done on rats and mice. It is stated as the amount of chemical given per unit of body mass. It also specifies how the animal received it—the usual ways are by mouth or applied to the skin. The table in the margin shows some examples of LD50 measurements. Notice that the more toxic the substance is, the lower its LD50 number is.

Substance	LD50	Subject/ How delivered
Table salt	3000 mg/kg	Rat, by mouth
Caffeine	192 mg/kg	Rat, by mouth
DDT (pesticide)	87 mg/kg	Rat, by mouth

reSEARCH

Heavy Metal Contamination

Choose one of the heavy metals mentioned in the text and research answers for the following questions:

- Where is the metal found?
- How could you be exposed to the metal?
- How can the metal enter your body?
- How can the metal affect your health?
- What level of exposure to the metal can cause health problems?

Begin your search at www.pearsoned.ca/scienceinaction. Prepare a summary of your research.

Heavy Metals

In the 1950s, many people in Minimata, Japan, were becoming sick and dying from a mysterious disease that affected their nervous systems. Investigators found that the disease could be linked to eating local fish that contained large quantities of mercury. The mercury was traced to a chemical company that had been dumping its waste into the ocean. People who caught and ate the fish from this area were affected by mercury poisoning. The symptoms of mercury poisoning include numbness of arms and legs, involuntary movements, nerve damage, and brain damage.

Mercury belongs to a group of substances called **heavy metals**. They are called heavy metals because they have a density of 5 g/cm^3 or more. This means they are five or more times heavier than an equal volume of water. Examples include copper, lead, zinc, mercury, cadmium, and nickel.

These metals occur naturally in rocks, soil, and sometimes in water. They are mined for processing into a wide range of products. Everyday items containing heavy metals include batteries, rubber tires, gasoline, paints, pipes, thermometers, and some fertilizers.

Heavy metals can be toxic to a wide range of organisms, including humans, so water quality monitoring includes checking concentrations of heavy metals.

Usually, large amounts of heavy metals are not readily available in the environment for uptake by plants or ingestion by animals. However some situations can increase their availability. For example, acidic water can dissolve lead in pipes. Cadmium is present in some fertilizers as an impurity. Plants growing in basic soils are able to take in this cadmium. If animals eat plants containing high levels of heavy metals over long periods, they may experience serious health problems.

The heavy metal lead is especially harmful to children. It can affect normal development and cause permanent brain damage or even death. In the past, lead was used in common products such as gasoline and pipes for water systems. It is no longer used in products that might result in its

Figure 2.9 This man has Minimata disease, a type of mercury poisoning that is named after the area in Japan where it was identified.

ACTIVITY C-7

Experiment on your own

WHAT KILLED THE FISH?

Before You Start

Officials are trying to determine what is causing a catastrophic fish kill along the southeast shore of Rowan Lake. Hundreds of dead fish have been reported where the Bearberry River flows into the lake. The Bearberry River is the best white-water trout stream in the province. Damage to this river will deplete the food supply for many people and harm the local tourist industry.

Biological testing has been completed, and chemical testing is underway at four sites. The results of the biological testing are shown in the following table:

Invertebrate	Number of Organisms in a Sample			
	Site 1	Site 2	Site 3	Site 4
Mayfly nymphs	187	0	35	233
Stonefly nymphs	155	0	23	162
Caddisfly larvae	34	0	6	27
Midge larvae	110	159	133	97
Worms	15	142	58	23

Your task is to determine the water quality at the four testing sites by carrying out chemical tests for dissolved oxygen, pH, and phosphates. Your teacher will provide the water samples. You will use these test results, combined with the information from the biological monitoring, to determine which site has the poorest water quality.

You may wish to review the table at the bottom of page 217. It summarizes the effect of changes in dissolved oxygen concentration on invertebrates.

The Question

Which test site has the poorest water quality?

Design and Conduct Your Experiment

1 From the biological data, form a hypothesis about which site will have the poorest water quality. Record your hypothesis.

2 With your partner or group, plan your procedure. Ask yourselves questions such as:
   a) How will we test for dissolved oxygen? For pH? For phosphates?
   b) What type of chart will we need to record data in?
   c) How long do we have to complete the experiment?
   d) How will we decide which site has the poorest water quality?

3 Write up your procedure. Show it to your teacher before continuing.

4 Carry out your experiment.

5 Compare your results with your hypothesis. Was your hypothesis correct? Why or why not?

6 Share and compare your experimental plan and findings with your classmates. How do your results compare with theirs? If they are different, give a possible explanation.

Figure 2.10 Determining water quality

Check and Reflect

Key Concept Review

1. Governments set water quality guidelines for five categories of water use. What are these?
2. List four different groups of invertebrates that can be found in freshwater systems.
3. Identify five chemicals that are regularly monitored in aquatic systems
4. What effect does spring acid shock have on aquatic organisms?
5. Identify an invertebrate family that would probably be among the first to die if the pH of its habitat decreased.

Connect Your Understanding

6. A student put 0.03 mL of food colouring into water to make 1000 mL of solution. Calculate the concentration of food colouring in parts per million.
7. Calculate the concentration in ppm of an alcohol/water solution if 30 drops of alcohol are stirred into water to make 1 L of solution. Note: 1 drop = 0.05 mL
8. Copy the table below into your notebook. Calculate the concentration of each solution in parts per million and fill in the last column.

Solute (mL)	Volume of final solution (mL)	Concentration (ppm)
2.0	1000	
0.0009	100	
0.62	10 000	

9. Look at the table below. In which location (A or B) will the water support the greatest diversity of organisms? Explain your answer. (The table on page 217 can help you with your answer.)

Characteristic	Sample A	Sample B
Dissolved oxygen	3.5	6.0
pH	5.5	6.5
Phosphorus	high	low

10. Explain the following statement about table salt: *The LD50 is 3000 mg/kg for rats.*

Extend Your Understanding

11. Explain what happens when a high concentration of phosphorus enters a water system.
12. Suppose that high levels of mercury were found in your community. List at least three recommendations that you would make to the government to deal with this issue.

2.2 Monitoring Air Quality

Take a deep breath. The air you take in is mainly nitrogen (78%) and oxygen (21%), with some argon (less than 1%), carbon dioxide (0.03%), and traces of hydrogen and neon. If you took a deep breath in the city shown in Figure 2.11, you might find that the air irritates your throat. You might also notice that your eyes sting a bit. These are indications of poor air quality. Like water quality, air quality is determined by the number of potentially harmful chemicals.

Air quality can be determined in two ways:

- by measuring the levels of pollutants in the air
- by estimating the amount of emissions from pollution sources

Measuring the amounts of chemicals in the air is more accurate than only estimating emissions from pollution sources, such as industrial plants. Measurements of chemicals in the air include chemicals produced by natural sources such as forest fires. This provides a more complete picture of air quality. Monitoring chemicals in the air over a period of many years provides information about seasonal variations, as well as long-term trends.

Figure 2.11 Smog seen over a city is a familiar sight on sunny days.

Sulfur Dioxide

Sulfur dioxide ($SO_{2(g)}$) is a major air pollutant that forms both smog and acid rain. It can affect your respiratory system (throat and lungs) and irritate your eyes.

Sulfur dioxide and other oxides of sulfur form when oxygen combines with sulfur. The major source of sulfur dioxide is industrial processes. In Alberta, the major source of sulfur dioxide is the oil and gas industry. Sulfur dioxide and other oxides of sulfur are also formed by burning fuels such as coal, oil, and natural gas.

Industrial and electrical generating plants use devices called "scrubbers" to reduce sulfur dioxide emissions by up to 99%. Scrubbers use limestone (calcium carbonate) to convert the pollutant sulfur dioxide to a useful product. The sulfur dioxide reacts with the calcium carbonate in the scrubber to produce gypsum (calcium sulfate). The gypsum is recovered and can be used in manufacturing. Here is the equation for the sulfur dioxide and limestone reaction:

$$2\ SO_{2(g)} + 4\ H_2O_{(l)} + 2\ CaCO_{3(s)} + O_{2(g)} \rightarrow 2\ CaSO_4{\cdot}2\ H_2O_{(s)} + 2\ CO_{2(g)}$$

sulfur dioxide + water + limestone + oxygen → gypsum + carbon dioxide

*info*BIT

Indoor Air Pollution

You can't always avoid air pollution simply by staying indoors. For example, a smoke-filled party room can be a health hazard. Other substances that contribute to indoor air pollution include paints, glues, and cleaning supplies.

Nitrogen Oxides

Nitrogen oxides ($NOx_{(g)}$) are also major air pollutants that form both smog and acid rain. They affect the respiratory system and eyes. The "x" in the chemical formula $NO_{x(g)}$ indicates that nitrogen oxides are mixtures of $NO_{(g)}$ and $NO_{2(g)}$ and sometimes other oxides of nitrogen.

Nitrogen oxides ($NO_{x(g)}$) form mainly from combustion in vehicles. They also form by combustion in generating plants and some industrial processes, such as oil refining. The nitrogen formed by burning fuels first combines with oxygen to form nitrogen monoxide gas ($NO_{(g)}$). This then combines with oxygen in the atmosphere to form nitrogen dioxide ($NO_{2(g)}$), a brownish gas. This is the gas that gives smog its distinctive colour.

Both sulfur dioxide and nitrogen oxides are carefully monitored, especially in cities and areas where industrial processes may release these pollutants. In cities, the main concern is with pollution from vehicles.

SKILL PRACTICE

Measuring Nitrogen Oxides

Measurements of Alberta's emissions of nitrogen oxides ($NO_{x(g)}$) are shown in the graph in Figure 2.12. Study the graph and answer the questions. Notice that the top line represents total emissions. The amounts contributed by major activities are shown in different shadings.

- What trends in nitrogen oxide emissions do the following lines on the graph show over time?
  a) total amount (top line)
  b) transportation
  c) electric power generation
  d) industrial processes
- What would you expect the total nitrogen oxide emissions to have been in the year 2000?
- Which sector contributed most to the increase in nitrogen oxides in Alberta since 1990? Suggest a reason for this increase.

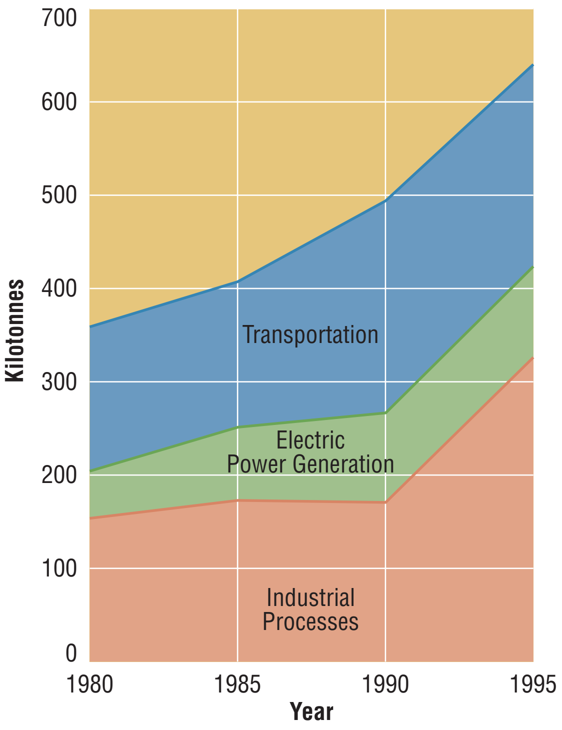


Figure 2.12 Alberta $NO_{x(g)}$ emissions by sector 1980–1995. (Information for graph supplied by Alberta Environment)

CARBON MONOXIDE

Carbon monoxide is called the silent killer because it is a colourless and odourless gas. When chemicals containing carbon burn, they produce carbon dioxide or carbon monoxide. Carbon monoxide ($CO_{(g)}$) forms if there is not enough oxygen to produce carbon dioxide ($CO_{2(g)}$). If there is enough oxygen during combustion, carbon dioxide is produced.

The main source of carbon monoxide from human activities is motor vehicles. Other sources are combustion of wood (e.g., fireplaces, wood stoves) and natural gas, industrial processes, airplanes, and even cigarette smoking. Carbon monoxide can also be produced in large quantities by forest fires. In cities, carbon monoxide is a major pollutant because of cars. In smaller communities, it can be a problem during the colder months when many people burn wood for heating.

If inhaled, carbon monoxide reduces the amount of oxygen carried by the blood. As a result, it can cause headaches, sleepiness, chest pains, brain damage, and death. Technologies such as catalytic converters in vehicles and industry convert carbon monoxide into carbon dioxide. Research is underway to develop improved and affordable catalyst materials that can better reduce emissions of carbon monoxide from vehicle exhausts and industrial facilities.

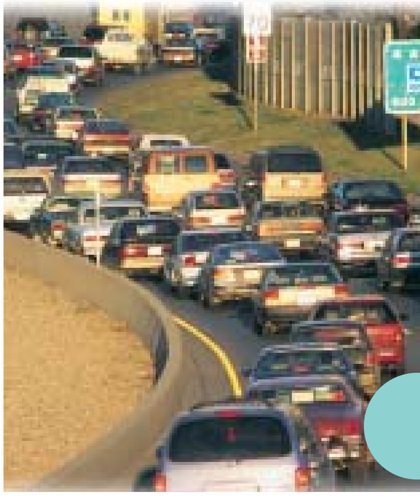


Figure 2.13 Motor vehicles are the main source of the major air pollutants $NO_{x(g)}$, $CO_{(g)}$, and $O_{3(g)}$.

GROUND-LEVEL OZONE

You read at the beginning of this section that a layer of ozone protects Earth's surface from harmful ultraviolet light. This layer is located high above Earth in the upper atmosphere. This same chemical—ozone—is also found at Earth's surface. But at ground level, ozone is a harmful pollutant. Ozone is an example of a chemical that may not be harmful and may even be beneficial in one situation. But in another situation, it may be a pollutant.

Ozone ($O_{3(g)}$) is an odourless, colourless gas composed of three oxygen atoms. At ground level, it forms from reactions between oxygen, nitrogen oxides, and compounds called volatile organic compounds (VOCs), in the presence of heat and sunlight. VOCs are organic chemicals that evaporate easily. Some plants and trees emit VOCs, but most of the VOCs come from human-made products such as solvents and gasoline.

The major source of ground-level ozone is fuel combustion in vehicle engines and industry. As a result, ozone pollution is a problem mainly in larger cities, especially during the summer. Some cities issue warnings on days where ozone levels are expected to be high so people with respiratory problems can stay indoors.

Ozone is especially harmful to people who have lung diseases such as asthma, and anyone with a cold. All children are at a higher risk than healthy adults because their lungs are still developing. Anyone who exercises outside in air containing high levels of ozone may suffer breathing problems and long-term lung damage.

Ground-level ozone can seriously affect crops such as wheat, soybeans, and onions. Ozone can also cause materials such as plastics to deteriorate more rapidly.

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Catalytic Converters

A catalytic converter is a device that uses platinum and palladium catalysts to remove pollutants from vehicle exhaust. Prepare a report on the chemical reactions that take place in a catalytic converter. Do they eliminate pollutants entirely? Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Match the chemicals that are components of air in column A with their correct percent composition in column B.

Column A	**Column B**
oxygen	78%
carbon dioxide	21%
nitrogen	less than 1%
argon	0.03%
hydrogen	trace

2. Scrubbers use a chemical reaction to remove a major pollutant from the air.
a) What pollutant is removed?
b) What are the products of the chemical reaction?

3. Why is carbon monoxide harmful to animals?

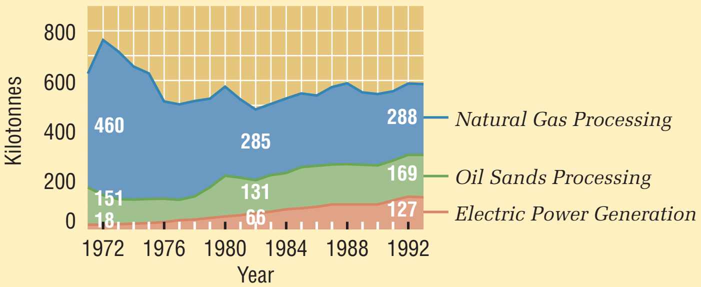
4. Scientists have two main methods of determining the amount of pollution in the air. Explain why a) is a more accurate method than b).
a) measuring the concentration of harmful chemicals in the air
b) estimating the amount of harmful chemicals in emissions from industrial plants and other sources

Connect Your Understanding

5. *Ozone can be both helpful and harmful.* Explain this statement.

6. Look at the graph in Figure 2.14. What trends do you see in the following sectors?
a) total amount (top line)
b) natural gas processing
c) oil sands
d) electric power generation

Figure 2.14 Alberta sulfur dioxide emissions by sector for questions 6 and 7 (Graph supplied by Alberta Environment)



7. Look at the graph in Figure 2.14. Which process has contributed to a reduction in total sulfur dioxide emissions in Alberta since the early 1970s? Suggest a reason for this.

Extend Your Understanding

8. a) Identify the harmful compounds in car exhausts and explain why they are harmful to the environment.
b) Explain one benefit of catalytic converters.
c) Explain why catalytic converters have become an issue for people concerned about global warming.

2.3 Monitoring the Atmosphere

Chemicals in the air can cause mild to serious health effects in local areas, but some chemicals in the atmosphere can affect the entire globe. Ozone depletion and climate change related to increased carbon dioxide concentration are both international issues.

Carbon Dioxide as a Greenhouse Gas

Carbon dioxide is not considered a pollutant since it is naturally present in the air. However, the increasing amount of carbon dioxide in the atmosphere has become a concern for governments and an important area of study for scientists.

Each time you exhale you release carbon dioxide into the atmosphere. Each time your parents drive you to music lessons or hockey practice, the family car releases carbon dioxide into the atmosphere. When you have a bonfire at the lake to roast marshmallows, the fire releases carbon dioxide into the atmosphere. One person, one car, and one bonfire don't add much carbon dioxide to the air. But consider the huge amount of carbon dioxide added to the atmosphere by billions of people, millions of cars, and millions of fires worldwide.

Many people wonder what effect this large amount of additional carbon dioxide in the atmosphere may have on the planet. Investigations into this question are going on around the world.

The Greenhouse Effect

Life on Earth thrives because we live in a natural greenhouse. Some gases in the atmosphere act like the glass in a greenhouse. They trap heat from the Sun's radiant energy. This heat keeps Earth at temperatures that allow living things to live, grow, and reproduce. The atmospheric gases that trap heat are called **greenhouse gases**. Water vapour, carbon dioxide, methane, and nitrogen oxides are all greenhouse gases.

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Canada's Chemical Contributions

Canada has only 0.5% of the world's population, but we account for about 2% of human-caused carbon dioxide emissions, 2% of nitrogen oxide, and 1% of methane emissions.

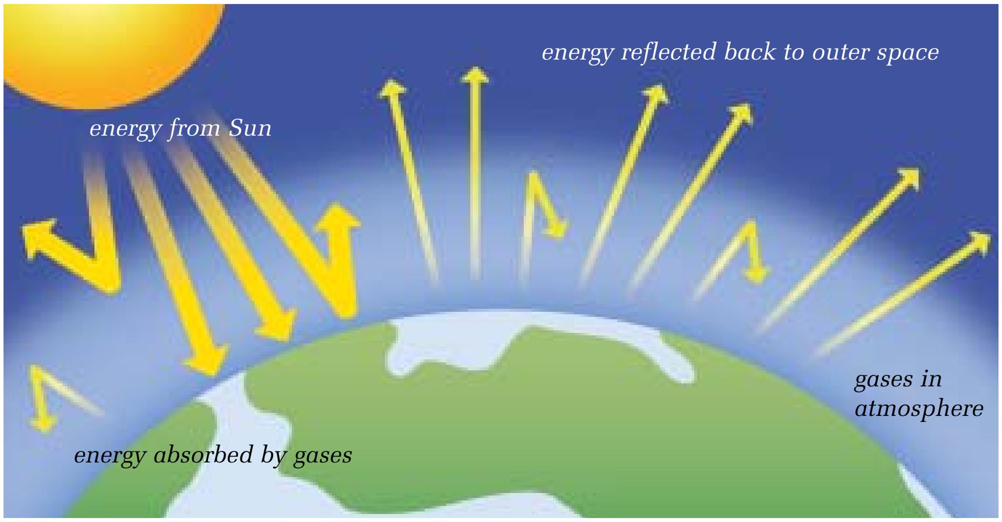

Figure 2.15 The Greenhouse Effect: When radiant energy from the Sun reaches Earth's surface, much of it is reflected back into space. But some of this energy is trapped near Earth's surface by a layer of gases that act like the glass in a greenhouse.

The Enhanced Greenhouse Effect

Many scientists support the theory that human activities such as burning fossil fuels and clearing land are contributing to an **enhanced greenhouse effect**. The enhanced greenhouse effect results from the greater concentration of gases trapping even more heat. In turn, this increases overall temperatures on Earth. This temperature increase worldwide is called **global warming**.

Global warming may lead to climate change, which could dramatically affect living things all over the world. These effects could include more violent storms, flooding of coastal areas from melting icecaps, and greater ranges in the spread of diseases.

After water vapour, carbon dioxide is the gas that contributes most to the enhanced greenhouse effect. Measurements of atmospheric carbon dioxide began late in the 1800s at various locations around the world. Over the years, more monitoring stations have been added. Data from these stations are continually being analyzed by scientists. Figures 2.15 and 2.16 show the difference between the greenhouse effect and the enhanced greenhouse effect.

math Link

In 1998, $SO_{2(g)}$ emissions in Canada measured 2696 kt. The national cap or prescribed limit was 3200 kt. Calculate the percent the 1998 amount was below the national cap.

Global Warming

Scientists have concluded that global warming is taking place and that it is caused at least partly by human activities. Natural events such as volcanic eruptions and forest fires may also be part of the cause of global warming. Like some human activities, they may increase the concentration of greenhouse gases in the atmosphere.

Some countries have started to reduce carbon dioxide emissions. For example, windmill farms are being used to power turbines in order to reduce the amount of fossil fuel being burned. Some companies are investing in forest projects so that growing trees can absorb carbon dioxide and offset the company's carbon dioxide production.

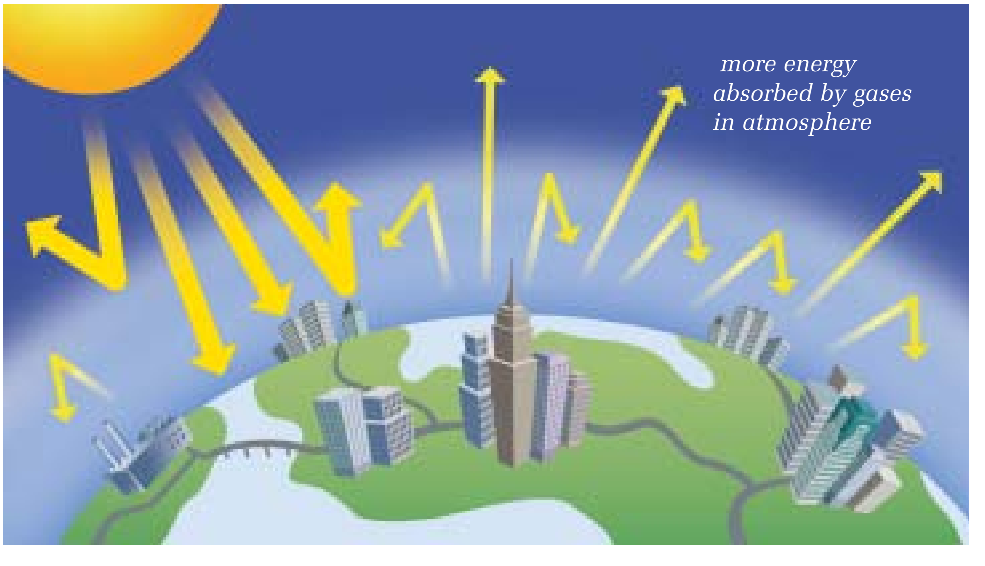

Figure 2.16 The Enhanced Greenhouse Effect: Human activities are generating more greenhouse gases, so many scientists have concluded that more heat is being trapped. This means that Earth's surface temperature will continue to rise. This worldwide increase is called global warming.

ACTIVITY C-8

Inquiry

ANALYZING CARBON DIOXIDE MEASUREMENTS

The Question

What does monitoring information indicate about trends in amounts of atmospheric carbon dioxide?

Materials & Equipment

- data sheet on $CO_{2(g)}$ concentration
- graph in Figure 2.18
- graph paper

Procedure

TOOLBOX

1. Collect data sheets from your teacher that show tables of data on carbon dioxide concentrations recorded at Mauna Loa, Hawaii, and Point Barrow, Alaska.
2. On the same graph, plot two line graphs, one from the data in Table 1 and one from the data in Table 2. Use different colours or symbols for each graph. These graphs represent **monthly** $CO_{2(g)}$ concentrations.
3. Use the data provided in Table 3 to prepare a line graph of **yearly** $CO_{2(g)}$ concentrations measured each May at Mauna Loa only.
4. Look at the graph in Figure 2.18 as a guide. Use a different-colour pencil or pen to draw a line of best fit on your graph of yearly $CO_{2(g)}$ concentrations (step 3).

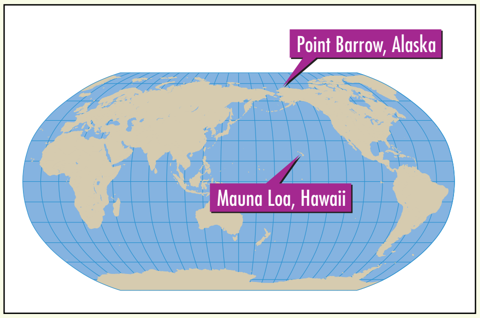

Figure 2.17 Locations of Point Barrow, Alaska, and Mauna Loa, Hawaii

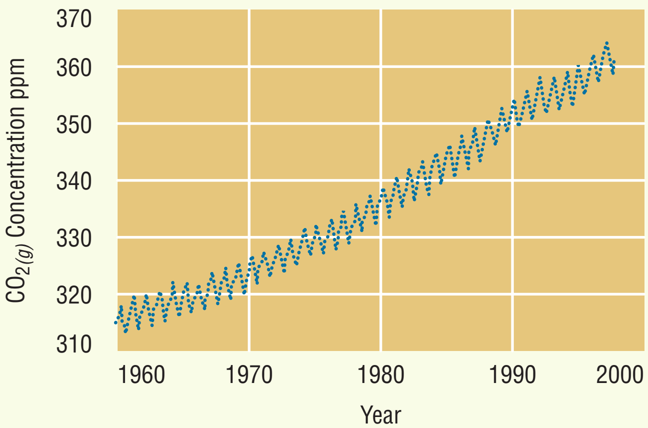

Figure 2.18 Monthly atmospheric $CO_{2(g)}$ data recorded at Mauna Loa. Mauna Loa is a mountain in Hawaii.

Analyzing and Interpreting

5. Look at the graph you prepared with the data from Table 1. What do you notice about the amounts of atmospheric $CO_{2(g)}$ over one year? Why do you think this occurs?
6. Is there any difference in the data from the two collecting sites? Why do you think this occurs?
7. Suggest a reason why Mauna Loa, Hawaii, and Point Barrow, Alaska, would be chosen as good sites to monitor atmospheric $CO_{2(g)}$.
8. What is the trend in the amount of atmospheric $CO_{2(g)}$ from 1974 to 1998, as recorded at Mauna Loa?

Forming Conclusions

9. Refer to your graphs and Figure 2.18 to explain what monitoring information indicates about monthly and yearly trends in atmospheric $CO_{2(g)}$ concentrations.

Figure 2.19 Scientists use ice cores from the Arctic and Antarctic to obtain information about $CO_{2(g)}$ concentrations over hundreds of years. Air is trapped as snow falls and held in ice as the snow builds up. Scientists drill down into the ice and take samples. They then analyze the $CO_{2(g)}$ content of the air bubbles in the ice.

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Enhanced Oil Recovery

To reduce carbon dioxide in the atmosphere, carbon dioxide is being captured and injected into depleted oil reservoirs for enhanced oil recovery (EOR). Use books, magazines, or electronic sources to find out how EOR is done. Write a summary of the environmental and economic benefits of EOR. Begin your search at www.pearsoned.ca/scienceinaction.

The Ozone Layer

In subsection 2.2, you learned about the dangers of pollution from ground-level ozone ($O_{3(g)}$). You also learned that this same chemical occurs high up in Earth's atmosphere, where it has an important function in protecting Earth's surface. This concentrated layer of ozone absorbs ultraviolet radiation (UV) from the Sun. By absorbing this radiation, the ozone layer protects organisms on Earth from damaging UV rays.

The ozone layer is a natural formation of ozone 15 to 50 km above Earth's surface. Scientists have been monitoring the ozone layer since the late 1970s. Over the years, they have noticed that this layer has become thinner, allowing more UV radiation to reach Earth's surface. Some areas are so thin that they are called "holes" in the ozone. This loss of ozone results in greater exposure to UV radiation on Earth's surface, which could have wide-ranging harmful effects on organisms. For example, the occurrence of human skin cancer and cataracts could increase. Plankton are sensitive to UV exposure, so increased UV radiation could cause plankton to die. This would affect all the animals that feed on plankton.

The Role of Chlorofluorocarbons

Scientists have concluded that the thinning of the ozone layer is caused by our use of chemicals called chlorofluorocarbons (CFCs). CFCs have been used in many different applications, including refrigerators, aerosol cans for products such as hair spray, and fire extinguishers. These chemicals move slowly from the lower atmosphere where we use them, up into the upper atmosphere. There, UV radiation breaks them down into substances, such as chlorine, that destroy ozone. Chlorine atoms react with the ozone molecules to form oxygen molecules ($O_{2(g)}$). One chlorine atom can remove 100 000 ozone molecules. You may have heard of the ozone hole over the south pole. The extremely cold temperatures in that area cause ice particles to form in the upper atmosphere. These ice particles speed up the reaction that removes the ozone molecules.

Many countries have recognized the danger to the ozone from the use of CFCs. They have signed international agreements on reducing their use of these chemicals. Monitoring substances such as CFCs is an important step in reducing their harmful impacts.

Check and Reflect

Key Concept Review

1. List four greenhouse gases.
2. International panels have been set up to study global warming and climate change. Describe three outcomes of global warming that are of concern.
3. a) What factor has contributed to the thinning of the ozone layer?
   b) What is happening as a result of this thinning?
4. What are countries doing to protect the ozone layer?

Connect Your Understanding

5. What trend has been observed in carbon dioxide levels over the past century? Describe two suggested causes of this trend.
6. Explain the difference between the greenhouse effect and the enhanced greenhouse effect.
7. In which months would you expect the carbon dioxide levels to be lowest in Alberta? Explain why you chose those months.
8. Match the four statements below with the following fields of study: political, scientific, economic, or technological. Suggest one question for further study that could be asked in each case.
   a) Carbon dioxide levels have been measured and analyzed. They have been rising since the Industrial Revolution.
   b) Scrubbers use calcium carbonate (limestone) to remove sulfur dioxide from smokestack emissions.
   c) Governments limit and monitor emissions such as sulfur dioxide and nitrogen oxides.
   d) People are demanding inexpensive electricity. Removing pollutants from smokestacks is expensive. Who will pay for it?

Extend Your Understanding

9. At Biosphere 2 near Tucson, Arizona, scientists are studying the growth of poplar trees in three different concentrations of carbon dioxide. Evidence suggests that slight increases in carbon dioxide levels stimulate plant growth. Why do you think this occurs?

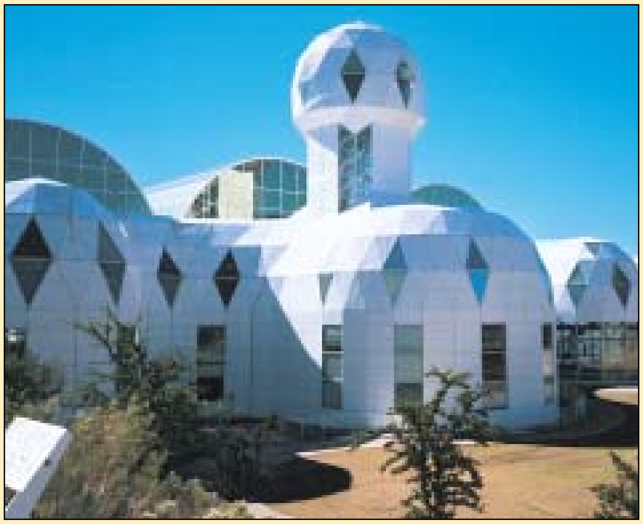

Figure 2.20 Biosphere 2 is a closed ecosystem laboratory used to investigate ecosystem interactions. It contains five biomes—a rain forest, a desert, a savannah, a marsh, and an ocean. It is about 30 m tall at its highest point.

SECTION REVIEW

Assess Your Learning

Key Concept Review

1. What do the presence of fish and a wide diversity of invertebrates in a river indicate?
2. Why is it important to have long-term measurements when studying ecosystems?
3. a) List six heavy metals that can be taken up by plants.
   b) Why are they considered pollutants?
4. Identify the organisms in Figure 2.21.

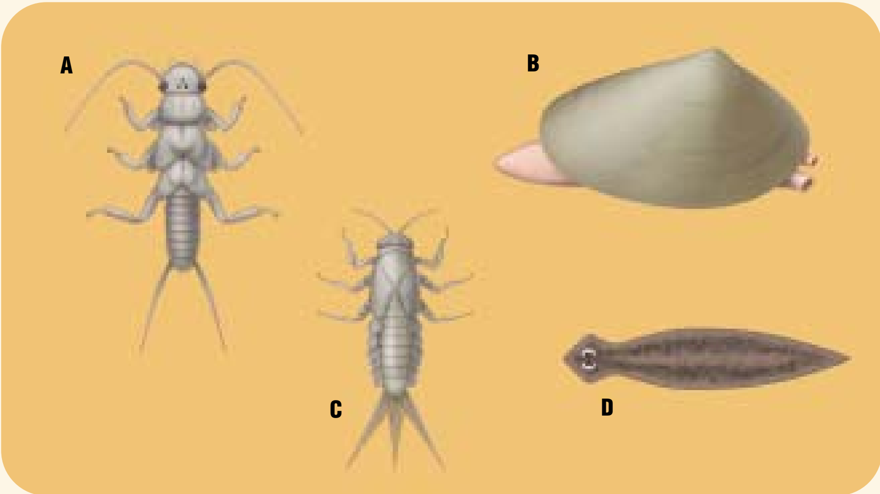

Figure 2.21 Question 4

Connect Your Understanding

5. The table below shows monitoring data from two water systems.

Characteristic	Sample A	Sample B
pH	6.5	5.5
Dissolved oxygen	5.5	4.5
Phosphorus	low	high
Nitrogen	low	high
Mayflies	present	absent

Which statement below is correct?

a) Sample A indicates good water quality for aquatic life because there are low concentrations of phosphorus and nitrogen.
b) Sample A indicates poor water quality for aquatic life because there are many mayflies.
c) Sample B indicates good water quality because there are high concentrations of phosphorus and nitrogen.
d) Sample B indicates good water quality because the pH is basic and mayflies are absent.

6. You have an air sample that has 0.02 mL of carbon dioxide in 1000 mL of air. What is the concentration of the carbon dioxide in parts per million?

7. Describe two situations that reduce the dissolved oxygen content of water.

8. Match the words/phrases in column A with the descriptions in column B.

A	B
LD50	chemical used to kill insects
neutralize	to bring closer to pH 7
insecticide	sudden lowering of pH
scrubber	measures toxicity
spring acid shock	removes $SO_{2(g)}$

9. Explain how the enhanced greenhouse effect may cause global warming.

Extend Your Understanding

10. Explain how the invention of the motor vehicle has been both beneficial and harmful.

11. How does reforestation affect the concentration of carbon dioxide in the air?

Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology are used to meet human needs and wants. However, they can have unintended consequences for both humans and the environment. In this section, you learned that monitoring chemicals in the environment is important because of both intended and unintended consequences. Consider the following questions, and use examples from this section to support your answers.

1. Pesticides are widely used in agriculture.
   a) What are the intended consequences of pesticide use?
   b) Give examples of some unintended consequences of pesticide use.
   c) How would monitoring be useful in helping to avoid some of the unintended consequences?

2. Spring acid shock is an unintended consequence of technology use. Suggest ways that technology could be used to reduce or eliminate this problem.

3. Explain why people are concerned about the rise in carbon dioxide levels over the past century.

3.0 Potentially harmful substances are spread and concentrated in the environment in various ways.

Key Concepts

In this section, you will learn about the following key concepts:

- concentration and dispersal
- stability and biodegradability
- evidence of toxicity
- hazards, probabilities, and risk assessment

Learning Outcomes

When you have completed this section, you will be able to:

- describe the transport of materials through air, soil, and water
- identify factors that may accelerate or retard the distribution of chemicals
- describe how the concentration of substances can be changed in the environment
- describe ways that biodegradation occurs and interpret information about the biodegradability of materials
- demonstrate how hazardous chemicals can affect the local and global environments
- identify potential risks resulting from consumer practices
- evaluate information and evidence related to an environmental issue

Just as balloons can be carried a long way on air currents, the molecules of potentially harmful chemicals can also travel long distances. For example, mercury can remain airborne for up to two years. The source of a pollutant can be in one country, but that same chemical may be deposited in another country—sometimes on the other side of the world. Chemicals carried in water also know no boundaries. It is easy to see why air and water pollution are global concerns.

In this section, you will learn how chemicals are transported in the environment through air, soil, and water. You will consider a case study that shows how a major oil spill can affect the environment. You will also learn more about handling and disposing of hazardous household chemicals safely.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Transport of Materials Through Air, Soil, and Water

When pollutants are detected far from where they are produced, many questions arise. What is the source of a pollutant? Who is to blame for its spread? Who should pay to correct any environmental problems created by the pollutant? To help resolve these issues, scientists attempt to understand the transport paths of potentially harmful substances.

Transport in Air

Figure 3.1 shows the three stages of transport of substances in air:

1. Release of the chemical at the source
2. **Dispersion** of the chemical in the atmosphere (the chemicals scatter in various directions)
3. Deposition of the chemical in soil or water

Sometimes, scientists must do a great deal of detective work to track down the source of a harmful airborne chemical. The direction and distance that airborne chemicals travel are determined by various factors. These include the pollutant's properties, the wind speed, and the direction of the prevailing winds. In Alberta, for example, the prevailing winds are from the west, so airborne substances are carried eastward.

The distribution of airborne pollutants may be limited by lack of wind. Precipitation is another factor that will affect distribution. An airborne pollutant will be deposited closer to its source if it is carried to the ground by rain or snow.

The source of a chemical that has travelled thousands of kilometres is usually impossible to identify. Often chemicals travel across borders, so deposition of airborne pollutants is an international problem. Many countries have signed international agreements and passed anti-pollution laws to limit the spread of airborne pollutants.

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Arctic Pollution

Chemical pollutants called dioxins have been detected across Canada's north—even where no humans live. In one study, scientists used complex models of air transport to identify the sources of dioxins found in Nunavut. They found that most of those specific dioxins came from waste incinerators and metal processing facilities in the United States, and some came from Mexico!

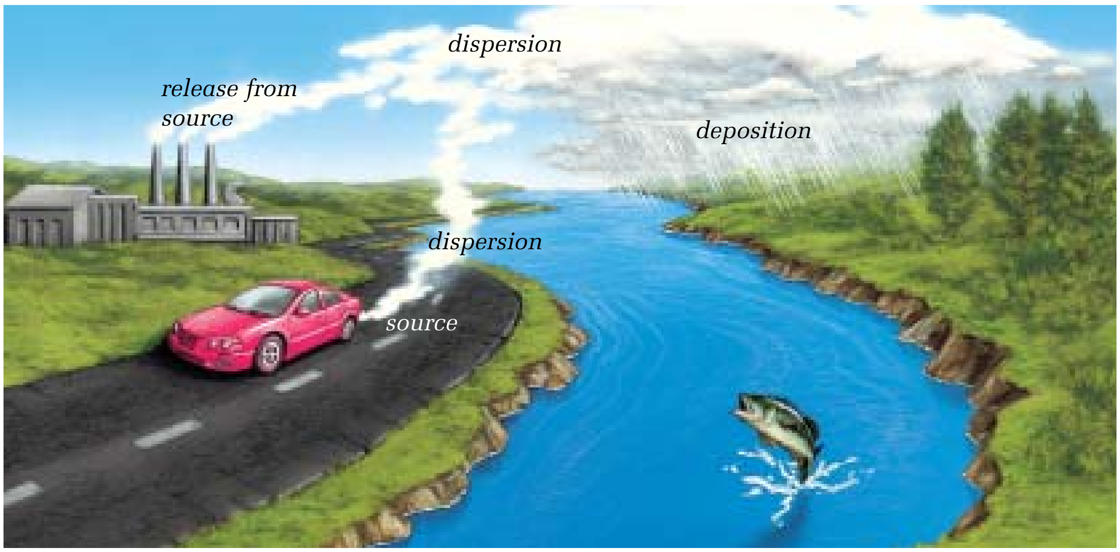

Figure 3.1 The stages of atmospheric transport of chemicals

*QUICK***LAB**

Environmental Transport

Purpose

To analyze movement of emissions in the environment

Procedure

1 Look at the maps in Figure 3.2 and answer the questions below.

Questions

2 Explain why sulfur dioxide emissions from the Alberta oil sands plants near Fort McMurray are a concern more for the people living in Saskatchewan than those living in western Alberta and British Columbia.

3 Explain why scientists consider sulfur dioxide emissions from a smelter in Trail, British Columbia, when they are studying environmental problems in Idaho.

4 Human-made chemicals have been found in Antarctica. How do you think they travelled there?

Figure 3.2(a) Fort McMurray, Alberta, and Trail, British Columbia

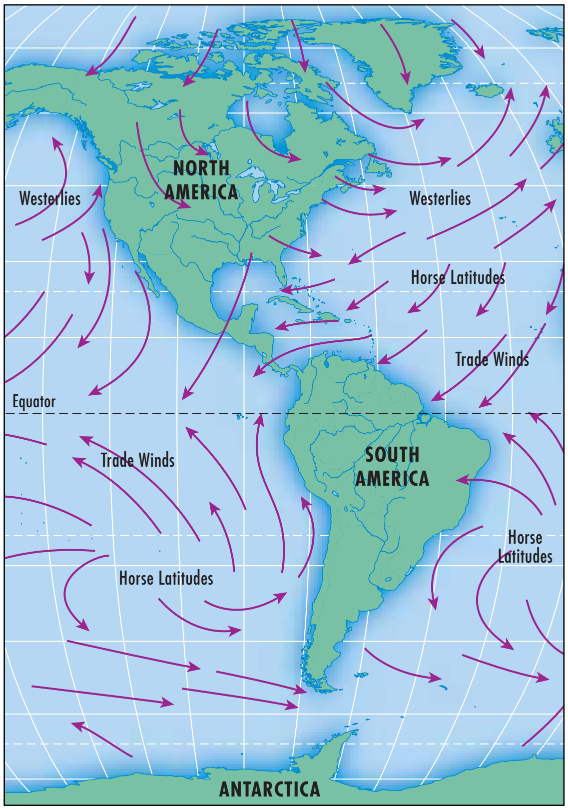

Figure 3.2(b) Surface winds

Figure 3.2(c) Ocean currents

Transport in Groundwater

Water that soaks into soil moves first into a zone near the surface. Here the spaces between the soil grains contain both air and water. As the water moves deeper, it enters the next zone where all the spaces are filled with water. This water is called **groundwater**. The top of the groundwater zone is called the **water table**. If your home or school uses a well, you are drinking and washing in groundwater.

Groundwater can move sideways, up, and down. It can move as slowly as 1 m per year or as quickly as 1 m per day. But even its faster rate is much slower than that of rivers or streams. Because of groundwater's slow movement, contaminants such as lead cannot be quickly dispersed. They may become concentrated over time. This creates a problem if the contaminated groundwater is needed for drinking, agricultural purposes, or industrial use.

Factors that affect the movement of groundwater include the number and connection of pores in the soil. **Pores** are the tiny spaces between soil grains. Sometimes the soil grains are so tightly packed that the pores are not connected. In that case, water cannot move easily through the soil. If the pores are connected, water can flow through them. A **permeable** soil is one with interconnected pores. Pollutants will be transported farther by groundwater that flows through permeable soils.

The substances that contaminate groundwater occur either naturally or as a result of human activities. The table below gives examples of some of these contaminants.

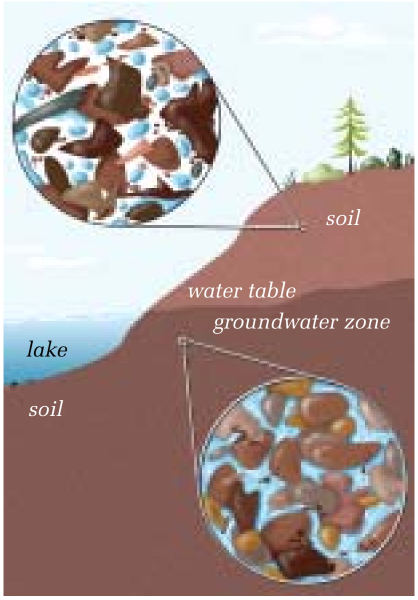

Figure 3.3 The water table is the top of the groundwater zone. Below the water table, all the pores in the soil are filled with water.

Some Substances That Contaminate Groundwater

Substance and Source	Examples
Minerals in rocks and soil	Iron, calcium, selenium
Organic substances occurring naturally or produced by humans	Pesticides, solvents, petroleum products
Substances leached from landfill sites and mine waste	Heavy metals (e.g., lead, mercury, cadmium), organic decomposition products
Substances that leak from underground storage tanks and pipelines	Gasoline, natural gas, oil
Inorganic substances from de-icing roads, agricultural and home use, industrial products, and vehicle exhausts	Salt, fertilizers, acidic deposition
Micro-organisms from improperly designed or maintained septic tanks and sewage treatment ponds, and improper storage and disposal of livestock wastes	Bacteria, viruses, protozoans
Household chemicals	Nitrates, phosphorus compounds, detergents, chlorine compounds

Activity C-9

Inquiry

Acid Rain and Soil

Materials & Equipment

- clay/loam potting soil
- sandy soil
- vinegar (diluted)
- graduated cylinder
- beakers
- funnel
- retort stand
- ring
- filter paper
- pH meter, chemical indicators, or pH paper

Before You Start

In this activity, you will use vinegar to simulate acid rain. The liquid that has passed through the soil is called **leachate**.

The Question

What effect does the type of soil have on an acidic solution that passes through it?

The Hypothesis

Restate the question above in the form of a hypothesis.

Procedure

1. In your notebook, draw a table like the one below to record your observations.

Sample	pH

2. Fold and place a filter paper in a funnel. (Hint: Dampen the paper with tap water and it will stay in place.) Put dampened clay/loam soil into the funnel and tamp it down gently.
3. Support the funnel in a ring attached to a retort stand. Place an empty beaker under the funnel.
4. Measure 20 mL of diluted vinegar into the second beaker. Measure and record the pH of the diluted vinegar.
5. Pour the vinegar into the soil and collect the leachate. Measure and record the pH of the leachate.
6. Repeat steps 2 to 5 using the sandy soil.

Figure 3.4 Step 5

Analyzing and Interpreting

7. Which type of soil allowed the liquids to pass through more easily? Explain why.
8. Was your hypothesis correct? Explain why or why not.

Forming Conclusions

9. Explain how the soil affected the pH of the leachate.

Applying and Connecting

The pH of soil is important for plants because certain nutrients are available to plants only within a specific pH range. For example, phosphorus availability is best between pH 6.0 and 7.0. Ground limestone (calcium carbonate) can be added to acidic soil to make it less acidic. Adding peat or sulfur to basic soil will make it less basic.

Extending

Design and carry out an experiment to answer this question: What amount of vinegar can pass through a soil sample before the neutralizing ability of the soil is reduced?

Transport in Surface Water

Potentially hazardous chemicals can enter surface water systems from many different sources. These include the air, groundwater, runoff from agricultural fields and industrial sites, and outflow from storm sewers and sewage treatment plants. Chemicals from these sources may not be a problem if their concentrations are very low. They can be dispersed and carried away by the water. However, they may become a problem if the chemicals do not disperse, and the concentrations increase locally.

A substance that dissolves easily in water may be carried a long way and dispersed by the water. Some substances do not dissolve easily, and they may become attached to solids such as soil grains. In that case, they will not travel as far as dissolved substances. Instead, they will sink and become concentrated closer to the source. Substances that become attached to solids can build up in lake or river bottoms, affecting the organisms that live there.

Understanding the transport of chemicals in surface water is important to communities that obtain their drinking water from rivers, lakes, or artificial lakes called reservoirs. People who live in these communities are very careful about protecting their water sources. The water quality is monitored continually. Any contamination is tracked to its source whenever possible and eliminated or reduced.

Transport in Soil

Water landing on a farmer's field or your front yard at home does four things:

- some evaporates
- some soaks into the soil and is taken up by plants
- some runs onto the street or into a stream
- some soaks through the soil and moves downward. As this water moves, it dissolves substances in the soil and carries them along. Such a liquid is called **leachate**.

The composition of soil can affect the rate at which a liquid moves through it. For example, you have learned in other science classes that water moves more easily through sand than through clay. Packed clay is impermeable—fluids cannot move through it because the soil grains are packed too closely. As you learned earlier in this unit, sanitary landfills are usually lined with a layer of impermeable clay. The clay prevents leachate containing harmful chemicals from moving into the soil and contaminating groundwater.

Some soils contain a large percentage of organic material, such as decayed leaves. This can slow the movement of chemicals if they are absorbed by the organic material. In some cases, the chemicals become attached to the soil particles, and their movement is slowed or stopped.

Hazardous materials can also be changed by chemical reactions that occur in the soil. For example, acids can be neutralized by substances such as calcium carbonate (limestone) in soil.

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Removing Phosphorus
Phosphorus compounds can be removed from sewage water. However, the technology is expensive. Its use must be weighed against the environmental damage that the phosphorus might cause. Using books or electronic resources, prepare a report about the removal of phosphorus from sewage discharges. Begin your information search at www.pearsoned.ca/scienceinaction.

Transport of Hydrocarbons in Soil

Contamination of soil by hydrocarbons is a problem at tens of thousands of sites across Canada. This contamination results from our daily use of hydrocarbons in vehicles and in industry, and from the extraction of hydrocarbons.

Some hydrocarbons are carried by water in the soil and can spread over a wide area. Others do not dissolve in water. These non-dissolving types of hydrocarbons may coat soil grains and completely fill the pores between the grains. This type of contamination does not spread very far from its source but is very difficult to clean up. It also creates high local concentrations of hydrocarbons. Most hydrocarbons are toxic to plants and animals (including humans).

Check and Reflect

Key Concept Review

1. State three reasons why an airborne pollutant might be deposited close to its source.
2. Suggest two ways that chemical pollutants could be carried far from their sources.
3. List four things that could happen to the water used in watering a local golf course.
4. Explain why airborne and water-borne chemicals are both local and global issues.

Connect Your Understanding

5. Lead from a car battery has been detected in a lake far from where the battery was discarded and buried. How did the lead get there?
6. Explain how soil can affect the composition of the solutions that move through it.
7. Match the pollutant in column A with its possible source in column B.

A	B
oil	rocks
acid rain	home gardening
bacteria	landfill
calcium	vehicle exhaust
leachate	sewage
pesticide	pipeline leak

Extend Your Understanding

8. One water well is located in sandy soil. Another water well is in soil that is mainly clay. Which well should be monitored more often? Why?
9. Many communities in Canada take their drinking water from rivers, lakes, or reservoirs. Why do they need to understand how chemicals are transported in surface water?

3.2 Changing the Concentration of Harmful Chemicals in the Environment

The best way to keep the environment safe is to prevent potentially harmful substances from entering it. However, this isn't always practical because most human activities introduce potentially harmful chemicals into the environment.

The concentration of pollutants in the environment can be changed using different techniques. The examples discussed here are: dispersion, dilution, biodegradation, phytoremediation, and photolysis.

Dispersion is the scattering of a substance away from its source. For example, suppose you are fertilizing your lawn and spill too much fertilizer in one spot. To prevent damage to the lawn in that spot, you could spread the fertilizer out over a larger area. In doing this, you would be dispersing the chemical.

Dilution reduces the concentration of a pollutant by mixing the polluting substance with large quantities of air or water. For example, if you place one drop of bleach into a sink full of water, the molecules of the bleach will mix with the molecules of water, and the bleach will be diluted.

A fast-flowing river or air mass can disperse and dilute a chemical very quickly. However, dispersion and dilution may not leave an area clean enough to meet government standards for clean water or air. Dilution or dispersion combined with another clean-up process, such as biodegradation, may be more effective.

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Biodegradation of a Chemical

A site in Sarnia, Ontario, was contaminated with an organic chemical called ethylbenzene. Approximately 400 t of clay soil were dug up and placed in piles, and micro-organisms were added to the piles of soil. Within five months, concentrations of ethylbenzene dropped from 434 ppm to 25 ppm.

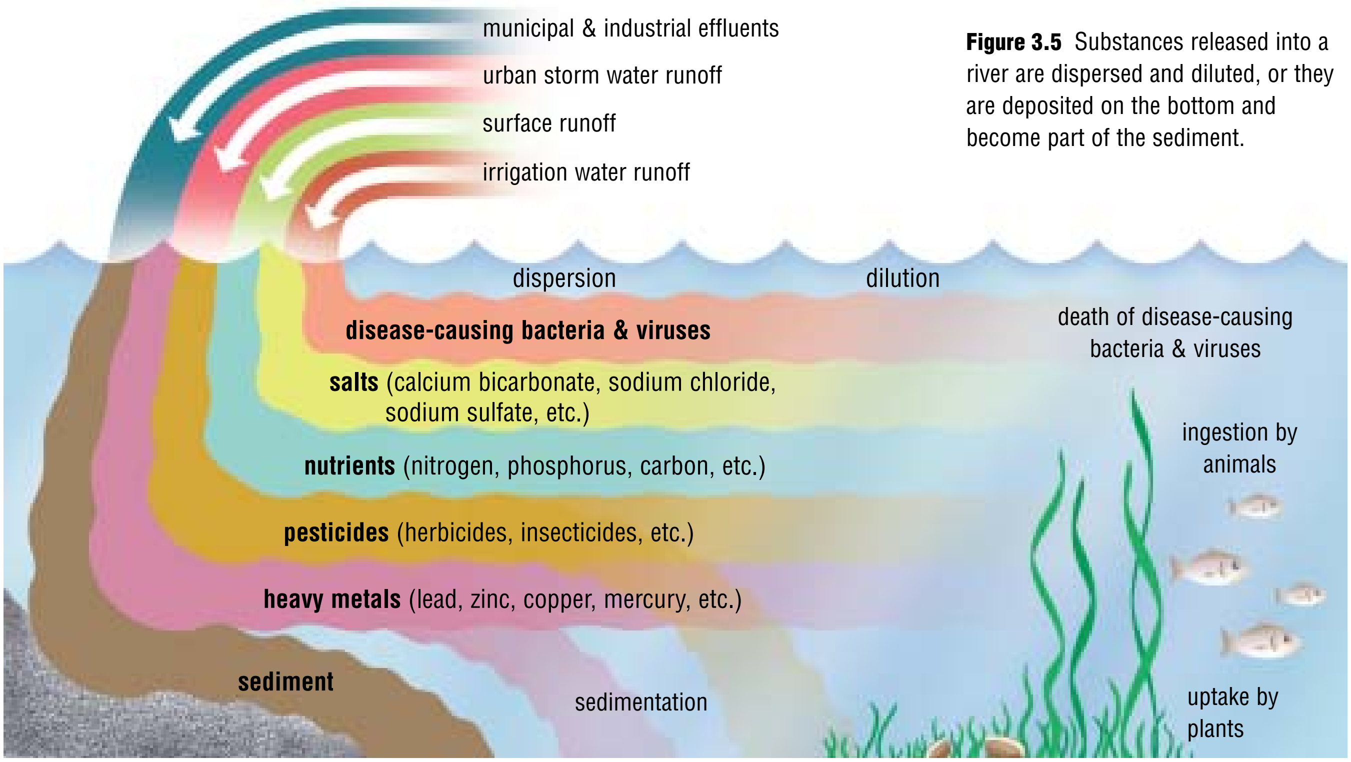

Figure 3.5 Substances released into a river are dispersed and diluted, or they are deposited on the bottom and become part of the sediment.

Biodegradation

Nature uses living things to clean the environment. Every autumn, leaves fall but they do not build up year after year because some of them decompose and become part of the soil. Organisms such as earthworms, bacteria, and fungi help the **biodegradation** of most organic substances, including many pollutants. "Bio" refers to living things and "degrade" means to break up.

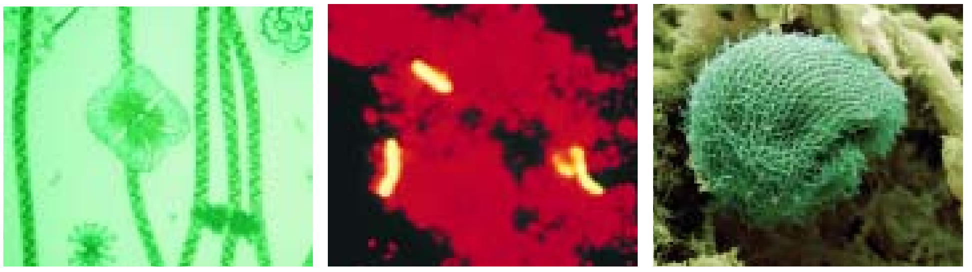

Figure 3.6 Micro-organisms that live in or on the soil and water can be important in the biodegradation of pollutants. Left to right: algae, bacteria, a protozoan.

Micro-organisms are especially important in the biodegradation of pollutants. Many different types of micro-organisms live in soil and water. Algae, bacteria, fungi, and protozoa are common. Algae live at the soil surface and can produce their own organic compounds for food by photosynthesis. Bacteria, fungi, and protozoa use existing organic compounds for food. Carbon atoms in these molecules can be used to build biological compounds such as carbohydrates and protein.

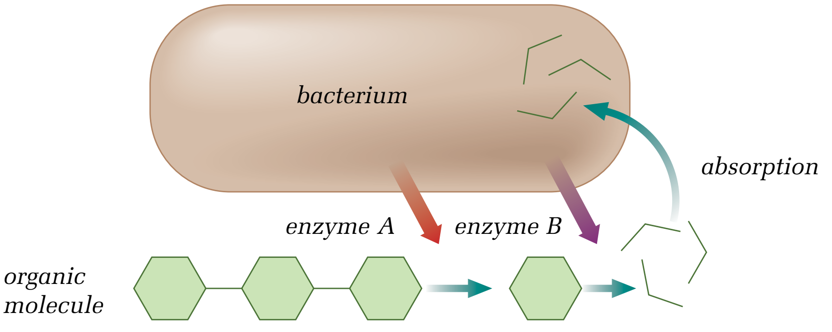

Figure 3.7 Large organic molecules are broken down (hydrolyzed) either inside or outside bacteria. The decomposition process usually involves several steps.

Bacteria

Each organism needs specific conditions to grow and reproduce. Some bacteria grow and reproduce only when oxygen is present. They use oxygen for the process of **aerobic** biodegradation ("aero-" means "air"). Some bacteria need an **anaerobic** environment—one without oxygen ("an-" means "without"). They thrive where there is little or no oxygen; for example, deep within landfill sites.

Some types of anaerobic bacteria remove chlorine from harmful chlorine-containing compounds such as PCBs (polychlorinated biphenyls). PCBs are human-made oils used in electrical equipment. These bacteria are able to remove chlorine atoms from the pollutant's molecules and replace them with hydrogen atoms. The molecules can then be used as food for the bacteria. In this way, some harmful pollutants are removed from the environment.

ACTIVITY C-10

Inquiry

BURY YOUR GARBAGE

Before You Start

Each group in the class will select one variable to investigate and present their findings to the class.

Materials & Equipment

- soil
- large clear plastic party glasses
- apple pieces or other easily biodegradable material
- refrigerator for 1b)
- other waste material for 1d) (e.g., potato, paper, metal, plastic, cotton, nylon)
- balance
- ruler
- water
- sticks for markers

Figure 3.8 Set-up for investigating factors that affect biodegradation

The Question

What effects do the following factors have on the rate of biodegradation of substances: moisture, temperature, surface area of pieces, type of waste?

Procedure

1 Your group will investigate one of the following questions:

a) What is the effect of moisture on the rate of biodegradation?

b) What is the effect of temperature on the rate of biodegradation?

c) What is the effect of the size of garbage pieces on the rate of biodegradation?

d) What is the effect of the type of garbage on the rate of biodegradation?

2 Controlling variables is important. As a class, determine the following before you begin:

- size of the apple pieces
- number of apple pieces
- number of pieces of other types of garbage (for 1d) only)
- amount of soil
- amount of water that will be used to keep the soil moist
- temperature of the set-up
- location of the set-up
- amount of time allowed for biodegradation
- type of data to be collected before and after the apple pieces are buried

3 Record the following:

- the question from step 1 that you will be investigating
- the manipulated, responding, and controlled variables in your investigation
- your hypothesis

4 With your group, plan your procedure and prepare a data table to record your group's observations. Show your procedure and data table to your teacher for approval before you begin. Carry out your experiment.

5 Prepare a data table to record the class results.

Analyzing and Interpreting

6 Was your hypothesis correct? Explain why or why not.

7 What effect did the manipulated variable have on the rate of biodegradation in your investigation? Suggest reasons for this.

8 Present your data and your interpretation of this data to the class.

9 Did any other group in the class use the same variables as your group did? Were your group's results the same as theirs? Suggest reasons why or why not.

Forming Conclusions

10 Write a summary of the results of your class's investigations. In your summary, describe the effect that the manipulated variables have on the rate of biodegradation. Suggest reasons for the class results.

reSEARCH

Pollution Clean-Up
Using books or electronic resources, find and describe a situation where either biodegradation or phytoremediation has been successfully used to solve a pollution problem. Begin your search at www.pearsoned.ca/scienceinaction.

Factors Affecting Biodegradation

In Canada, little bacterial growth occurs in the cold winter months, so biodegradation is very slow then, if it occurs at all. Temperature is just one factor that affects the rate of biodegradation. Other factors are soil moisture, pH, oxygen supply, and nutrient availability.

Bioreactor technology is a developing technology based on a knowledge of the effects of these factors. Bioreactors are designed to speed up the decomposition of organic wastes such as food and paper in municipal landfills. Liquids are added to the landfill to create ideal conditions for micro-organisms that decompose organic waste. Under these conditions, biodegradation occurs much more quickly.

Another method of encouraging biodegradation in soil involves planting vegetation. Bacteria and fungi occur in larger numbers in soil that contains plants than they do in soil without plants. The bacteria and fungi live around the roots of the plants. This greater microbial activity may increase the biodegradation of hazardous materials.

Phytoremediation

Green plants can also be used in another way to remove or degrade hazardous materials. **Phytoremediation** is a technique that can be used to reduce the concentration of harmful chemicals in soil or groundwater. "Phyto" means plant and "remediation" means correction or cure. Plants have been used to clean up metals, hydrocarbons, solvents, pesticides, radioactive materials, explosives, and landfill leachates. Some plants can absorb and accumulate (build up) unusually large amounts of metals from the soil. The plants are allowed to grow for some time and then harvested and burned or composted. In some cases, the metal can be recycled. Once the plants used for phytoremediation have "cleaned" the soil, other plants can be planted there.

Figure 3.9 Sunflowers have been used at Chernobyl to remove radioactive substances from groundwater.

Photolysis

Some substances degrade from exposure to light. **Photolysis** is the breakdown (lysis) of compounds by sunlight (photo). An example of photolysis is the formation of ozone. Nitrogen dioxide in the presence of light breaks down to form nitrogen monoxide and an oxygen atom. The oxygen atom then combines with an oxygen molecule to form ozone.

$$NO_{2(g)} \rightarrow NO_{(g)} + O_{(g)}$$

nitrogen dioxide → nitrogen monoxide + oxygen atom

$$O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$$

oxygen atom + oxygen molecule → ozone

Another example of photolysis is photodegradable plastic. Ordinary plastic does not degrade easily and can last for hundreds of years. Photodegradable plastic is made of chemicals that react when exposed to sunlight. After about three months, these reactions have changed the plastic to a fine powder that is easier to dispose of than the original plastic objects. The problem with photodegradable plastic is that it will not decompose if it's buried or placed anywhere else that sunlight cannot reach it.

Check and Reflect

Key Concept Review

1. List five ways of reducing the concentration of pollutants in the environment.
2. What element do bacteria remove from a PCB molecule?
3. How do micro-organisms change large organic molecules to forms that can be absorbed and used inside the cell?
4. Define and give an example of photolysis.
5. Cattails in swamps are used to absorb chemical pollutants. What method of reducing pollutant concentration is this?

Connect Your Understanding

6. Would you rather live in an aerobic environment or an anaerobic one? Explain your answer.
7. Will a potato decay faster in warm soil or cold soil? Give a reason for your answer.
8. Are dispersion and dilution the same process? Explain.

Extend Your Understanding

9. a) Suppose there was an oil spill in soil in a remote section of southern Canada. What would you suggest as an effective clean-up method? Give a reason for your answer.
   b) Suppose the oil spill were in a sandy soil near a community water supply. What would you suggest as an effective clean-up method in this case?
10. Write the procedure for an experiment that would show the effect of pH on the rate of biodegradation of waste material.

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Lead in the Environment
The City of Calgary issued a press release on May 17, 2001, stating that environmental monitoring results indicated that lead levels in surface soil in the Lynnview Ridge area were above the current environmental guidelines. Precautions were recommended. Lead can damage the kidneys, the nervous system, and the reproductive system. It is especially damaging to young children and fetuses.

3.3 Hazardous Chemicals Affect Living Things

So far in this unit, you have learned how chemicals can enter the environment, move through it, and be taken into organisms. You have also learned how harmful chemicals can be concentrated in the environment. For example, they can become concentrated in soil and river or lake bottoms. They can also accumulate in plants through uptake of water and nutrients. This increase in concentration means that some chemicals may remain in the environment for long periods. This also makes it possible for some chemicals to increase in concentration as they move up the food chain.

Biomagnification

Biomagnification is the increase in concentration of a chemical or element as it moves up the food chain. A good example is mercury. Figure 3.10 shows what happens when mercury is introduced into the environment. The mercury comes from emissions from coal-fired power plants, waste incinerators, and commercial boilers and furnaces that burn mercury-containing materials. The mercury falls onto fresh or salt water where bacteria join it to an organic molecule that algae can absorb. Any one algal organism isn't affected by the mercury because it takes in very little.

At this point, the mercury enters the food chain when the algae are eaten by invertebrates such as insects. The mercury concentration is low in the algae because it is spread over many of them. But an insect has to eat many algae to survive. The insect is eaten by a fish, which has to eat many insects to survive. If these insects contain mercury, then the fish takes in a large quantity of mercury, which it stores in its body tissues. The fish may be affected by this concentration of mercury. Then you and your family catch several fish and eat them. If you eat enough of these mercury-contaminated fish, you may become ill. Mercury-contaminated fish have been a problem in parts of Canada, such as the Great Lakes.

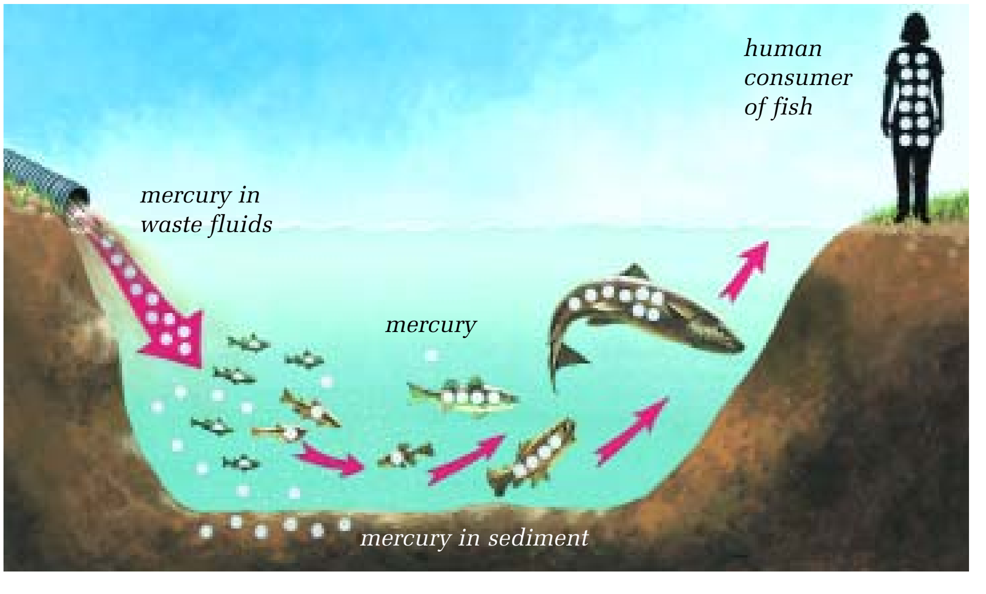

Figure 3.10 Mercury can enter water systems in two ways. One way is from the air as a result of emissions from industrial plants. Another way is from industrial waste fluids, as shown here. Once in the water, the mercury increases in concentration as it moves up the food chain.

ACTIVITY C-11

Decision Making

MOSQUITO CONTROL

The Issue

In the spring, you look forward to playing baseball and having picnics in the park. To make your time outside more enjoyable, your city or town may use insecticides to kill mosquitoes. This cuts down or destroys the mosquito population so you don't have to be bothered by itchy bites. But such chemicals can harm other organisms in the environment. Should municipalities use insecticides to kill mosquitoes?

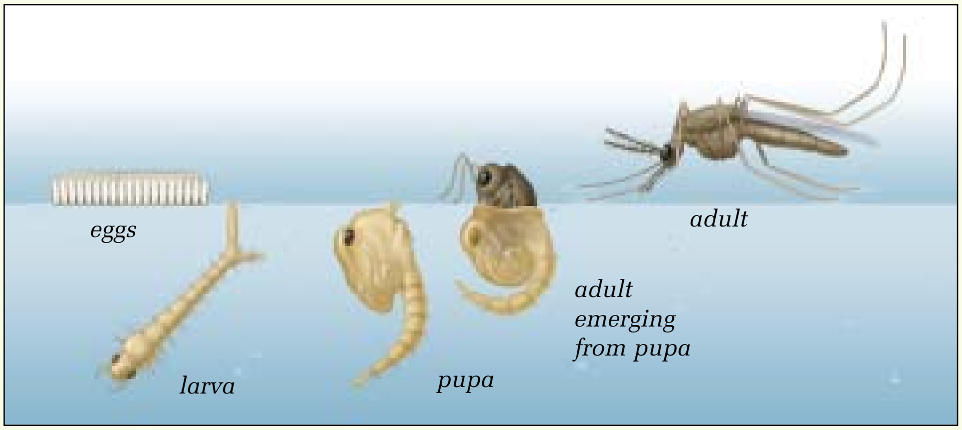

Figure 3.11 Life cycle of the mosquito. Communities can monitor the mosquito larvae population in local water systems to gain useful information for deciding on a springtime insecticide program.

Background Information

1 Every time an insecticide is used, it introduces chemicals into the local environment. These chemicals are carefully regulated (controlled by the government) to make sure they do as little damage as possible to the environment. However, an insecticide used to control mosquitoes may kill other species of insects as well, including those that eat mosquitoes.

2 Working with your group, research the benefits and costs of controlling mosquitoes with insecticides. Begin your search at www.pearsoned.ca/scienceinaction. Consider the following:

a) the effect of mosquito populations on people's activities

b) the potential for disease transmission by mosquitoes

c) the effect of insecticides on other species besides mosquitoes. Remember to include effects on other members of the food web.

d) alternative methods of mosquito control not using insecticides

Analyze and Evaluate

3 With your group, design a presentation to summarize your group's findings. Be prepared to share your group's findings with the rest of the class.

4 Do you think insecticides should be used to control mosquitoes in your community? Give reasons to support your opinion.

A Case Study: The *Exxon Valdez* Oil Spill

Figure 3.12 Prince William Sound is on the south coast of Alaska.

Some chemicals in the environment have immediate short-term effects on organisms (for example, when a herbicide kills a weed). Some have longer-term effects through concentration and accumulation (for example, biomagnification of mercury). You will now have an opportunity to consider a case study of a chemical spill that had both short- and long-term consequences: the oil spill from the tanker ship *Exxon Valdez*.

In 1989, the *Exxon Valdez* went aground in Prince William Sound on the southern coast of Alaska. This huge tanker was carrying crude oil from Alaska to a refinery farther south on the west coast of the United States.

Crude Oil

Crude oil is a mixture of many chemicals. It contains hundreds of different molecules in all shapes and sizes. For example, paraffin wax and asphalt are very large hydrocarbon molecules. Methane is a small one. Some molecules in crude oil contain atoms of nitrogen, oxygen, and sulfur. Metals such as mercury and lead may also be present. Crude oil cannot be used as soon as it is pumped from the ground—it must be processed in an oil refinery. There, it is heated and the chemical components are separated as they cool.

Crude Oil Spills

Accidents happen. Loaded tanker ships can be accidentally driven onto reefs or rocky shores. Hazardous chemicals can change a beautiful setting. The beautiful setting of Prince William Sound changed when the *Exxon Valdez* spilled approximately 260 000 barrels (41 337 m^3) of crude oil into the sound.

The composition of oil changes after it is spilled. The lighter and smaller molecules disperse into the air or water. "Tar balls" of heavy hydrocarbons are washed ashore or sink into the sediment below the water. Bacteria are able to degrade some of this oil for use as food.

Long-term studies of oil spills, such as the one in Prince William Sound, have increased our knowledge of the impact of oil on the environment. It has been shown that some hydrocarbons are toxic in concentrations as low as 1 ppb, and that oil can persist in the environment for more than 10 years.

Impact of the Oil Spill on the Environment

Oil from the *Exxon Valdez* spill covered thousands of square kilometres of water and polluted hundreds of kilometres of shoreline. A study done in 1992 estimated that 2% of the oil made it to shore. Most of it evaporated or dispersed into water. Ten years after the spill, bacteria and light had broken down much of the oil.

Figure 3.13 The *Exxon Valdez* was a large oil tanker. Thousands of such tankers sail all over the world.

Impact of the Oil Spill on Plants and Animals

Many different types of organisms were affected by the *Exxon Valdez* oil spill. Floating algae were killed. Invertebrates near shore could not survive the decreased oxygen, loss of food, and the toxic effect of the hydrocarbons. Fish eggs and young fish were especially sensitive to the toxic chemicals in oil. Pacific herring and pink salmon fry died or were physically deformed. Adult fish could avoid the oil by swimming away, but they lost habitat and food resources.

Seabirds and mammals became covered with oil. Oily feathers could not protect birds, and oily fur could not protect mammals such as sea otters from cold temperatures. It is estimated that over 30 000 birds and 5000 sea otters died because of the oil spill.

Figure 3.14 Some oil-covered birds and animals were rescued and cleaned but many others died of the oil's effects.

Impact of the Oil Spill on People

The *Exxon Valdez* oil spill also affected people who lived in the area. Many were commercial fishers, and now they could no longer fish. People who relied on wildlife for their food had to purchase more expensive groceries from stores. The tourist trade decreased dramatically as recreational users (campers and kayakers) chose not to come to the contaminated area.

Clean-up and Restoration of Prince William Sound

Figure 3.15 shows that 14% of the oil was recovered. This was done by using skimming systems and containment booms. However, 10 years after the spill, oil still remained on some of the beaches.

Soon after the oil spill, the sediment near parts of the shoreline was removed and replaced with clean sediment. Those areas have recovered better than areas where the sediment was left in place.

Some birds and mammals were washed and kept in captivity for several days before being released. Most of these survived.

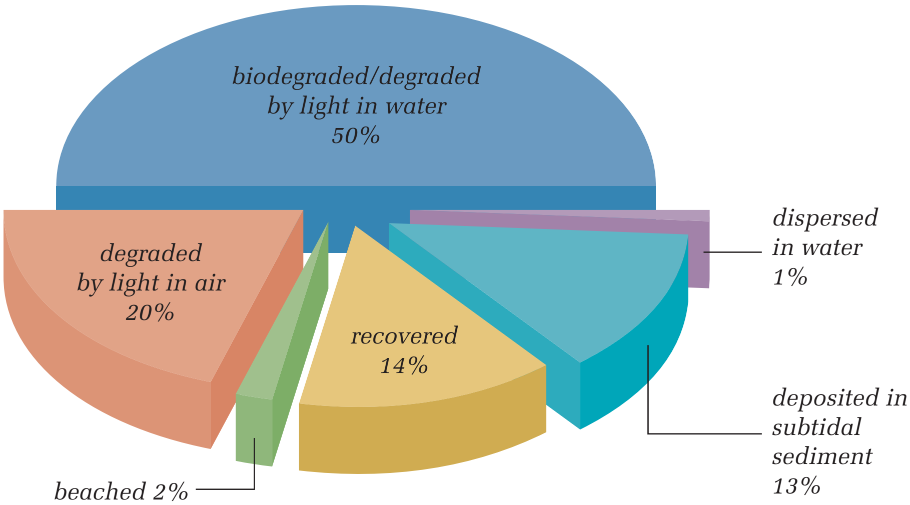

Figure 3.15 This chart shows what happened to the spilled oil.

reSEARCH

Hazardous Chemicals

Select a hazardous chemical mentioned in this section or one approved by your teacher. Find out more about it by using books or electronic resources. Determine possible sources of the chemical, its effects on people and the environment, and how it can be removed or prevented from entering the environment. Prepare a multimedia presentation for the class about the chemical. Begin your search at www.pearsoned.ca/scienceinaction.

New Oil Spill Clean-up Procedures

Oil spills and leaks can happen on land as well as on the ocean. Pipelines can rust and leak. Tanker trucks can spill their loads. Oil wells can blow out. Storage tanks can spill or leak. Since the large spill in Prince William Sound, government regulations have changed and new procedures have been put in place to deal more effectively with future spills.

In Alberta, companies are required to report spills greater than 2 m^3. Companies and governments have emergency response plans in place. Hands-on training for people working with oil and gas takes place yearly. These training sessions demonstrate effective techniques for controlling and cleaning up spills.

Figure 3.16 Booms can be used to contain oil spills and help with clean-up.

Check and Reflect

Key Concept Review

1. Use an example to explain the term "biomagnification."
2. List five ways that the *Exxon Valdez* oil spill affected Prince William Sound.
3. a) Look at Figure 3.15 on page 251. What percent of the oil was degraded by light after evaporating into the air?
   b) What percent of the oil reached the shores in Prince William Sound?

Connect Your Understanding

4. Describe two ways that chemicals can become concentrated or build up in the environment.
5. Explain why using pesticides to kill mosquitoes has become an issue.
6. Suggest two reasons why some chemicals remain unchanged in the environment for a long time.

Extend Your Understanding

7. Imagine that you are a newspaper reporter summarizing the *Exxon Valdez* oil spill. Write your report using the following headings:
   - what happened
   - the results
   - the clean-up
   - the after-effects (e.g., technology, government regulations)

3.4 Hazardous Household Chemicals

Housecleaning and gardening can be hazardous to your health. Products that we purchase for use in housecleaning, home improvement, gardening, and car maintenance may contain chemicals that could harm us or the environment. Hazardous household chemicals include:

- household cleaners
- personal hygiene products
- pet-care products
- paint and paint products
- pesticides and fertilizers
- automotive fluids

Estimates indicate that the average North American house contains between 12 L and 40 L of hazardous products. Improper transport, storage, and disposal of these products can contribute to health problems such as burns, heart, kidney, and lung ailments, cancer, and even death. We can use these products safely by paying attention to the information on labels and in fact sheets about them.

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Dishwasher Detergents

Poison control centres report that dishwasher detergents are the number one cause of child poisonings. Many dishwasher detergents contain very concentrated chlorine in a dry form.

Government Regulations

TOOLBOX

Government regulations are designed to protect consumers and reduce the risks of transporting, storing, using, and disposing of hazardous materials. The regulations reflect the information available from scientific research done on these products. Such research considers not only the effects of a product alone, but also its interactions with other products. The regulations are reviewed and modified when scientific research provides new information.

As students working in a school, you must be familiar with the **Workplace Hazardous Materials Information System (WHMIS)**, set up by the federal government. WHMIS provides information on hazardous materials used in the workplace. Anyone who works with or must be near hazardous products must be familiar with WHMIS symbols and labelling, and with **Material Safety Data Sheets (MSDSs)**.

Labels

If a potentially hazardous chemical is being transported, stored, or used, it must be labelled to alert workers to the dangers of the product and to provide basic safety precautions. There are different labels for different purposes: transport, supply, use in the workplace, and disposal. As students, you will be reading workplace labels that will include the name of the chemical and information on safe handling.

The labels on goods that you buy in a store for home use are covered by regulations as well. Figure 3.17, on the next page, is an example of a consumer goods label. You have seen WHMIS labels in earlier studies. For more information on WHMIS and other hazardous products labels, see Toolbox 1.

GIVE IT A **TRY**

USING A HAZARDOUS PRODUCT

Suppose that you have been hired by your neighbours to apply wood preservative to a fence that surrounds their property. A vegetable garden is close to the fence, and a small stream runs near the fence at the back. Wood preservatives contain fungicides that protect wood from destruction by fungus (mildew) and insects. The wood preservative you will use is an arsenic compound that can be harmful to humans and other organisms, both on land and in the water. Figure 3.17 shows the information provided by the manufacturer on the product's label.

Use Limitations
- Use on exterior surfaces only.
- Use only above ground.
- Keep away from water systems since product is toxic to fish.

Directions for Use
- Be sure to have a clean dry surface before you apply this product.
- Use a brush to apply. Do not spray.
- Use full strength. Do not dilute.

Precautions
- Avoid breathing vapours.
- Keep away from open flames or sparks.
- Avoid skin contact.
- Wash with soap and water after using this product.

First Aid
- If swallowed do not induce vomiting. Call a doctor or a poison centre immediately.
- If spilled on skin, wash with vegetable oil followed by soap and water.
- If splashed in eyes, flush eyes with water for 15 minutes.

Figure 3.17 Information about the wood preservative

- What clothing would you wear while applying the wood preservative?
- What tools and materials would you need for the job?
- List four precautions you would take while using the preservative.
- Suppose that several years after you put the preservative on the fence, your neighbours decide that they don't need all of the fence. They plan to burn the unwanted wood in their fire pit where they have wiener roasts. What advice would you give them?

MSDS

All suppliers of potentially hazardous materials will provide the buyer with additional information about their products. This information is found in a Material Safety Data Sheet (MSDS). The MSDS gives a detailed description of the product—its composition, physical appearance, and chemical characteristics. The MSDS also describes the precautions that should be taken when handling, using, transporting, and disposing of the product. And it provides details of health effects, first aid treatments, and spill procedures. You should know where the binder containing the MSDSs is kept in your school.

New Product Regulations

Certain types of products, such as pesticides, require government approval before they can be sold. Companies applying for product approval must follow a strict testing process according to government legislation. They must also provide detailed information that includes:

- intended use, physical and chemical properties, active ingredient(s)
- instructions for use, safety precautions
- health effects, environmental effects, toxicity to humans, and first aid instructions in case of poisoning

Figure 3.18 Examples of hazardous household chemicals

Storage of Hazardous Chemicals

The safe storage and use of chemicals prevent accidents and injury. Here are some safe storage suggestions:

- Leave all products in their original containers with the label intact.
- Keep all products in a location not accessible to children. If possible, keep hazardous products locked up.
- Be sure all containers are in good condition and have secure lids.
- Store products in a cool, dry, ventilated place away from pilot lights, stoves, and water heaters. If you can smell a household product that is in storage, the lid may be loose or ventilation may not be adequate.
- Never store flammable liquids and gases in glass containers—they might break. Store gasoline in a metal container with a safety cap, or a red plastic container approved for use with gasoline. Keep it outside the house in a storage shed. Never store propane inside the house because a leak can cause an explosion.
- Store corrosive, flammable, reactive, and poisonous products on separate shelves or in separate locations. Toilet and drain cleaners are examples of corrosive substances. Keep acids and bases separate from each other.
- Do not store oxidizers such as hydrogen peroxide, pool chemicals, and some fertilizers near flammable liquids. Oxidizers can cause other substances to burn.
- Place products in their storage areas so that they cannot fall over.
- Always return a hazardous product to its storage place when you have finished using it.
- Safely discard hazardous substances that are old or not needed.
- If a container is rusting or leaking, place it inside a second, secure container. Dispose of both containers together at a household hazardous waste collection site.

ACTIVITY C-12

Inquiry

HOUSEHOLD CHEMICALS AND THE ENVIRONMENT

The Question

What effect do household chemicals have on the germination of radish seeds?

The Hypothesis

Reword the question in the form of a hypothesis.

Materials & Equipment

- 10% and 50% solutions of household bleach
- 10% and 50% solutions of window cleaner containing ammonia
- 10% and 50% solutions of rubbing alcohol
- water
- graduated cylinder
- 4 small plastic bags
- marking pen
- 4 paper towels
- 20 radish seeds
- thumbtacks, pins, or tape

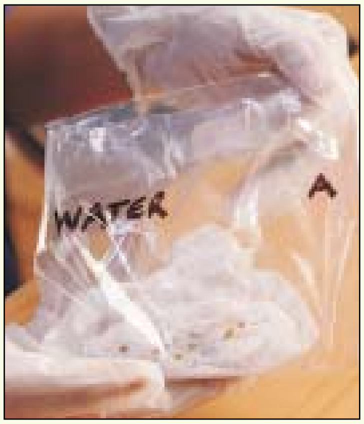


Figure 3.19 Determining the effect of household chemicals on radish seeds

Caution!
Handle bleach, window cleaner, and rubbing alcohol very carefully. Bleach is corrosive. It can also take the colour out of your clothes.

Procedure

1. Using a marking pen, label 4 small plastic bags: one each for water, bleach, ammonia, and rubbing alcohol. Place your name or group symbol on each bag.
2. Crumple a paper towel and place it in the bag labelled "water."
3. Place 10 mL of water in the labelled bag. If that is not enough to moisten the paper towel, add more water. (The bottom of the bag should have a little extra water in it.)
4. Put 5 radish seeds into the bag. Place them between the plastic and the paper towel so that you will be able to see the seeds easily.
5. Repeat this procedure with one concentration of each household product. (Another group will use the other concentration.) Be sure to use the same amount of liquid in each bag.
6. Using tacks, pins, or tape, attach the bags to a bulletin board.
7. At the end of 5 days, count and record the number of seeds that have germinated in each bag.
8. Obtain the data for all the household products from other groups in the class.
9. Follow your teacher's instructions for disposing of all substances you have used.

Analyzing and Interpreting

10 Why did one bag contain only water?

11 Which product had the greatest effect on the radish seeds?

12 Did different concentrations of the same product affect the radish seeds differently? Explain your answer.

Forming Conclusions

13 Describe the effect of household chemicals on radish seeds.

Transportation of Consumer Goods

There are two times when you or your family transport hazardous household materials:

- when the product is first bought
- when the unused portion of the product or the waste from it is taken to a hazardous waste collection site

In both cases, care should be taken to protect people in the vehicle from toxic fumes or spills from the containers. At all times, hazardous products should be kept out of the reach of children and family pets.

The hazardous materials should be placed in the trunk of the car or the box of the truck. Care must be taken that the containers stand upright and do not move.

When transporting hazardous household wastes to a collection site, never mix them together in one container. Mixing chemicals may cause a chemical reaction that results in an explosion or a poisonous product. The products should be left in their original containers with the labels intact so that the people at the collection site know how to process them.

Disposal of Hazardous Chemicals

Never pour hazardous wastes down a drain or into soil. And never throw them away in the garbage. Hazardous wastes poured down a drain go into public sewer systems or septic tanks.

Occasionally, sewage treatment processes are not effective in removing some hazardous chemicals. If that happens, the chemicals are accidentally released to surface water. There they may harm aquatic organisms or end up in someone's drinking water. In a septic system, hazardous substances may harm the organisms that break down wastes. As a result, the system won't function properly, and pollutants may pass unchanged into the surrounding soil and water.

Disposing of hazardous household products by pouring them into the soil or putting them in the solid waste garbage can contribute to contamination of drinking water, soil, and even air.

Hazardous Waste Collection Sites

Hazardous waste collection sites can be found in almost all Alberta communities. Wastes such as paints and fertilizers can be taken to these sites for disposal. Materials that cannot be recycled are safely packaged into larger containers. They are then labelled according to government regulations, and transported in labelled trucks with trained drivers to incineration plants.

Figure 3.20 A hazardous waste collection site

Solid Waste Garbage

Solid waste—what we usually call garbage—goes to a landfill site (unless it can be recycled). At the landfill site, some garbage may burn, explode, give off fumes, or be leached out. Leachate could potentially enter groundwater if it escapes from the protective plastic or clay liners of the landfill site.

Before you put something into the garbage, think about the following guidelines for safe disposal of household hazardous products:

- Take antifreeze to a recycling centre if one exists in your community. If recycling is not possible, dilute antifreeze well before pouring it down a drain connected to a sewage system. Seal the empty container before putting it into the garbage. Never pour antifreeze on the ground or down a drain connected to a septic tank.
- Take automotive products such as gasoline and oil to a hazardous waste collection centre. Oil can be recycled.
- Never place car batteries in a home garbage because they usually contain lead and sulfuric acid. Batteries can be recycled.
- Use up bleach according to directions on the container. Never pour it down drains because it might mix with acids or ammonia and create fatal toxic fumes.
- Use up cleaners and polishes. The empty containers should then be sealed before being thrown in the garbage.
- Use up corrosive products such as drain cleaners completely according to the directions on the container. Dilute very small amounts of drain cleaners in large quantities of water so that it is safe to pour the diluted mixture down the drain.
- Take fertilizers and pesticides to a hazardous waste collection site.
- Take leftover paint and paint products such as paint thinners, turpentine, and varnish to collection sites where they may be recycled. For empty paint cans, remove the lids so the remaining paint will dry before you put the cans in the garbage.
- Pack syringes in rigid containers and take them to collection sites.
- Empty aerosol containers completely so that they will not explode in the garbage. In a well-ventilated area, turn the container upside down with the nozzle facing a paper towel or other absorbent material. Depress the nozzle until the spray loses pressure.

Figure 3.21 How to empty an aerosol can before placing it in the garbage

*re*SEARCH

Household Hazardous Material

Select a household hazardous material for study and use labels, books, personal interviews, and electronic resources to find out more about it. Look for the following information: active chemical ingredient(s), instructions for use, first aid suggestions, safe storage ideas, and disposal of leftover product or containers. Create an information poster about the material. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. List five household chemicals that have the potential to be harmful.
2. What is WHMIS and why was it set up by the government?
3. List five ways you can prevent accidents when using or storing hazardous household chemicals.
4. Explain how the following products should be stored:
   a) gasoline
   b) toilet cleaner
   c) bleach

Connect Your Understanding

5. Sodium hydroxide solution (pH 10.3) is used in school experiments. Explain the proper way to:
   a) handle it
   b) store it
   c) dispose of it
6. Explain two reasons why it is important to take leftover fertilizers and pesticides to collection sites.
7. Use the product label in Figure 3.22 to answer the following questions:
   a) What does the warning symbol represent?
   b) What are the names of the active ingredients?
   c) What is the intended use of this product?
   d) Describe the directions that must be followed before and during use.
   e) How can this product enter your body?
   f) Why should this product be kept away from ponds and streams?

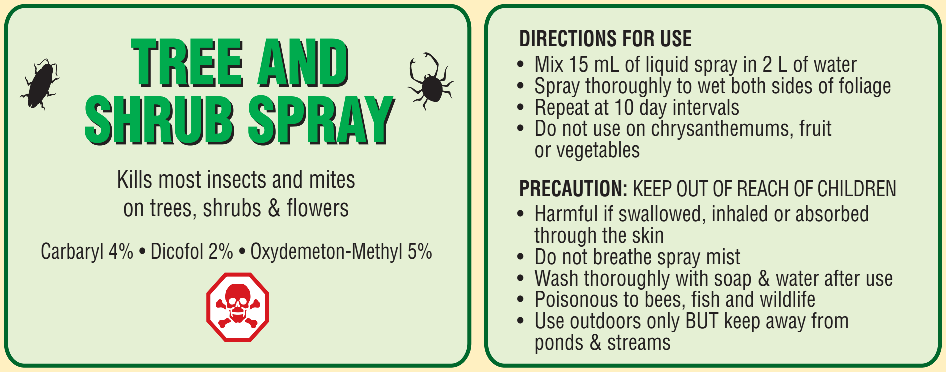


Figure 3.22 Product label for question 7

Extend Your Understanding

8. You are helping to clean the garage, and you come across a substance in an old container without a label. Your brother suggests dumping it down the drain.
   a) Why is this not a good practice?
   b) What is a safer method of disposal?

Section Review

Assess Your Learning

Key Concept Review

1. Why is it important for pollution chemists to know about prevailing winds?

2. Match the words in column A with their synonyms or definitions in column B.

Column A	Column B
dispersion	degradation caused by light
dilution	scattering
biodegradation	break up by living things
photolysis	reduction in concentration

3 Why should an aerosol container be completely emptied before it is discarded?

4. You have designed a new insecticide. In order for your new insecticide to be sold to the public, what information would be required by government regulations?

5. Describe three factors that affect biodegradation.

Connect Your Understanding

6. Explain why you must be very careful when storing oxidizers such as hydrogen peroxide.

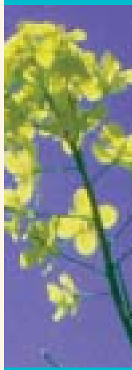
7. Why is it bad practice to throw household chemicals such as bleach on garden soil?

8 Look at Figure 3.23. Some hazardous household products are being transported in an unsafe manner. List as many things as you can that are wrong or unsafe in this picture. Then suggest better, safer ways to transport or handle these products.

Figure 3.23 Question 8

9. Why is it important that chemicals used in the classroom be labelled?

10. What types of information are found on MSDS documents?



Extend Your Understanding

11. Choose two of the substances listed below and write a paragraph or draw a series of pictures to show how each affects living things.
nitrogen compounds
mercury
oil
selenium

12. An old gasoline storage depot is torn down, and the land is used for a children's playground. Later, it is discovered that the soil in the playground is contaminated with lead. What clean-up program would you suggest to the town?

13. Suppose that you have just finished using a poisonous zinc solution to preserve a wood deck.
a) How would you dispose of the leftover product and the tools that you used? Are there any risks in the method that you chose?
b) If the leftover product were going to be stored, how and where would you suggest storing it?

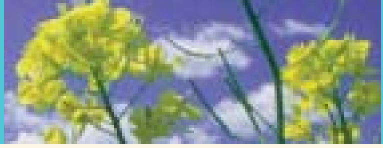
Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Chemicals exist naturally everywhere on Earth. However, human activities can introduce other potentially harmful chemicals to the environment. Decisions on developing and using chemicals should be based on a variety of considerations. These include social, environmental, ethical, and economic concerns. Answer the following questions, and use examples from this section to support your answers.

1. Write a statement that expresses an economic viewpoint in favour of few restrictions on the transport of crude oil.

2. Write a statement that expresses an environmental viewpoint in favour of strict government controls on the transport of crude oil.

3. Testing indicates that the soil in a new subdivision is contaminated with lead. Identify the types of viewpoints expressed in the following comments made by residents in the area. (Hint: Are they worried about health, economic considerations, the environment, ethics?)
a) "I am worried about my three young children developing serious nerve problems."
b) "I think that the people responsible for the lead problem should pay for the clean-up."
c) "I am very concerned about property values going down."
d) "I think that more testing should be done so that all of the problem areas can be identified."
e) "My family is interested in finding out the various methods that can be used to reduce the concentration of lead."



Unit Summary: Environmental Chemistry

Key Concepts

1.0

- chemicals essential to life
- organic and inorganic material
- acids and bases
- ingestion and absorption of materials
- substrates and nutrients

2.0

- air and water quality
- concentration and dispersal
- uncertainties in environmental monitoring and in assessing toxicity and risk

3.0

- concentration and dispersal
- stability and biodegradability
- evidence of toxicity
- hazards, probabilities, and risk assessment

Section Summaries

1.0 The environment is made up of chemicals that can support or harm living things.

- Chemicals form everything in the environment—both living and non-living things.
- Pollution is any change in the environment that produces a condition that is harmful to living things. It can result from human activities or other events (e.g., volcanoes).
- Acids and bases occur naturally or as a result of human activities. Acids have a pH below 7. Bases have a pH greater than 7. A substance with a pH of 7 is neutral. Some acids and bases can neutralize each other. Never mix acids and bases unless you know it is safe to do so.
- Common substances are needed by plants and animals for healthy growth. Carbon, oxygen, and hydrogen are the most common elements in living things.
- Organic molecules such as carbohydrates contain carbon. Inorganic molecules, such as many minerals, generally do not contain carbon.
- Plants use inorganic substances to produce organic molecules such as carbohydrates, lipids, proteins, and nucleic acids. Consumers rely on producers for their food.
- Organisms require optimum amounts of nutrients for good health.
- Plants take in substances through their roots by osmosis and active transport. Animals, including humans, ingest food and absorb nutrients into their blood.
- The environments and substrates where organisms live affect the availability of nutrients.

2.0 The quantity of chemicals in the environment can be monitored.

- Guidelines for water quality help to protect humans, animals, crops, and other organisms that live in or near water systems.
- Concentrations of chemicals in the environment are usually measured in parts per million.
- Water quality can be measured using biological and chemical indicators. Invertebrates are often used as biological indicators. Examples of chemical indicators include the amount of dissolved oxygen, phosphorus, and nitrogen.
- Air quality is monitored by measuring substances such as sulfur dioxide and nitrogen oxides over time.
- Carbon dioxide and ozone are monitored worldwide because of their global effects.

3.0 Potentially harmful substances are spread and concentrated in the environment in various ways.

- Chemical substances are transported through the air, soil, and water.
- Substances transported in air are dispersed, diluted, and eventually deposited onto Earth's surface.
- Substances may be transported through soil or rock by groundwater, and they can be chemically changed.
- Processes such as dispersion, dilution, biodegradation, phytoremediation, and photolysis can change the concentration of chemicals in the environment.
- Hazardous materials affect living things. For example, oil spills affect micro-organisms, plants, animals (including humans), and the abiotic environment.
- Care must be taken in the use, storage, transport, and disposal of hazardous household goods. Government regulations, such as WHMIS, and new product regulations attempt to protect consumers in the home and in the workplace.

Fuel Combustion in Electrical Power Plants

The Issue

As you read in section 1.0, the need to produce more electricity must be weighed against the environmental impact of more electric power plants. Electric power generation is the third largest producer of sulfur dioxide and nitrogen oxide emissions in Alberta. Mercury emissions from coal-fired power stations are also a concern because mercury harms the human nervous system.

Almost 60% of Alberta's electricity is generated by coal-fired plants. Natural gas-fired plants generate about 33%. Hydro provides most of the rest, with some from wind and biomass. Coal-fired generating plants are built close to coal mines to limit the distance required for coal transportation. Long transmission lines transport the electricity to consumers. Pipelines transport natural gas to natural gas-fired plants.

Suppose that your community is in the process of deciding if an electricity generating plant should be built in your area. There are two options: a coal-fired plant or a natural gas-fired plant.

Go Further

Now it's your turn. Look into the following resources to help you learn more:

- Look on the Web: Check the Internet for information on generating electricity in Alberta and the benefits and costs of using coal or natural gas. Begin your search at www.pearsoned.ca/scienceinaction.
- Ask the Experts: Try to find an expert on electricity generation, such as an engineer or a planner. Experts can be found various places: the electric company, universities, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about electricity generation.

Analyze and Address the Issue

Use the information you collected to help you analyze the risks and benefits of each method of electricity generation. Then write a brief report that states your conclusion about the type of fuel that could be used to produce electricity for your community. Give evidence to support your conclusion.

What people in favour of coal say	What people in favour of natural gas say
Coal is plentiful in Alberta.	Natural gas is plentiful in Alberta.
Burning coal is less expensive than burning natural gas. Electricity produced by burning natural gas costs much more than electricity produced by burning coal. Also, the price of coal is more stable than the price of natural gas.	A coal-fired plant is much more expensive to construct than a gas-fired plant. Expensive technology is required to remove pollutants from the smokestacks of coal-fired plants.
Alberta coal is low in sulfur content.	Natural gas is a cleaner burning fuel than coal because most of the pollutants, such as sulfur and nitrogen compounds, are removed in processing before the gas is burned.
New coal-burning technologies are efficient and meet stringent emission regulations.	New technology for co-generation allows the use of natural gas to generate electricity in a more environmentally friendly manner.

A Refinery Mega-Project—Considering the Options

Getting Started

Human activities such as mining, forestry, agriculture, transportation, and wastewater treatment all supply us with needed products and processes, but they all have the potential to produce chemicals that harm the environment.

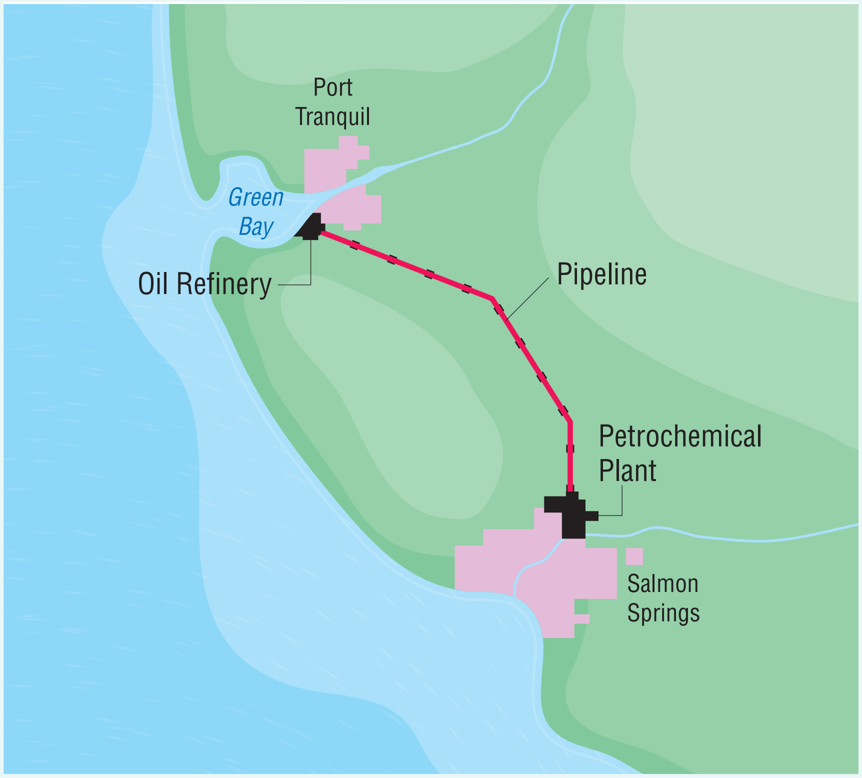
The fictitious community of Port Tranquil is located in Green Bay, an area similar to Alaska's Prince William Sound. It is considering a proposal to build an oil refinery near the port.

Your Goal

The goal for your class will be to decide whether or not an oil refinery should be built at Port Tranquil. You will work in small groups to prepare for a public hearing. After listening to presentations from people with different points of view, you will make a decision about the building of the oil refinery.

What You Need to Know

The harbour of Port Tranquil is safe for tanker ships to unload crude oil at the proposed refinery. If the refinery is built, the citizens of Port Tranquil will have access to jobs such as building and operating the refinery and a pipeline to a nearby petrochemical plant. They will also have cheaper heating fuel for homes and gasoline for vehicles. Despite the economic benefits, many people here still remember the environmental problems caused by the *Exxon Valdez* oil spill.



The Port Tranquil area

The town council of Port Tranquil will hold a public hearing on the issue of whether the town should allow an oil refinery to be built. The participants who have registered to speak are:

- A citizen of Port Tranquil who has been looking for employment for six months
- A fishing guide whose main income is from tourists who come to the Green Bay area for salmon fishing
- A developer who owns land near the town that would be suitable for new housing
- An environmentalist who helped clean up the oil spill in Prince William Sound
- An artist who paints natural scenes that include wildlife
- A homeowner who likes the quiet life in Port Tranquil
- The manager of the company planning to build the oil refinery
- Others you may wish to add to the list

Steps to Success

1 The class will be divided into 10 groups. One group will represent the officials (chairperson, secretary, and assistant) at the public hearing. Another group will represent reporters and photographers. The remaining groups will prepare the two-minute speeches of the registered participants. You may want to dress as the person you will represent at the hearing.

2 The officials will need to plan the following:
- room arrangement (e.g., seats for speakers at the front of the room)
- opening remarks made by the chairperson
- order of the presentations
- procedure for the question period
- a way to determine whether the refinery will be built, built with restrictions, or not built (e.g., you could collect the individual decisions made by the students and report the count in the next class period)

3 The reporters and photographers will decide:
- how to gather information for their news report (TV or newspaper)
- title, length, and content of their article or report
- the number and type of photographs needed (if the report will be a newspaper article)

4 The students working on the speeches for the registered participants will decide:
- if they are writing a speech for or against the building of the oil refinery
- what to say in a two-minute presentation
- which member of the group will make the speech at the hearing

5 At the public hearing, the chairperson will call the meeting to order and state its purpose. One of the officials will introduce each speaker. The chairperson will maintain order during the presentations and the question period to make sure no one is interrupted.

6 As each speech is being made, analyze the presentation by filling in an information sheet like the one shown below.

Speaker	Viewpoint : For/Against/ For with restrictions	Reasons

7 If you need to clarify a fact or viewpoint, ask questions during the question period after the last presentation.

8 The chairperson will close the meeting and announce when the decision will be made public.

9 Use your information sheet to help you analyze the risks and benefits of each possible decision about the refinery's construction: for it, against it, or for it with restrictions. You may want to use a chart like the one below to organize the information. After you have analyzed all the options, write down your decision on a piece of paper.

Risks associated with my decision	Benefits associated with my decision

10 The officials will collect the decision sheets and count the results to determine a class decision on whether or not the refinery should be built.

How Did It Go?

11 What role did or could science play in this decision-making process?

12 What role did or could technology play in this decision-making process?

13 Do you think an individual can make a difference by speaking at a public hearing? Explain your answer.

14 Do you think a public hearing like this is a good way to make decisions about major issues that involve science and technology? Explain your answer.

15 What would you do differently if you had to participate in a hearing like this again?

Unit Review: Environmental Chemistry

Unit Vocabulary

1. Create a concept map that illustrates the relationships among the following terms. Start your concept map with the words *environmental chemistry*.

   pollution
   fertilizer
   pesticides
   acids
   bases
   organic chemicals
   inorganic chemicals
   dispersion
   dilution
   biodegradation
   groundwater
   monitoring

Key Concept Review

1.0

2. Name three sources that can increase the amounts of the following substances in the atmosphere:
   a) carbon dioxide
   b) sulfur dioxide
   c) nitrogen oxides
3. In what form is nitrogen available for plant use? List three ways that nitrogen is made available for plant use.
4. Describe the difference between an acidic solution and a basic solution.
5. How does acid rain form?
6. How is magnesium used by plants and humans?
7. Explain one difference and one similarity between osmosis and active transport.

2.0

8. What biological indicators in a freshwater sample indicate a healthy environment?
9. Explain a possible reason for the recent rise in atmospheric carbon dioxide.
10. Why do governments monitor emissions of sulfur dioxide and nitrogen oxides?
11. Fish are not usually found in water that has a pH below a certain level. What is this pH level?
12. Define the term "heavy metal" and give an example.

3.0

13. What are the three phases of atmospheric transport?
14. Explain the difference between the terms "aerobic" and "anaerobic."
15. a) What is groundwater?
    b) Why should it be protected from pollution?
16. Why is it important to know where the MSDSs are located in your school?
17. Why is the transport of chemicals a global concern?

Connect Your Understanding

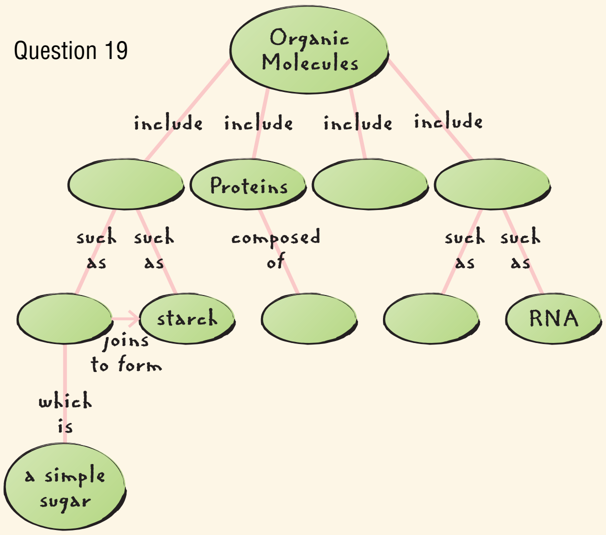
18. a) What is the difference between an organic chemical and an inorganic chemical?
    b) Indicate if the following substances are organic or inorganic:

glucose	mercury
lead	oxygen
amino acids	fertilizer
carbon dioxide	crude oil
protein	propane
lipids (fats)	DNA

19. Copy the concept map shown here in your notebok. Complete it by placing the terms below in the appropriate places.

DNA	carbohydrates
lipids	glucose
amino acids	nucleic acids

Question 19



20. Which of the following processes returns carbon to the atmosphere most quickly?
a) decomposition of dead plants and animals
b) photosynthesis
c) formation of oil
d) fuel combustion

21. Explain why the following tests are used to determine water quality.
a) pH
b) dissolved oxygen
c) phosphorus

22. Match a technological process or product with the resource it is meant to protect or conserve.

Resource	Technological product or process
air	smaller, lighter cars
soil	fertilizer
water	scrubber
plants	sewage treatment
fossil fuel	insecticide

23. A solution has an initial pH of 3.5. After it passes through soil, the pH is 5.3. Explain what has occurred.

24. Write a paragraph about cleaning up pollutants in the environment using the following terms:

biodegradation
phytoremediation
accumulation

25. Describe the correct storage and disposal of:
a) gasoline
b) hydrochloric acid (used in toilet and sink cleaners)
c) car batteries
d) leftover paint

26. Read the label shown below and answer the following questions.
a) What precautions should you take when handling a corrosive material like this bleach?
b) Suggest safe ways to store a corrosive substance.
c) Why does the label say that bleach should not be mixed with other household products, especially acids?
d) Name two acidic substances commonly found in homes.
e) Why would it not be a good idea to put undiluted bleach into a septic tank?

Question 26

Extend Your Understanding

27. How does inorganic carbon become available to living things?

28. Most people in Alberta have a high standard of living. What pollutants are associated with a high standard of living? Why?

29. Using atmospheric carbon dioxide as an example, explain what is meant by "optimum amount." In your answer, identify a problem related to too little carbon dioxide in the atmosphere. Also explain the problems that might arise if there is too much carbon dioxide.

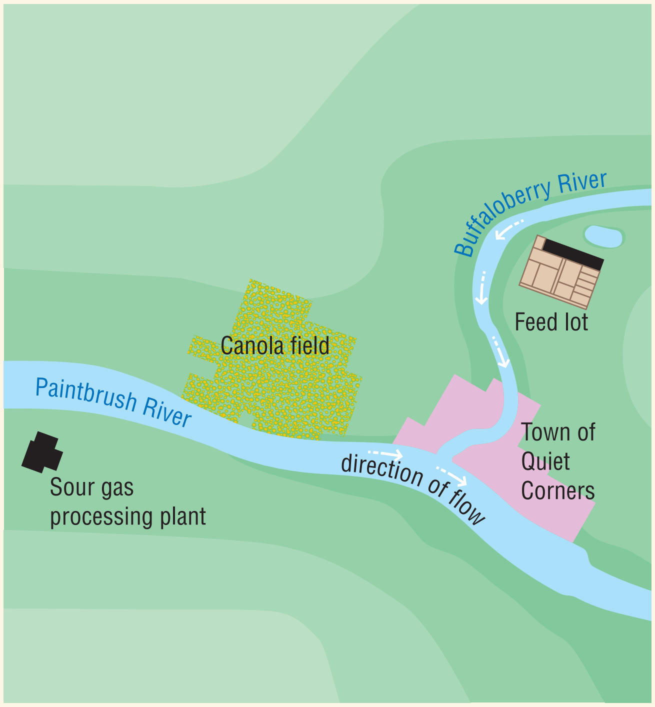
30. Suppose that the government passes legislation stating that no release of sulfur dioxide and nitrogen oxides would be permitted.
a) How do you think this would affect industry?
b) How do you think it might affect you?

31. Imagine that a farmer has tested the soil and found that it is low in nitrogen.
a) The farmer plans to use a fertilizer to improve the soil. Which of the three numbers on the fertilizer bag should be highest?
b) A heavy rain falls just after fertilizing is completed. What effect might this have on the availability of nitrogen for the crop?
c) A neighbouring farmer suggests that the field should be planted in clover (a legume) for one year and then ploughed under before it is used again for a commercial crop. How would that suggestion benefit the soil?

Practise Your Skills

32. Suppose a bag is almost filled with a glucose-water solution. The bag is permeable to water molecules but not to glucose molecules. Predict what would happen if the bag were placed in water. How could you test your prediction?

33. Look at the map below. Imagine that you have worked for the town of Quiet Corners for the past 15 years managing the drinking water supply. You notice that this year there has been no large emergence of adult mayflies as there has been in previous summers.
a) What water tests might help you identify problems?
b) How might you identify the source of the problem?



Question 33

34. Testing has found 0.004 mL of lead in a 1000-mL sample of soil. Calculate the concentration of lead in parts per million.

Self Assessment

35. Think about your work in group activities. Consider the following skills and answer the questions below:

- listening to all suggestions made by your team
- contributing to brainstorming sessions
- being creative
- doing your share of the work
- completing tasks on time

a) What did you do well?
b) What do you need to improve?

36. What did you learn in this unit about the role of science in social and environmental issues?

37. Describe three ways in which your lifestyle affects the environment.

38. What questions or issues about environmental chemistry would you like to explore further?

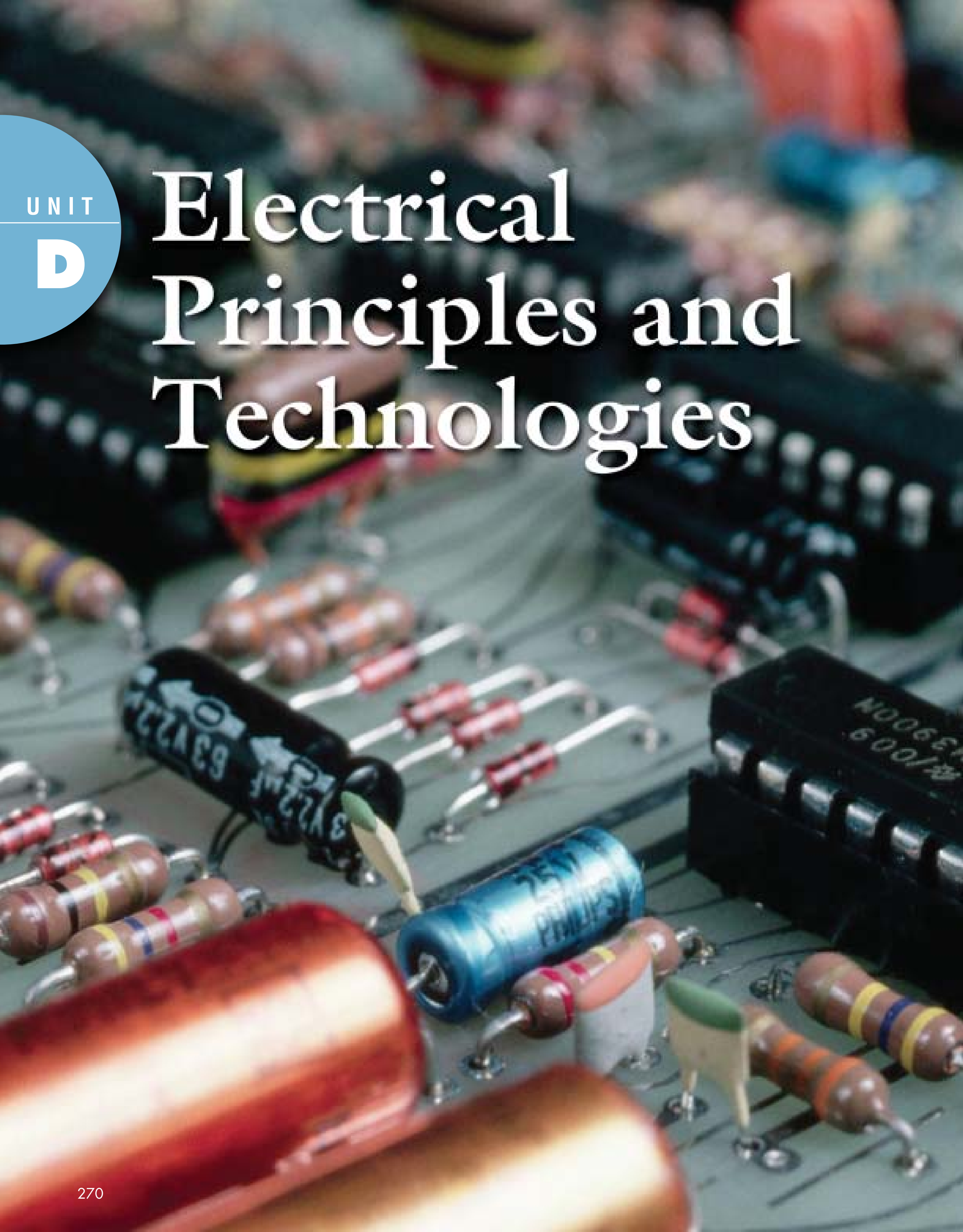
Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

In this unit, you have investigated the social and environmental context of environmental chemistry. Consider the following questions.

39. Re-read the three questions on page 181 about the social and environmental context of environmental chemistry. Use a creative way to demonstrate your understanding of one of these questions.

40. Explain two benefits of analyzing different viewpoints when making decisions.

41. Use two examples from this unit to explain why it is important to monitor chemical changes in the environment.



UNIT D

Electrical Principles and Technologies

In this unit, you will cover the following sections:

1.0 Electrical energy can be transferred and stored.

1.1 Static Electricity
1.2 Current Electricity
1.3 Electrical Safety
1.4 Cells and Batteries

2.0 Technologies can be used to transfer and control electrical energy.

2.1 Controlling the Flow of Electrical Current
2.2 Modelling and Measuring Electricity
2.3 Analyzing and Building Electrical Circuits

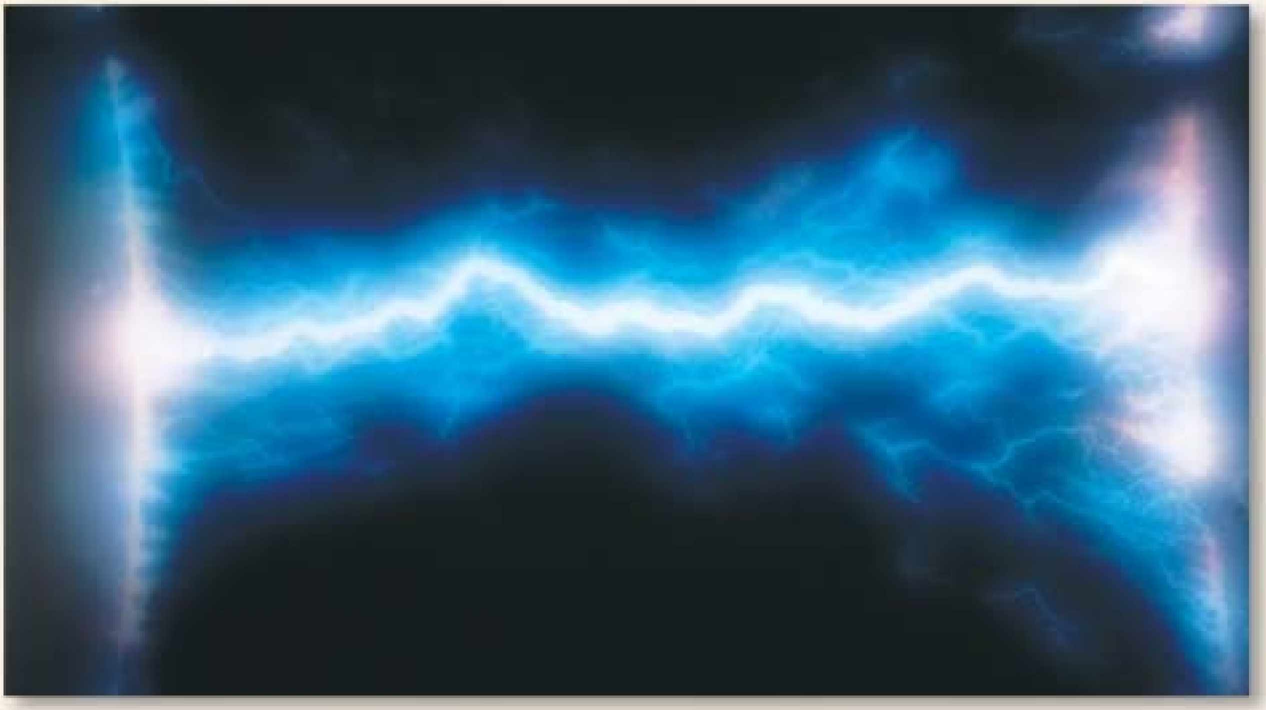
3.0 Devices and systems convert energy with varying efficiencies.

3.1 Energy Forms and Transformations
3.2 Energy Transformations Involving Electrical and Mechanical Energy
3.3 Measuring Energy Input and Output
3.4 Reducing the Energy Wasted by Devices

4.0 The use of electrical energy affects society and the environment.

4.1 Electrical Energy Sources and Alternatives
4.2 Electricity and the Environment
4.3 Electrical Technology and Society

Exploring



A Tesla coil

Electrical Energy

A Tesla coil vividly demonstrates electrical energy. This interesting device was invented over 100 years ago by Nikola Tesla, one of the pioneers of electricity. The Tesla coil can generate large amounts of electricity and create spectacular discharges. Amazing to watch, it operates with enough electricity to be very dangerous, even lethal. Tesla coils have often been used in films for special effects, but they are also used in laboratory studies of high voltage electricity.

Another device that you might have seen at the movies is the Jacob's ladder. It sometimes appears sparkling and crackling in the background as the villain tries to use huge machines and large amounts of electricity to take over the world.

The rising, crackling arcs of electricity in a Jacob's ladder are caused by electricity jumping from one piece of metal to another. When the electricity jumps, it heats the air that it passes through. This hot air rises and carries the electrical discharge upward. Unfortunately, this very impressive device has limited practical use. However, both the Jacob's ladder and the Tesla coil dramatically illustrate an important feature of electricity—its ability to move from place to place. Using technology, we can generate and move electricity to where it's needed in a wide range of applications that affect all parts of our lives.

A Jacob's ladder

QUICKLAB

Charge It!

Purpose

To experience the nature of electrical forces

Procedure

Trial 1

1 Attach the cork to about 15 cm of thread. Hang the cork from the end of your desk by taping the opposite end of the thread to the edge.

2 Rub an acetate rod or plastic drinking straw with some wool or fur.

3 Slowly bring the rod close to the hanging cork. Record you observations.

Trial 2

4 Now rub the cork on the wool or fur, and then rub the acetate rod with the wool or fur.

5 Slowly bring the rod close to the hanging cork. Record your observations.

Trial 3

6 Turn on a water tap so that only a very thin stream of water comes out.

7 Rub the acetate rod with the wool or fur once again, and slowly bring the rod near the stream of water. Record you observations.

Questions

8 Describe the behaviour of the piece of cork and the water in this experiment.

9 Explain your observations for each trial.

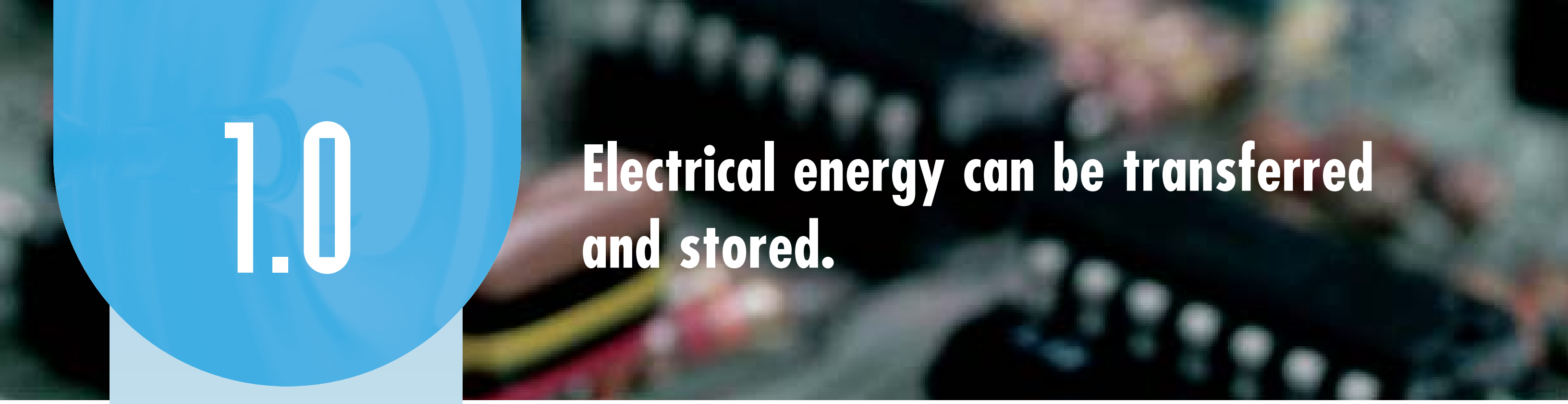
Materials & Equipment

- small pieces of cork or polystyrene
- tape
- thread
- acetate rod or plastic drinking straw
- wool or fur
- water tap

Focus On Science and Technology

While studying this unit, you will be asked to organize your thoughts about electrical principles and technologies. Think about the following questions while you study the science of electricity and some of the technology that has developed from an understanding of this science. The answers to these and other questions about electricity will help you understand how to transfer, modify, measure, transform, and control electrical energy.

1. **How do we obtain and use electrical energy?**
2. **What scientific principles are involved in developing, selecting, and using energy-consuming devices?**
3. **How can the principles of electricity be applied in technology to promote efficient and effective energy use?**



1.0 Electrical energy can be transferred and stored.

Key Concepts

In this section, you will learn about the following key concepts:

- electric charge and current
- circuits
- electrical energy storage
- energy transmission
- measures and units of electrical energy

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between static and current electricity and identify evidence of each
- assess the potential danger of an electrical device by checking its voltage and amperage
- distinguish between safe and unsafe activities when dealing with electricity
- identify electrical conductors and insulators
- evaluate the use of different chemicals, chemical concentrations, and designs for electrical storage cells

The late evening weather report warns that thunderstorms are developing in your area. You step outside to view the skies and look for funnel clouds. You notice a dark gray cloud, and BOOM! A bolt of lightning strikes just down the street, the clap of thunder startling you. You decide to stay safe and go inside to bed. In your dark room, you pull your sweater over your head and see a shower of small sparks as the fabric rubs over your hair. You wonder for a moment: Are the sparks you see in the sweater related to the lightning you saw outside? Yes, they are! Both are examples of **static electricity**. In this section, you'll learn more about static electricity and the current electricity that powers the many devices you use in your home. You'll also learn about electrical safety.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Static Electricity

You hurry down the hallway and reach for a doorknob. Zap! An electric shock jolts you. Your friend hands you a pair of scissors. Zap! Another shock. You have probably heard this type of shock called "static" or "static electricity." When you feel these jolts of static electricity, you are experiencing the same electrical force that causes lightning. This is also the electrical force that causes clothing to stick together and paper to stick to the glass on the photocopy machine.

The explanation of static electricity starts with the atom. Recall that all substances are made of atoms, and atoms are made of much smaller particles. If you have studied Unit B: Matter and Chemical Change, you know that some particles in an atom are electrically charged. The **proton** has a positive charge and the **electron** has a negative charge. The charges on the particles can cause either attractive or repulsive (pushing away) forces between the particles.

infoBIT

Thales' Amber

The first person known to have experimented with static electricity was the philosopher Thales around 600 B.C. He found that rubbing amber, a fossilized tree resin, caused it to attract some materials. The word electricity is from the Greek word for amber, *elektron*.

QUICKLAB

STATIC CHARGE

Purpose

To observe the characteristics of static electricity

Procedure

1. Sprinkle some confetti or gelatin powder in a small area on your desk. Push a plastic drinking straw through your hair several times and bring it close to the confetti or gelatin powder. Record your observations.
2. Inflate two balloons and knot the ends. Rub one side of each balloon on your hair or clothing. Hold the balloons by the knots and bring the rubbed surfaces slowly together. Turn one balloon so that its rubbed surface faces away from the other balloon. Again bring the balloons together. Record your observations.
3. If your classroom has a Van de Graaff generator (VDG), your teacher will assist you with the following experiments. In each case, put the materials in place, then turn on the generator, and record your observations.
   a) Tape the thin paper strips to the VDG.
   b) Place a stack of 3 aluminum pie plates on the VDG.
   c) Place a clear plastic cup full of polystyrene "peanuts" or "popcorn" on the VDG. Put a loose-fitting lid on top of the cup.
   d) Attach a metal rod to a lab stand and place it close to the VDG.

Questions

4. Provide an explanation for any movements that you observed.
5. How could you use the VDG to make someone's hair stand on end? Test your hypothesis with the VDG. Did it work? Explain why or why not.

Materials & Equipment

- plastic drinking straw
- confetti or gelatin powder
- 2 balloons
- Van de Graaff generator
- thin paper strips
- tape
- 3 aluminum pie plates
- clear plastic cup
- polystyrene "peanuts" or "popcorn"
- metal rod and lab stand

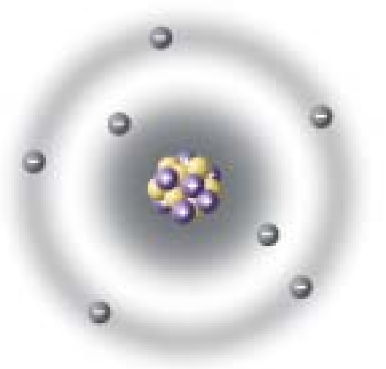


Figure 1.1 In an atom, the protons are in the nucleus. The electrons orbit the nucleus.

Electrical Charge

If you did the QuickLab on page 275, you noticed that some of the objects attracted each other and others repelled each other (pushed each other away). The objects reacted to each other in these ways because they are electrically charged.

You may have heard the phrase "opposites attract" in discussions about people. This is definitely true for electric charges. Opposite charges attract each other, and like charges repel each other. Figure 1.2 shows what happens when charged particles are close together.

Most objects have equal amounts of positive and negative charge, which makes them **neutral**. Sometimes an object has more of one type of charged particle than another. For example, an object with more electrons than protons is negatively charged. When this happens, we say that an object has built up a static charge. "Static" means "not moving" or "stationary." This type of charge does not flow like the electrons in an electrical current. You will learn more about electrical currents in subsection 1.2.

Charged objects cause **charge separation** when they are brought close to neutral objects. Rubbing a balloon on your head transfers electrons from your hair to the balloon. When you bring the charged side of the balloon near a wall, the negative charge of the balloon repels the electrons in the wall. This leaves the area of the wall closest to the balloon positive. The balloon and wall are attracted because of these opposite charges.

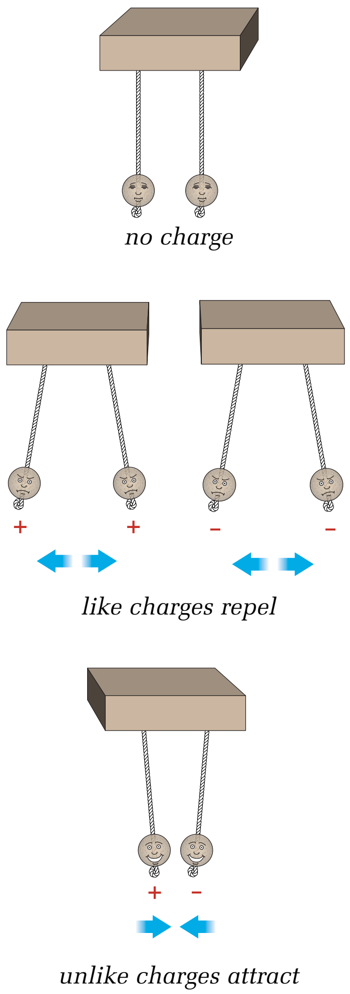


Figure 1.2 Charged particles exert force depending on their charge.

Electrical Discharge

Static electricity may not flow like a current, but it does sometimes discharge. The built-up charge on an object may be attracted to another object and jump to that object. This is what happens when you feel a shock as you reach for the doorknob after walking across a carpet. When your feet move across the carpet, electrons transfer from the carpet to your body. This excess charge of electrons in your body repels the electrons in the doorknob as you get close to it. The side of the doorknob closest to you becomes positively charged. As you move closer, the electrons in your hand are attracted to this positive charge on the doorknob. You may feel a shock or see a spark as you reach to touch the doorknob. The resulting spark is usually referred to as **electrical discharge**.

We can summarize the behaviour of electric charges in two laws. These laws describe what happens when two charged particles or objects are brought close together.

The Laws of Electrical Charges

- Opposite charges attract each other.
- Like charges repel each other.

ACTIVITY D-1

Inquiry

INVESTIGATING STATIC ELECTRICITY

The Question

What is the effect of charged objects on each other and on neutral objects?

The Hypothesis

Reword the question in the form of a hypothesis.

Materials & Equipment

- 2 vinyl strips
- tape
- ring stand
- paper towel
- 2 acetate strips
- beaker
- watchglass
- metre-stick

Procedure

1 Copy the following table into your notebook.

Hanging Object	Approaching Object	Observations
Charged vinyl	Charged vinyl	
Charged acetate	Charged acetate	
Charged acetate	Charged vinyl	
Metre-stick	Charged vinyl	
Metre-stick	Charged acetate	

2 Tape one end of a vinyl strip to the ring stand so the strip hangs down. Rub the strip with the paper towel to charge it. Now rub the other vinyl strip with the paper towel, and bring it close to the suspended strip. Record your observations in your table.

3 Repeat step 2, using the two acetate strips and the paper towel. Record your observations.

4 Bring one of the charged vinyl strips close to the suspended acetate strip. Record your observations.

5 Place the beaker upside down on the desk or table, and place the watchglass on top of the beaker. Balance the metre-stick so it is lying flat and centred on the watchglass. Bring a charged vinyl strip near, but not touching, one end of the metre-stick. Record your observations.

6 Bring a charged acetate strip near, but not touching, one end of the metre-stick. Record your observations.

Figure 1.3 Balance the metre stick on the watchglass on top of the beaker.

Analyzing and Interpreting

7 Usually, charged vinyl is negative, and charged acetate is positive. How does this information explain your observations?

8 Do your observations agree with the laws of electrical charges? Support your answer with your data.

Forming Conclusions

9 Describe the effect of charged objects on each other and on neutral objects. Use your observations in your description.

Applying and Connecting

The interaction between charged and neutral objects can lead to dangerous discharges. For example, helicopters build up a large static charge from their blades spinning in the air. Because of this, baskets lowered for sea rescues must touch the water before anyone approaches them. The static discharge could knock people overboard or stop their hearts.

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Cleaning the Air

In the early 1900s, factories with large smoke stacks were belching pollutants into the atmosphere. In 1907, Frederick G. Cottrell patented a device called the electrostatic precipitator. It not only cleaned the air, but also recovered products from the smoke that would otherwise pollute. Write a short biography of Cottrell, and a brief illustrated report on how electrostatic precipitators work. Begin your information search at www.pearsoned.ca/scienceinaction.

Van de Graaff Generators

Scientists often study electrical discharge with a device called a Van de Graaff generator (VDG). If you did the QuickLab earlier in this lesson, you may have used one of these generators. VDGs are particularly effective at building up static charge. They produce static build-up by using friction. Figure 1.4 shows how a VDG works. A rubber belt rubs on a piece of metal and transfers the charge to a sphere. The charge builds up on the sphere and transfers to you when you touch the sphere.

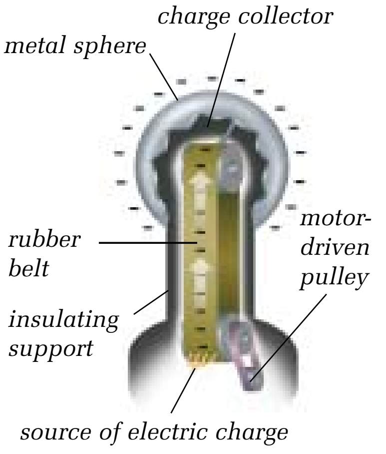

Figure 1.4 A Van de Graaff generator uses friction to build up a static charge on its sphere.

Check and Reflect

Key Concept Review

1. How does a proton differ from an electron?
2. What does it mean to be "statically charged"?
3. Explain how a Van de Graaff generator builds up a static charge.
4. a) What happens when like charges interact?
   b) What happens when unlike charges interact?

Connect Your Understanding

5. You rub your feet across a floor and electrons transfer from you to the floor. Are you now negatively or positively charged?
6. *A neutral object contains no charge.* Is this statement accurate? Explain.
7. Why is a neutral object attracted to a charged object?
8. You bring a negatively charged rod close to some tiny pieces of plastic. Some of the pieces jump up to the rod, but as soon as they make contact, they immediately fly away from the rod. Explain.

Extend Your Understanding

9. Large trucks that carry flammable liquids often have a metal wire or chain that drags on the ground. Why? (Hint: Have you ever been shocked when getting out of a car?)

1.2 Current Electricity

Figure 1.5 The electric eel *(Electrophorous electricus)* uses electricity to kill or stun prey, for defense, and for communication.

The electric eel is not really an eel, but it is definitely electric—and dangerous. Large specimens (they grow up to 2.4 m long) can discharge enough electricity to kill a human being. The electricity is produced by a special organ in the tail that contains thousands of modified muscle cells called *electroplaques*. Each electroplaque can produce only a small amount of electricity. But working together, all the electroplaques in the eel's body can produce large amounts of electricity to help the eel survive. The eel has no teeth and can eat only prey that isn't moving. When a prey animal comes close, the eel releases an electrical charge to stun it. These electrical flows are so strong they have even been known to knock down a horse!

Electrical Current

The electricity of the electric eel is similar to the static charges you have felt or the huge static charges of lightning. Unfortunately, static charges are not useful for operating electrical devices. They build up and discharge, but they do not flow continuously.

The steady flow of charged particles is called **electrical current**. This is the type of electricity needed to operate electrical devices. Unlike static electricity, an electrical current flows continuously, as long as two conditions are met. First, the flow of electrical current requires an energy source. Second, electrical current will not flow unless it has a complete path or **circuit** for the charged particles to flow through.

*QUICK***LAB**

Electrical Current

Purpose

To observe the characteristics of electrical current

Materials & Equipment

- 1 dry cell
- 5 wires
- 2 light bulbs

Procedure

1. Using any of the materials provided, make one light bulb light up.
2. Using the dry cell, one bulb, and one wire, make one light bulb light up.
3. Using any of the materials provided, make two light bulbs light up.
4. Make two light bulbs light up so that when you unhook one bulb, the other one goes out.
5. Make two light bulbs light up so that when you unhook one bulb, the other one stays on.

Questions TOOLBOX

6. Draw your set-up for each step from 1 to 5.
7. Write captions that explain what happened to the electricity in each step.

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The Challenge of Measuring Current

The first measurements of current were done with simple galvanometers. They detected current by using a compass needle. A current-carrying wire creates a magnetic field, which deflects a compass needle. However, Earth's magnetic field sometimes interfered with readings. In 1825, Italian physicist Leopold Nobili invented the astatic galvanometer, which greatly reduced the effect of Earth's magnetism. This new device provided more sensitive measurements.

Amperes

The rate at which an electrical current flows is measured in **amperes** (A). Often called "amp" for short, the ampere is named in honour of the French physicist, mathematician, and philosopher André-Marie Ampère. Most electrical devices around your home have a current of less than 15 A. For example, the current through an ordinary 60-W light bulb is 0.5 A. Microwave ovens usually use between 5 and 8 A, and electric kettles usually use 13 A. In contrast, a digital wristwatch uses a current of only a tiny fraction of an ampere, while a generating station produces many thousands of amperes.

A continuous flow of electrical charge can be produced by devices ranging from miniature cells in watches to huge generators in power stations. The key problem is how to move the charge from where it is produced to where it is needed. Fortunately, there are many materials that electrical charge can move through easily. Such materials are called **conductors**. Conduction of electricity through wires allows for the transfer of electrical energy from place to place.

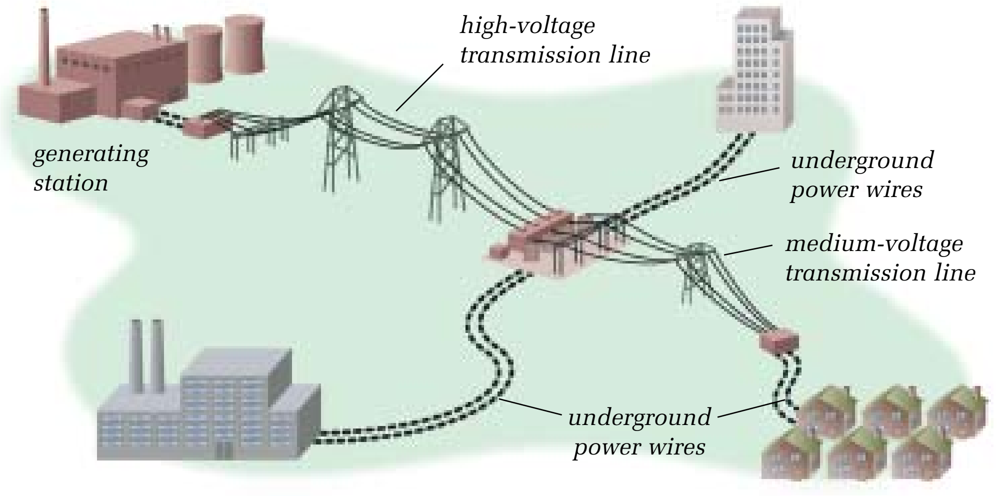

Figure 1.6 An electric power grid transfers energy from the generating station to the users. Multiple wires are needed at every part of the grid (including the devices you use in your home) because the whole grid is a complete circuit.

Circuits

Figure 1.7 shows a light bulb lit by electrical current flowing through a simple circuit. A **circuit** is a path that controls the flow of electricity. If you compare electricity with water again, the water system in your house is like an electrical circuit. The pipes and taps in the water system control the flow of water.

In most electrical circuits, the path that the electricity flows along is made of solid metal wires. But circuits can also include gases, other fluids, or other substances. A circuit usually includes a conductor, an energy source, and a **load**. The load is a device to convert electrical energy to another form of energy. For example, in Figure 1.7, the light bulb is the load. It converts electrical energy to light and heat.

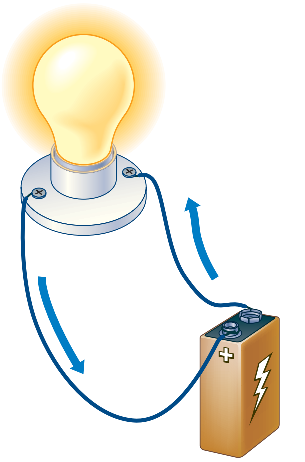

Figure 1.7 Current electricity flows continuously through a circuit.

ELECTRICAL ENERGY AND VOLTAGE

Electrical energy is the energy carried by charged particles. **Voltage** is a measure of how much electrical energy each charged particle carries. The higher the voltage is, the greater the potential energy of each particle. Voltage is also called "**potential difference**." The energy delivered by a flow of charged particles is equal to the voltage times the total charge of the electrons.

The unit of voltage is the **volt** (V), named for the Italian physicist Alessandro Volta. For safety reasons, most of the voltages in everyday devices are fairly low. Flashlights and portable stereos rarely use more than 6 V, almost all cars have a 12-V electrical system, and your home and school have 120-V wall sockets. On the other hand, industrial machinery operates at 600 V, and major electrical transmission lines can have over 100 kV.

MEASURING VOLTAGE

The simplest way to measure voltage is with a **voltmeter**. Many voltmeters have sensitive needles that can be damaged if connected improperly. Make sure to attach the red lead to the positive terminal and the black lead to the negative terminal.

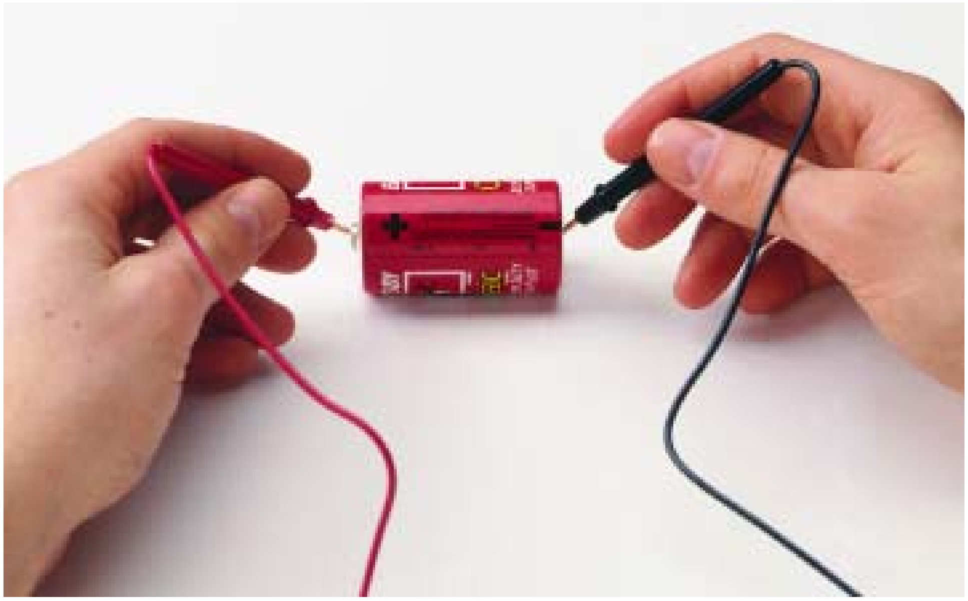

Figure 1.8 It's important to connect a voltmeter properly.

Some voltmeters have more than one red terminal. These are used to change the range of voltage readings on the voltmeter. For example, the meter could indicate either 0 to 5 V or 0 to 15 V, depending on which red terminal is used. If your meter has several ranges, you may not be sure which one to use. Start with the highest one and work down until you get a clear reading.

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Corona Discharge

High-voltage transmission lines sometimes have an eerie blue glow. Sailors saw this same glow around the tips of ships' masts before storms and called it St. Elmo's fire. Today it's called corona discharge. Find out more about corona discharge, and summarize your research as a magazine article. Begin your information search at www.pearsoned.ca/scienceinaction.

You may encounter several types of voltmeters. For example, some meters may give readings in millivolts. Each millivolt is 1/1000 of a volt (e.g., 30 mV is 0.030 V). Some meters have digital displays, which make the voltage values very easy to read.

Figure 1.9 Some voltmeters have more than one range of measurement.

Figure 1.10 A digital voltmeter display

SKILL PRACTICE

Using Voltmeters

Your teacher will provide you with cells of various sizes and shapes. Use the voltmeters you have in your class to test and report on the voltages of the cells. Note the voltage numbers that are written on the cells.

- Can you account for any difference between your voltage readings and the numbers on the cells?
- Suppose you connected any two of the cells in this activity. (Connect cells by placing positive and negative terminals together.) Can you predict what the voltage reading would be? Use your voltmeter to see if your prediction is correct. Explain your results.

Measuring Voltage with Computers

Another method of measuring voltage is with a voltmeter connected to a computer. With this device, you connect the terminals the same way as for other voltmeters, but your voltage reading appears on a computer screen.

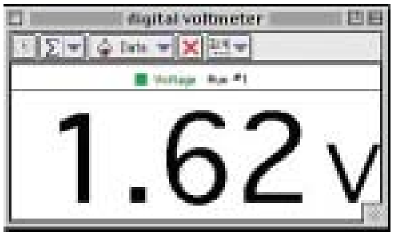

Figure 1.11 A voltage reading displayed on a computer screen

Check and Reflect

Key Concept Review

1. What is electrical energy?
2. How does current electricity differ from static electricity?
3. How would you describe voltage?
4. What are the units for measuring a) current and b) voltage?

Connect Your Understanding

5. You require a high-current battery to start a large tractor. While shopping for this battery, should you be more concerned with the battery's rating of volts or amps? Explain.
6. *A wire carrying more electrons will transfer more energy than a wire carrying fewer electrons.* Is this statement accurate? Explain.
7. Describe how electricity gets from the generating plant to an appliance in your home.
8. Electricity flows into a hairdryer when it is plugged into a socket. If electricity has been added to the hairdryer, why doesn't it keep operating for a while after being unplugged?

Extend Your Understanding

9. What is the reading on the voltmeter in Figure 1.12? Give your answer in both millivolts and volts.

Figure 1.12 Voltmeter reading for question 9

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Fulgurites

Lightning can be dangerous because it discharges so much energy. Lightning strikes can actually melt sand and rock when they hit the ground, creating intriguing glass-lined tubes call fulgurites.

1.3 Electrical Safety

In January 1998, eastern Ontario and western Quebec were hit by a massive ice storm. In many places, power lines and towers were knocked down. Such situations can be extremely dangerous because power lines carry electrons at thousands of volts—enough to seriously injure or kill anyone who comes close to them. You should never approach a downed power line.

Any person coming in contact with a power line may create an unintended path for the electricity. Such a path is sometimes called a **short circuit** because the current bypasses part of the normal circuit. If a power line goes down, the electricity goes off in the entire area served by that power line. Without a complete circuit, electricity can't flow. However, if the electricity can find another path, such as through a person's body to the ground, then it will take that path.

Figure 1.13 Downed power lines in Quebec during the 1998 ice storm

The Dangers of Electrical Shock

To get an idea of how dangerous a current flowing through your body may be, consider two important aspects of electricity: voltage and amperage. High voltage is more dangerous than low voltage; for example, 50 000 V are more likely to kill than 10 V. However, even small voltages can kill if the shock carries a significant number of amps. The number of amps is much more important than voltage when assessing the potential danger of an electrical shock. If 0.001 A passed through your body, you would likely not feel it. Current in the range of 0.015 A to 0.020 A will cause a painful shock, and loss of muscle control. This means a person grabbing a wire at this current level may not be able to let go. Too much electricity flowing through the body can have extremely harmful effects, including burns and damage to the heart. Current as low as 0.1 A can be fatal.

In Figure 1.14, a downed power line is touching the truck, but the driver is not electrocuted as long as he stays in the truck. If he must leave, he should jump free, not step out. Stepping to the ground would provide a path for the electricity to flow through him to the ground.

Figure 1.14 The driver should stay in the truck and wait for help.

Factors Affecting Electrical Shock

The danger of electrical shock varies, depending on the situation. The current is greater when it can flow easily. Current does not flow easily through **insulators** such as wood, rubber, and air. Other substances such as mud and damp soil conduct electricity somewhat. Thus, you might feel just a tingle if you touch an electrified fence on a dry day when you are wearing running shoes. But you could get a nasty shock if you touch the fence when you are barefoot in the rain.

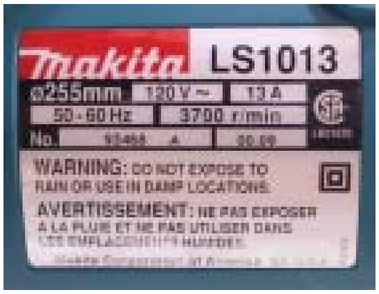

Figure 1.15 A Canadian Standards Association label listing voltage and current for an appliance

Protecting Yourself from Electrical Shock

Every plug-in device sold in Canada must have a label listing what voltage it requires and the maximum current it uses. Usually, this label is on the back or bottom of the appliance. The higher the voltage or current, the more harm the device can do if it malfunctions.

However, the amperage rating doesn't have to be high for you to get a shock. If there is a short circuit or if the insulation is damaged, you could get a shock from the electricity before it goes through the device. So, no matter what the current rating of the device is, you should always take electrical safety seriously.

Electrical Safety Pointers

- Never handle electrical devices when you are wet or near water unless they are specially designed and approved for use in wet areas.
- Don't use any power cord that is frayed or broken.
- Always unplug electrical devices before looking inside or servicing them.
- Don't put anything into an electrical outlet other than proper plugs for electrical devices.
- Don't overload circuits by plugging in and operating too many devices.
- Stay away from power lines.
- Don't bypass safety features built into home wiring, appliances, and other electrical devices.
- When unplugging a device, pull on the plug, not on the electrical cord.
- Never remove the third prong from a three-prong plug.

Plugs, Fuses, and Breakers

The grounded three-prong plug in Figure 1.16(a) has an extra wire that connects the device to the ground wire of the building. As you can tell by its name, this wire leads to the ground. It provides another pathway for electricity, just in case there is a short circuit in the device. It's better to have electricity travel to the ground than through an unfortunate user!

The **fuses** in Figure 1.16(b) and the **circuit breakers** in Figure 1.16(c) interrupt a circuit when too much current is flowing through it. Fuses contain a thin piece of metal that is specially designed to melt if too much current passes through it. Most household circuit breakers also have a special wire that heats up if there is too much current. Instead of melting, the hot wire triggers a spring mechanism that turns off the switch inside the circuit breaker. As soon as the wire has cooled, the circuit breaker can be turned back on. Never turn a circuit breaker back on until you have fixed the problem that caused it to switch off.

(a)

(b)

(c)

Figure 1.16 Three-prong plugs (a), fuses (b), and breakers (c) help prevent electric shocks and overloads.

*QUICK*LAB

Blow a Fuse!

Purpose

To observe the function of a fuse

Procedure

1. Connect the cell, switch, wires, and bulb as shown in Figure 1.17. Leave the switch open.
2. Remove a single strand from the steel wool. Clip the alligator clips onto the ends of the steel wool strand.
3. Close the switch and observe the bulb and the strand of steel wool carefully.

Questions

4 Explain your observations.

5 Why is a fuse a safety feature in a circuit? Use your observations to support your answer.

Materials & Equipment

- D-cell
- connecting wires with alligator clips
- switch
- 15-V bulb and holder
- steel wool

Figure 1.17 Set up your circuit like this one.

The Danger of Lightning

The current in a lightning strike can be as high as 30 000 A, so it's not surprising that it has the potential to kill. People can survive lightning strikes when the full amount of current travels through only part or over the surface of their bodies, but severe injury usually results. The best way to survive a lightning strike is to avoid getting hit in the first place. Lightning is a huge amount of negative charge and tends to seek the highest point on the horizon to discharge. Therefore, avoid standing on hilltops or under trees, or holding objects over your head (especially metal ones) if you are out in a thunderstorm.

Because tall buildings are a natural target for strikes, lightning rods are often added to their peaks. Lightning rods are connected to the ground with a wire. Instead of the lightning destroying the building's roof or electrical wiring, the discharge is conducted harmlessly to the ground.

Figure 1.18 The metal lightning rod on the roof is connected to the ground by a wire.

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Are Breakers Better?

All new houses have circuit-breaker panels instead of fuse panels. Are circuit breakers safer than fuses? Why do many commercial and industrial buildings still use fuses? Prepare a brief report comparing circuit breakers and fuses. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is more dangerous, current or voltage? Why?
2. What is the purpose of a fuse?
3. What is meant by a "ground wire"?
4. What is a short circuit?

Connect Your Understanding

5. A power line carrying a high current falls on a car, but the people inside are not electrocuted. Explain.
6. Are all electric shocks to the body dangerous? Explain.
7. Tall buildings often have a steel lightning rod that is connected to the ground with a wire. Lightning tends to strike these rods during storms. Why are these rods added and how do they work?
8. A friend has told you about plugging in a radio and putting it on the edge of the tub while taking a bath. Why is it unwise to listen to music this way?
9. Why is it a bad idea to take shelter under a tree in a thunderstorm?

Extend Your Understanding

10. You notice a friend removing the third prong of a plug so that the plug will fit into an extension cord that has only two holes. Is the removal of this third prong safe? Explain why or why not.

1.4 Cells and Batteries

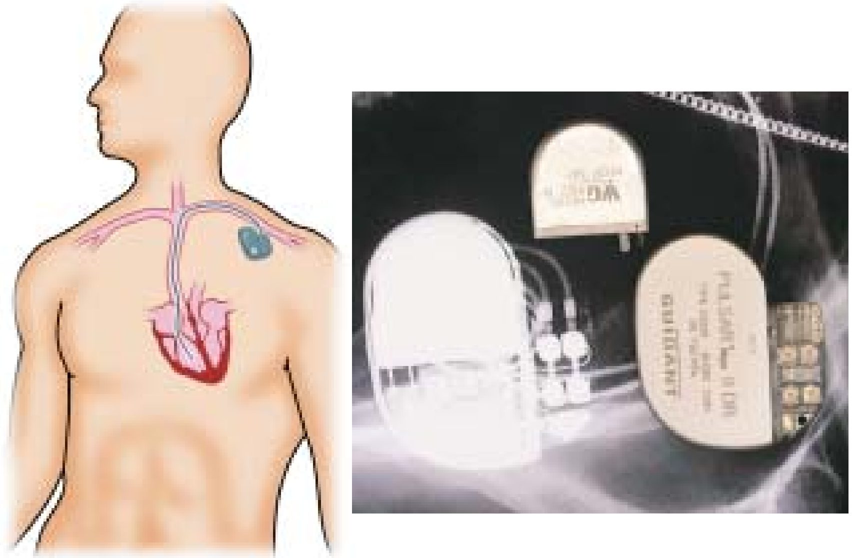
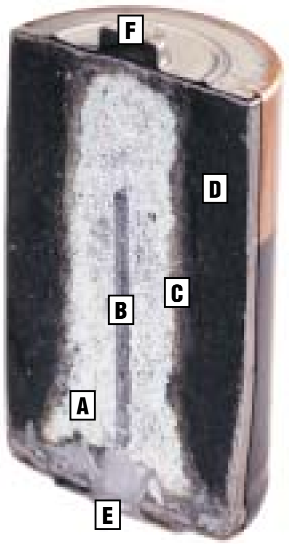


Figure 1.19 A pacemaker is inserted just under the skin, near the shoulder, and connected to the heart. An electrochemical cell supplies the electricity to keep the person's heart beating regularly.

Some people have problems with the small electrical signal that the body uses to control the beating of the heart. Doctors can implant a device called a pacemaker to help such people. The pacemaker delivers a small amount of current at regular intervals to keep the heart beating normally. The electricity used to operate a pacemaker comes from an **electrochemical cell** that supplies a steady current. An electrochemical cell is a package of chemicals designed to produce small amounts of electricity. The electricity the cell produces comes from chemical reactions. The tiny cells used in pacemakers are made with lithium and iodine and last from 5 to 12 years. Other cells, made with different chemicals, are used in devices ranging from toys to cars to computers. There are two main types of cells: dry cells and wet cells.



A – zinc powder and electrolyte, where electrons are released
B – electron collecting rod
C – separating fabric
D – manganese dioxide and carbon, where electrons are absorbed
E – negative terminal, where electrons leave
F – positive terminal, where electrons return

Figure 1.20 An alkaline dry cell

Dry Cells

The electricity-producing cells that we use every day in flashlights and portable radios are **dry cells**. They are called "dry" because the chemicals are in a paste. They are also sealed so they can be used in any position without the chemicals leaking out. Figure 1.20 shows an example of a typical alkaline dry cell, used in flashlights and other devices.

The chemical reaction in the cell releases free electrons. These electrons travel from the negative terminal of the cell, through the electricity-using device, and back to the positive terminal of the cell. While at first glance this cell may look complex, it is simply two different metals in an electrolyte. An **electrolyte** is a paste or liquid that conducts electricity because it contains chemicals that form ions. An **ion** is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons from one atom to another. You can learn more about ions in Unit B: Matter and Chemical Change.

The electrolyte reacts with the two metals, called **electrodes**. As a result of this reaction, one electrode becomes positively charged, and the other becomes negatively charged. These electrodes are connected to the cell's terminals. In a dry cell, electrons leave from the negative electrode, and return to the positive electrode.

The cell shown in Figure 1.20 uses an alkaline electrolyte with zinc and manganese electrodes, but many other combinations of metals and electrolytes are possible. Alkaline cells have become the most common type of dry cell because they offer a good combination of cost, electricity output, shelf life, reliability, and leak resistance.

Wet Cells

Another type of electrochemical cell is shown in Figure 1.21. Such cells are known as **wet cells** because they *are* wet. A wet cell uses a liquid electrolyte that is usually an acid, such as sulfuric acid. Many of the earliest cells were wet cells, as are most cells in cars and trucks today. Wet cells are generally cheaper and easier to make than dry cells. However, care must be taken not to spill the liquid electrolyte, which may be highly corrosive.

Each electrode in the wet cell in Figure 1.21 reacts differently with the electrolyte. The acidic electrolyte gradually eats away the zinc electrode. This process leaves behind electrons that give the slowly disappearing electrode a negative charge. Eventually the zinc electrode must be replaced. The chemical reaction between the copper electrode and the acidic electrolyte leaves the copper with a positive charge, but does not eat away the copper. Electrons travel along the wire from the negative zinc electrode to the positive copper electrode. If you connected a wire from one electrode to a light bulb and another wire from the light to the other electrode, the bulb would light up. The electric current flowing from one electrode to the other provides the energy for the light. Car batteries like the one in Figure 1.22 are made up of wet cells.

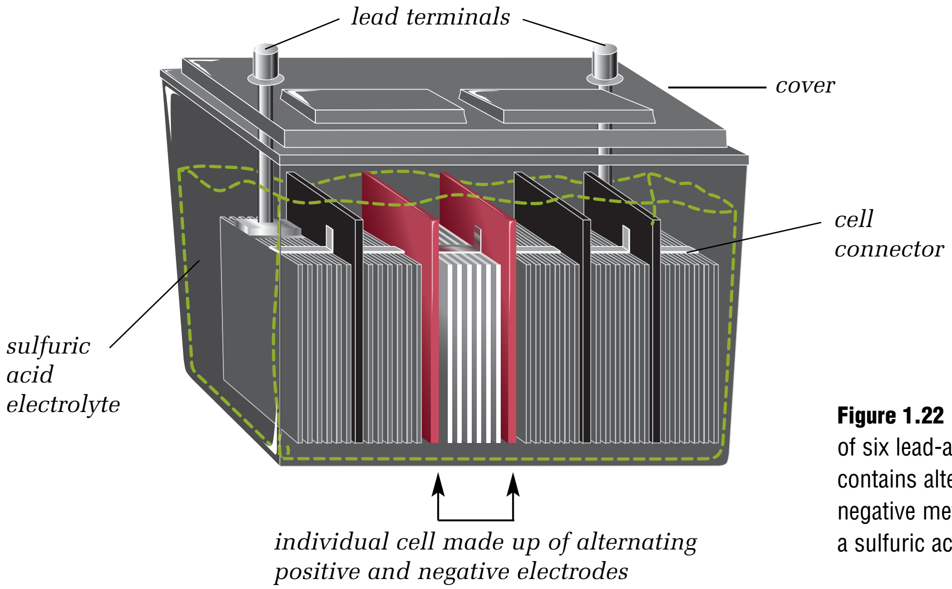


Figure 1.22 A car battery made up of six lead-acid wet cells. Each cell contains alternating positive and negative metal plates (electrodes) in a sulfuric acid electrolyte.

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Plastic Cells

One of the drawbacks of cells is that they tend to be heavy and rigid. One solution to this is to make cells out of plastic. Normally plastic is an insulator, but substances can be added to make the plastic act like metal electrodes. While plastic cells are not yet as powerful as metal-based cells, they are very light and flexible. They can be made as thin as a credit card.

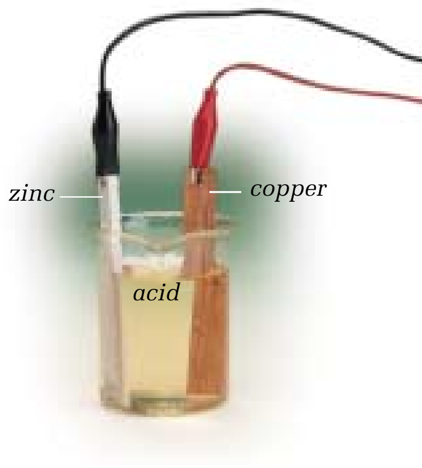


Figure 1.21 A simple wet cell includes two electrodes and a liquid electrolyte.

QUICKLAB

FRUIT CELLS

Purpose

To test the ability of fruits and vegetables to act as electrolytes

Procedure

1. Choose one fruit or vegetable. Insert the two different electrodes into the fruit about 1 cm apart. Push them down to a depth of about 2 cm, making sure they remain about 1 cm apart.
2. Use the connecting wires to connect the electrodes to the voltmeter. Record the reading on the voltmeter scale.
3. Predict which fruit or vegetable will produce the largest voltage. Test your prediction by repeating steps 1 and 2 with the different fruits and vegetables.

Questions

4. What do you think would happen if you reversed the connections on the electrodes? Explain.
5. Would it be possible to use two or more fruits linked together to produce voltage? Draw a diagram of how you might accomplish this, and predict the voltage results. Test your prediction by connecting several fruits to a voltmeter.

Materials & Equipment

- straight pieces of copper wire (electrode)
- straightened paper clips (electrode)
- connecting wires
- voltmeter
- various fruits and vegetables (e.g., lemons, potatoes)

RECHARGEABLE CELLS

The dry cells and wet cells you have read about are called **primary cells**. Primary cells produce electricity from chemical reactions that cannot be reversed. However, the chemical reactions in a **rechargeable cell** can be reversed by using an external electrical source to run electricity back through the cell. The reversed flow of electrons restores the reactants that are used up when the cell produces electricity. We can say that the chemicals in a rechargeable cell store electricity supplied by the external source. Rechargeable cells are also known as **secondary cells**. They are used to start cars and to operate portable electronic devices such as notebook computers and cellular phones.

Not all reversible chemical reactions are suitable for use in rechargeable cells. The reverse reaction must occur efficiently, so that hundreds of recharging cycles are possible. Nickel oxide and cadmium is one combination of chemicals often used in secondary cells. You may have seen them advertised as Ni-Cd or Ni-Cad batteries. Applying electricity to the rechargeable cell reforms the original reactants. This process does not reform the electrodes perfectly, however, so even rechargeable cells wear out in time.

ACTIVITY D-2

Inquiry

CHOOSING ELECTROLYTES

The Question

What type of solution is the best electrolyte for a wet cell?

The Hypothesis

Form a hypothesis for this investigation based on the question. Use the terms "manipulated variable" and "responding variable" in your hypothesis.

Materials & Equipment

- two 500-mL beakers
- voltmeter or voltage sensor
- zinc and copper electrodes
- electrode clamps
- connecting wires
- distilled water for rinsing
- various liquids including distilled water, tap water, sugar solution, salt solution, lemon juice, vinegar, dilute hydrochloric acid of varying concentrations, dilute potassium hydroxide of varying concentrations, or other solutions provided by your teacher

Figure 1.23 Testing electrolytes

Procedure

1. In your notebook, make a table for recording voltages for the different solutions.
2. Attach the clamps to the copper and zinc electrodes. Place the electrodes in the beaker, making sure they don't touch each other. Your set-up should resemble the one in Figure 1.23.
3. Use connecting wires to hook the electrodes up to the voltmeter. Connect the negative terminal of the voltmeter to the zinc electrode.
4. Fill the beaker with distilled water, so that the bottom halves of the electrodes are immersed. Note the level of the liquid or mark it on the beaker. Record the voltage.
5. Disconnect the electrodes and empty the beaker, then rinse them all with distilled water.
6. Set up the beaker and electrodes again, using a different solution. Fill the beaker to the level noted in step 4 with one of the solutions you want to test.
7. Repeat steps 4–6 until all the solutions have been tested. Each time, be sure to rinse the beaker and electrodes with distilled water before pouring in the next solution.
8. When you have finished testing the solutions, follow your teacher's instructions for disposing of them.

Analyzing and Interpreting

9. Are all the liquids electrolytes? Why or why not?
10. Why do you think some substances are better electrolytes than others?

Forming Conclusions

11. Write a summary describing the type of solution that is the best electrolyte for a wet cell. Use your data to support your conclusion.

Applying and Connecting

Electrolytes are also found in the body in the form of many different dissolved ions, such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^-). These dissolved ions serve several functions in the body. One of the most important is to help establish voltages across the cell membranes of nerve cells. Resting nerve cells maintain an internal voltage of about –70 mV. When these cells are stimulated, Na^+ ions rush into them, changing the voltage briefly to about +35 mV. This momentary voltage change makes up the impulses that allow nerve cells to send messages all over the body.

Extending

A variety of substances can function as electrodes in cells. These include aluminum, iron, carbon, tin, lead, and nickel. Design and conduct an experiment that tests different pairs of electrodes to see which pairs produce the greatest voltage.

Figure 1.24 This 6-V battery is made up of four 1.5-V cells.

Batteries

You probably own electronic devices that require more than one dry cell. Connecting cells together creates a **battery**. Most batteries are sealed into cases with only two terminals, so many people don't realize that batteries contain more than one cell. For example, the rectangular battery in Figure 1.24 is a "true" battery because it contains four cells.

Electrochemistry

Alessandro Volta made the first practical battery around 1800. He piled many copper and zinc discs on top of each other, separating them with electrolyte-soaked paper discs. When scientists realized that connecting many cells together could produce more voltage and power, innovation soon followed. For example, in 1807, Humphry Davy, a professor in England, filled a whole room with 2000 cells to make one massive battery.

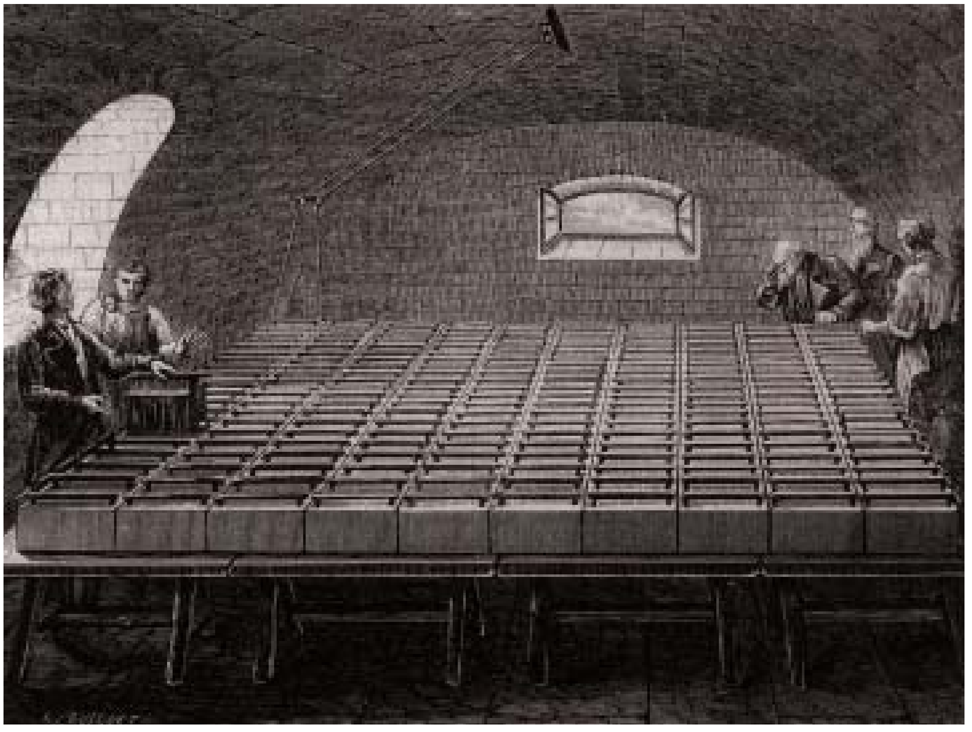


Figure 1.25 Humphry Davy connected 2000 cells together to form one battery.

Other scientists had earlier used smaller batteries to split molecules into their elements, a process called **electrolysis**. For example, they were able to split water into hydrogen and oxygen. Davy's battery was so powerful that he was able to separate pure metals out of molten compounds and ores. Using electrolysis, Davy discovered potassium, sodium, and other elements. The work of Davy and others led to a whole new field of science: **electrochemistry**, the study of chemical reactions involving electricity. Obtaining electricity from a chemical cell is just one of the many applications of electrochemistry. Electrolysis is another.

Electrolysis

Many industrial processes use electrolysis to separate useful elements from solutions. For example, chlorine produced by electrolysis is used to make drinking water safe. It is also used to produce polyvinyl chloride (PVC) products such as pipe and wire insulation.

Electrolysis of water produces the fuel for the space shuttle. The water molecules are separated into pure hydrogen and oxygen. When these two gases are mixed and ignited, they release a tremendous amount of energy, making these two elements a powerful rocket fuel.

Figure 1.26 These PVC pipes and the PVC insulation on these wires are made with chlorine produced by electrolysis.

Figure 1.27 Electrolysis produces rocket fuel by separating water molecules into the elements hydrogen and oxygen.

Electroplating

Metals such as silver and gold are popular for use in jewelry and other decorative items, but they are expensive. Less expensive products can be made by coating a cheaper metal with a thin layer of silver or gold. This process is called **electroplating**. The cheaper metal is also usually stronger than pure silver or gold. The spoon in Figure 1.28 was silver-plated.

Figure 1.29 shows how electroplating is done. The item to be coated and a bar of the coating metal are immersed in an electrolyte, like the electrodes in a wet cell. A source of electricity is connected between the two metals. The flow of electricity through the electrolyte deposits atoms from the positively charged metal onto the negatively charged one. Electroplating is often used to protect metals from corrosion. For example, a plating of chromium or nickel can protect iron or steel from rusting.

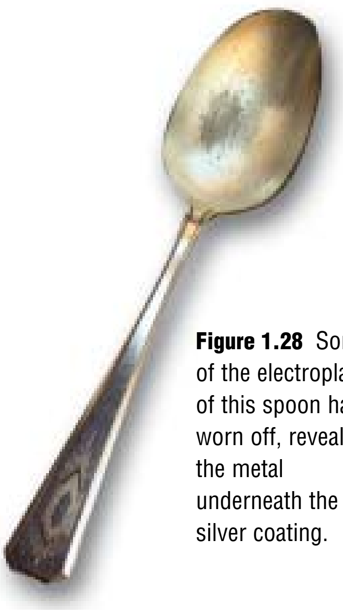


Figure 1.28 Some of the electroplating of this spoon has worn off, revealing the metal underneath the silver coating.

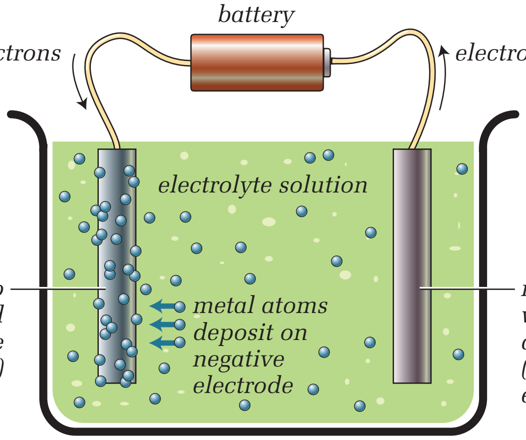


Figure 1.29 The process of electroplating. Different metals can be electroplated by using different electrodes and electrolytes.

reSEARCH

Galvanizing

Galvanizing is the process of applying a coating of zinc onto metals such as iron or steel. Using books or electronic resources, prepare a brief report about the advantages and disadvantages of galvanizing. Begin your search at www.pearsoned.ca/scienceinaction.

Other Electrochemical Applications

Anodizing and electrorefining are two more examples of electrochemical processes used in Canada. Anodizing is a process to coat aluminum parts with a layer of aluminum oxide. This oxide coating is much harder than pure aluminum. Anodizing is used on a wide range of products including aluminum screen doors, airplane or car parts, kitchenware, and jewellery.

Electrorefining can be used to remove impurities from metal. For example, impure gold can be formed into bars that serve as an electrode in an electrolytic cell. The impure bars are put into a strong acid solution (the electrolyte), along with a thin strip of pure gold. When current is applied, it moves from one electrode to the other. At the same time, pure gold dissolves from the impure electrode into the acid electrolyte. The dissolved pure gold moves to the electrode made out of pure gold and is deposited there. The other impurities and unwanted metals are left behind in the electrolyte. This process produces very pure gold.

In another application of electrochemistry, some automobile companies use an electrochemical process to bond special paints onto car parts.

Check and Reflect

Key Concept Review

1. What is electrolysis? Give one example of an application of electrolysis.
2. What is an electrolyte?
3. What was Alessandro Volta's contribution to battery technology?
4. How does a rechargeable cell work?

Connect Your Understanding

5. Which would be a more practical source of electricity for a car: a wet cell or a dry cell? Why?
6. Describe the components of a wet cell and explain how the cell produces electricity. Use a diagram in your answer.
7. Dry cells are designed to keep electrons flowing. Why do they eventually "die" (stop working)?
8. Draw a diagram of an electroplating apparatus that would coat copper with gold. Be sure to label all parts of your apparatus.

Extend Your Understanding

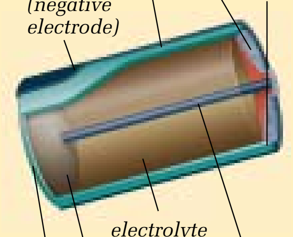
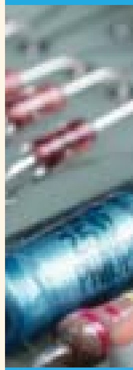


Figure 1.30 Question 9—older design for dry cell

9. Figure 1.30 shows an older design for a dry cell, which is still widely used. How does this design differ from the alkaline cell shown in Figure 1.20 on page 288?
10. A car designer has proposed a new car battery. She is planning to test the following different electrode combinations:
    a) both zinc c) both copper e) both carbon
    b) zinc and copper d) zinc and carbon
    Will all of these combinations work? Explain why or why not.

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. Describe the charged particles in an atom.
2. What are electrodes? Explain their role in a dry cell.
3. What is the difference between a cell and a battery?
4. State three guidelines for electrical safety.

Connect Your Understanding

5. Describe how a static charge might build up on you as you walk across a carpet.
6. Some cells are rechargeable. Others must be discarded when they run out of energy. Explain the difference between these two cell types.
7. Fuses are designed to interrupt the flow of current. Why are they included in a circuit?
8. Lightning is a dangerous discharge of electrons built up by friction between air and water molecules in a cloud. Is this discharge current electricity or static electricity? Explain the reason for your choice.
9. Static discharges are classified as electricity, but cannot provide the energy to operate your household devices. Why?

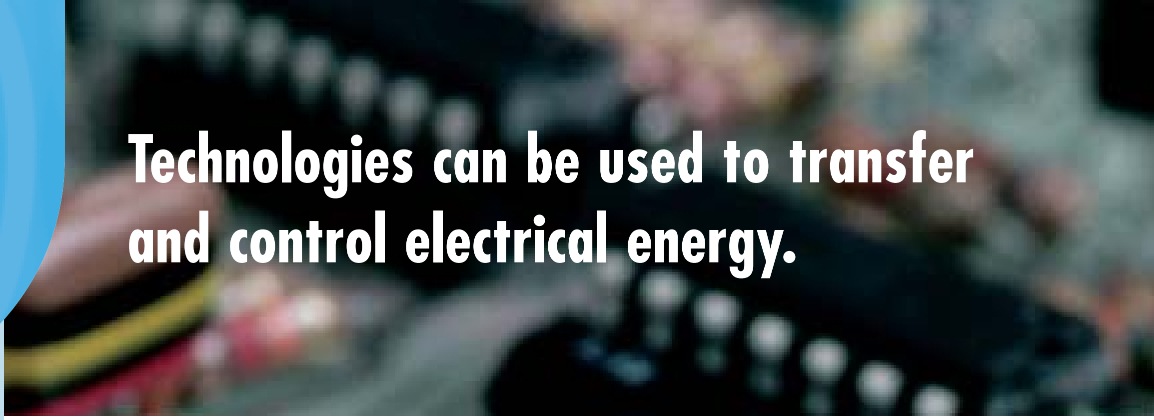
Extend Your Understanding

10. Computer circuits can be damaged by static discharges. To prevent this, technicians usually wear an anti-static strap that is connected to the metal case of the computer. Explain how wearing such a strap protects computer circuits.
11. A tall tree stands in a yard, towering over a one-storey house. There are no other trees in the area. A car is parked on the street. Which object is most likely to be struck by lightning: the tree, the house, or the car? Explain your answer.

Focus On SCIENCE AND TECHNOLOGY

Scientific knowledge may lead to the development of new technologies. And new technologies may lead to scientific discovery. Think about what you learned and the activities you did in this section.

1. Describe one example from this section of how scientific knowledge led to a new technology, which then led to scientific discoveries.
2. What would someone who wanted to invent a new type of electrical cell need to know about electricity?
3. Describe one example of an electrical technology that is used in scientific research today.



2.0 Technologies can be used to transfer and control electrical energy.

Key Concepts

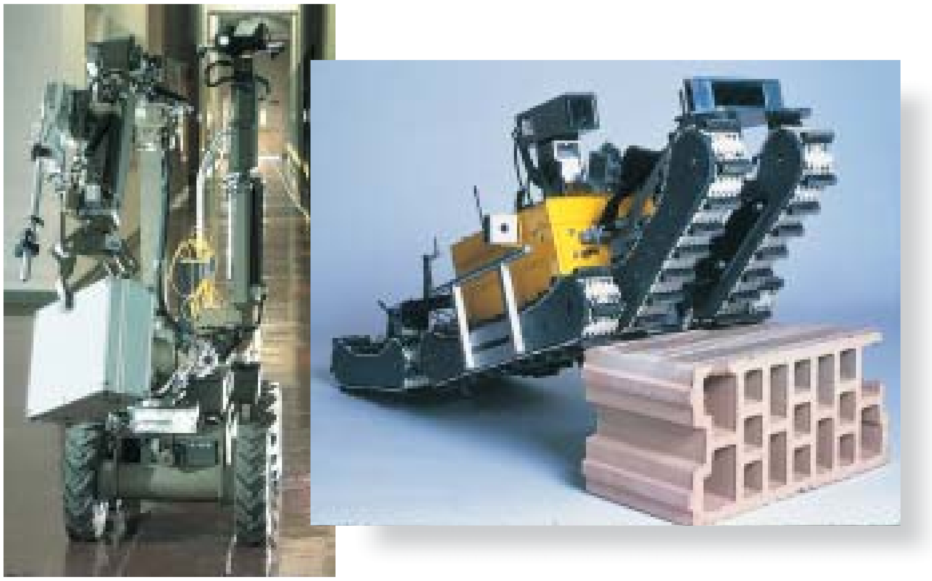
In this section, you will learn about the following key concepts:

- electric current
- circuits
- energy transmission
- measures and units of electrical energy
- electrical resistance and Ohm's law

Learning Outcomes

When you have completed this section, you will be able to:

- identify electrical conductors and resistors
- compare the resistance of different materials
- use switches and resistors to control current
- predict the effects of switches, resistors, and other devices
- use models to describe and relate electrical current, resistance, and voltage
- measure voltages and amperages in circuits
- calculate resistance using Ohm's law
- develop, test, and troubleshoot circuit designs
- draw circuit diagrams for toys, models, and household appliances
- compare and contrast micro-electronic circuits and circuits in a house



Specially equipped remote-control (RC) vehicles like the ones in these photos protect people from risky situations. Robotic video crawlers can be sent into dangerous or hard-to-reach places to provide remote "eyes" for experts. Bomb disposal robots can help with inspection, removal, and disposal of suspicious packages. These sophisticated RC vehicles can do a variety of difficult and dangerous tasks. They are powered with electric current and controlled with the help of special circuits.

When you manipulate the controls of an RC vehicle, it moves and turns. But behind these seemingly simple actions are devices that control the flow of electric current. A small battery in the transmitter unit that you hold provides current that allows the antenna to produce radio waves. These radio waves travel through the air and induce a current in the antenna on the RC vehicle. This antenna is connected to circuits. The circuits control current through wiring that leads to the battery-powered motors inside the vehicle. These control speed, turning, direction, and other special equipment such as limbs and video cameras.

The transfer and control of electrical energy in an RC vehicle is one example of the application of electrical technologies. In this section, you will learn about technologies for controlling electricity, how to measure electricity, and how to analyze and build electric circuits.

2.1 Controlling the Flow of Electrical Current

Figure 2.1 The controlled use of electricity creates a colourful neon display.

A neon sign has several interesting applications of electrical technology. First, electricity must travel all the way through the tube in order to make the neon gas inside glow. Second, the sign must be equipped with a control so it can be turned on and off. Third, the whole thing must be contained so that people nearby aren't accidentally electrocuted. These tasks can all be done by controlling the flow of electric current.

A Unique Circuit

Neon signs usually consist of a glass tube, twisted into the desired shape. The tube is filled with gas and metal terminals are sealed into the ends. The metal terminals of the tube are then connected to the positive and negative terminals of the electrical source. So the sign is a circuit, but unlike the wire circuits you saw earlier, this circuit includes a gas as a conductor.

Signs with more complex designs may have several different tubes, each with its own electrical connectors. These tubes may have special coatings or contain different gases that produce different colours. A mixture of neon and argon provides a purple light. Helium provides yellowish-white light.

Usually, neon gas is an insulator—it does not conduct electricity. But when current is applied to the tube, electrons in the neon atoms are "excited" by the added energy, and free themselves from the atoms. The negative electrons leave behind positive neon ions. This creates a mixture of charged particles inside the tube, which is excellent at conducting current. As the current continues to add energy to the neon gas, some of the electrons "fall" back into the neon ions, releasing their energy as the orange-pink neon light we see in the sign.

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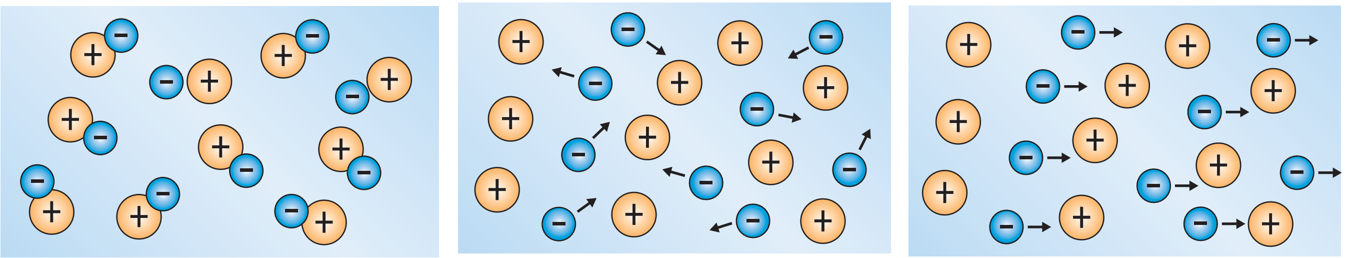
Semiconductors

Labelling a substance a conductor or insulator isn't always easy. Some substances, such as glass and rubber, make excellent insulators—they don't conduct at all. Many metals, such as copper and iron, are excellent conductors. Semiconductors are somewhere in between. Germanium and silicon are two commonly used semiconductor elements. At high temperatures, they act like conductors. At low temperatures, they act like insulators.

Conductors and Insulators

As shown in Figure 2.2, electrons in insulators are tightly bound to the positive nucleus of their atoms. They resist moving away from the nucleus. In conductors, the electrons are not as tightly bound. They are freer to move. However, a current will flow only when the conductor is connected to an electrical source. The electrons then move toward the positive end of the voltage source. Another way of saying this is that the electrons move when a voltage is applied.

Figure 2.2 is a simplification to help you see how electrons generally behave in insulators and conductors. However, the atomic structure of a substance affects how well it conducts or insulates. In other words, some substances are more resistant to electron flow than others. Depending on how you want to control current, you may choose to use a substance that is an insulator, conductor, or partial conductor.



(a) Insulator: The electrons (–) are bound tightly to the nuclei (+) so they resist movement.

(b) Conductor with no voltage applied: The electrons are not as tightly bound to the nuclei. They can drift away from the nuclei but do not flow in any one direction.

(c) Conductor with voltage applied: The electrons flow toward the positive terminal of the voltage source.

Figure 2.2 Electrons in a conductor are free to move, while those in an insulator are not.

Superconductors

Metals such as silver, copper, mercury, and gold are all excellent conductors, but they are not perfect conductors. Electrons travelling through them encounter some resistance. This resistance varies from metal to metal, which is why one metal is a better conductor than another. However, it is possible for metals to superconduct. **Superconductors** are perfect conductors—they have no resistance to electron flow. Superconductivity was discovered by Dutch physicist Heike Kamerlingh Onnes in 1911 when he brought the temperature of mercury down to near absolute zero (−273°C) using liquid helium. At this temperature, Onnes found that mercury was a perfect conductor, with no resistance to current flow. Since that time, substances have been found to superconduct at temperatures well above absolute zero. But these temperatures are still too low for practical applications. Research into superconductivity continues.

ACTIVITY D-3

Inquiry

INVESTIGATING CONDUCTIVITY

The Question

How does the conductivity of different solutions compare?

The Hypothesis

Reword the question to form a hypothesis.

Procedure

1. Design a table to record the conductivity readings of the solutions you will test.
2. Put 50 mL of distilled water into a 250-mL beaker.
3. Place the metal tips of your conductivity tester in the distilled water.
4. Record the conductivity reading of the distilled water in your table. If your conductivity tester is a light bulb, describe the brightness of the bulb.
5. Repeat steps 2–4 with 50-mL samples of tap water, salt water, vinegar, copper(II) sulfate solution, and any other solution you wish to test. After each conductivity measurement, empty the beaker and rinse it with distilled water. Also wipe off the tips of the conductivity tester. Make sure that you insert them to the same depth in each solution.
6. When you have finished testing the solutions, follow your teacher's instructions for disposing of them.

Materials & Equipment

- 100-mL graduated cylinder
- 250-mL beaker
- distilled water
- conductivity tester
- tap water
- salt water
- vinegar
- copper(II) sulfate solution
- other solutions provided by your teacher

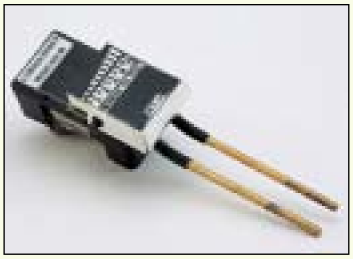


Figure 2.3 A conductivity tester

Analyzing and Interpreting

7. Were there differences in conductivity among the solutions you tested? How could you tell?
8. Account for the differences in conductivity among the solutions by explaining what is happening in the solutions.

Forming Conclusions

9. Write a summary of your results that answers the question: How does the conductivity of different solutions compare?

Applying and Connecting

Solution conductivity is a powerful tool for studying the environment. Electrical conductivity (EC) increases with the number of ions dissolved in water. This means that conductivity readings can be used as indicators of water quality and the composition of the surrounding soil. Higher EC values in water can be natural because of minerals dissolved in the water; for example, in lakes that have limestone basins. But higher EC levels can also signal the presence of pollutants in a watershed because pollutants are a source of additional ions. An example is the use of salt on roads as a safety measure to remove ice. Unfortunately when the snow and ice melt, large amounts of salty run-off water enter lakes and streams and can be harmful to aquatic organisms. EC readings can be used to monitor the concentration of salt and other pollutants in the water.

Extending

Design and conduct an experiment to investigate the relationship between the amount of a dissolved solute (such as salt) and electrical conductivity.

Using Conductors, Resistors, and Insulators

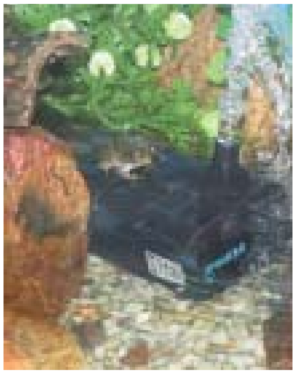


Figure 2.4 This pump is sealed in waterproof rubber and plastic.

Engineers need to know how well different materials conduct electricity so they can design devices that are both effective and safe. For example, sometimes electricity must be used around water. This is dangerous unless all the current-carrying wires are carefully insulated and sealed from the surroundings.

In some applications, a type of conductor called a **resistor** is useful. A resistor allows electric current to pass, but provides resistance to it. This limits the amount of current. For any given voltage, more current flows through a resistor with a low resistance than through one with a high resistance. **Resistance** is a measure of how difficult it is for electrons to flow through a substance. It is measured in **ohms**. The symbol for ohm is Ω, the Greek letter omega.

The more resistance a substance has, the more the substance gains energy from each electron that passes through it. The energy gained by the substance is radiated to its surroundings as either heat or light energy.

Figure 2.5 shows two examples of metal resistors that produce heat and light.

Figure 2.5 The tungsten filament in an incandescent bulb and the element in a heater both radiate heat and light because of resistance.

Solutions can also be resistors. The more charged particles in a solution, the better it conducts. Distilled water is not a good conductor because it contains only water molecules. These molecules have no electrical charge. Tap water and water in the environment are conductors because of the many dissolved minerals they contain. Knowing the conductivity of a particular solution can be of practical use. For example, you could use a simple conductivity measurement to check the purity of a batch of distilled water. In a factory, a technician may use conductivity to check whether a solution for an industrial process has been mixed properly.

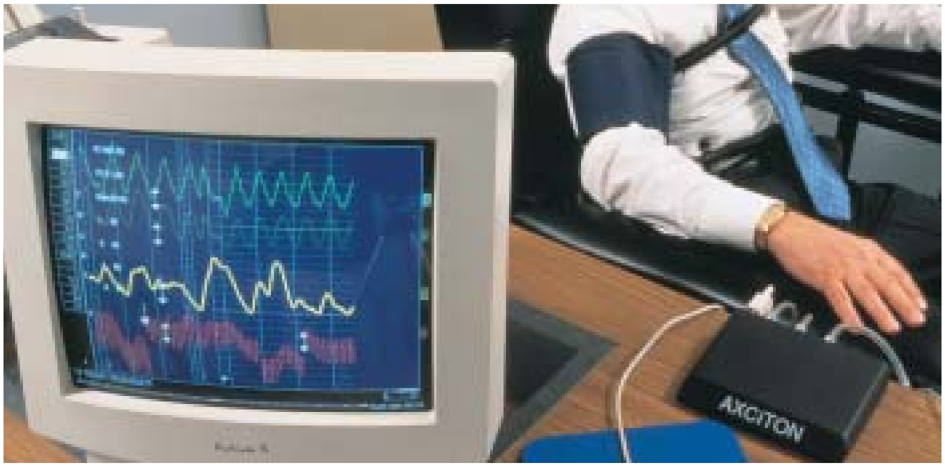


Figure 2.6 A person taking a polygraph test

The polygraph machine or "lie detector" is another application of resistance. It usually measures skin resistance, blood pressure, and respiration. All of these change when people are under stress. Sweat is mostly a salt solution, so it contributes to the change in skin resistance. To measure this change, two or more metal electrodes are attached to the skin of the person taking the test. In theory, the person is under the most stress when lying in response to a question. Thus, a lie should cause an increase in conduction between the electrodes. This would show up as a peak on the graph plotted by the polygraph machine.

mathLink

The more resistance a component has, the lower its conductivity, and vice versa. Resistivity (R) and conductivity (G) are inversely related. The equation for this relationship is $R = 1/G$.

If chemicals are added to a sample of solution so that its conductivity doubles, what happens to its resistivity? How does the conductivity change if the sample is diluted so much that its resistivity quadruples?

QUICKLAB

Make Your Own Dimmer Switch

Purpose

To control the amount of current flowing through an electrical device

Procedure

1. Connect all the materials to form a big loop, as shown in Figure 2.7.
2. Make sure the Nichrome wire is connected by the ends, making all of the wire part of the circuit. Note the brightness of the bulb.
3. Now move the alligator clips on the Nichrome wire closer together, so that only a small amount of the Nichrome wire is part of the circuit. Note the brightness of the bulb.
4. Continue to observe the bulb as you slide one of the alligator clips back and forth on the Nichrome wire.

Question

5. What happened to the brightness of the bulb when you moved the alligator clips? Explain your observations.

Materials & Equipment

- battery
- connecting wires
- bulb and socket
- about 40 cm of 32-gauge Nichrome wire
- board with screws (optional)

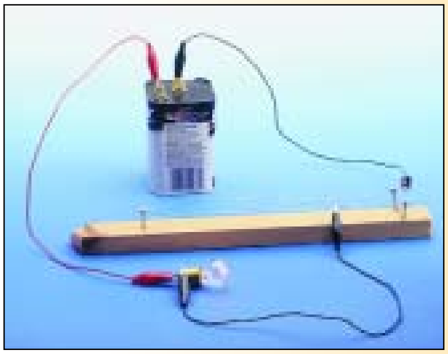


Figure 2.7 Apparatus for controlling current

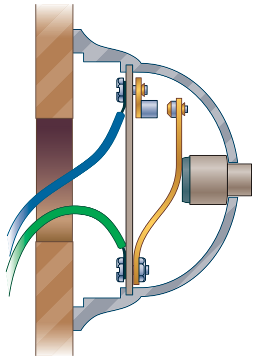


Figure 2.8 This doorbell button is an example of a momentary switch. As soon as you release the button, the contact arm springs back and opens the switch. The switch is closed only for a moment.

Switches and Variable Resistors

A switch is usually the best method for turning electricity on and off in a circuit. Although there are thousands of kinds of switches, they all work on the same basic principle. Look at Figure 2.9. When a switch is on, two conductors are pressed together so that current can flow from one to the other. When the switch is off, the conductors are separated and no current flows. Most switches are enclosed in an insulated casing or a metal box to prevent shocks and short circuits. The casing also keeps dust and other contaminants out of the switch mechanism.

Sometimes you want to change the current flow gradually in a circuit, rather than just turning it on or off. For example, you may have a light switch in your house that's used to dim the lights. This type of control device is called a **variable resistor** or **rheostat**.

Rheostats can increase or decrease the amount of current in a circuit by adjusting the portion of the resistor that the current travels through. Examples of rheostats are volume controls on stereos and foot-operated speed controls for sewing machines. As you turn the knob or press the pedal, you change the amount of current flowing through the circuit.

*re*SEARCH

Discovering Electricity

Michael Faraday, Luigi Galvani, and Joseph Henry all made major contributions to the science of electricity. Write a brief profile of each person, describing his life and work. Begin your information search at www.pearsoned.ca/scienceinaction.

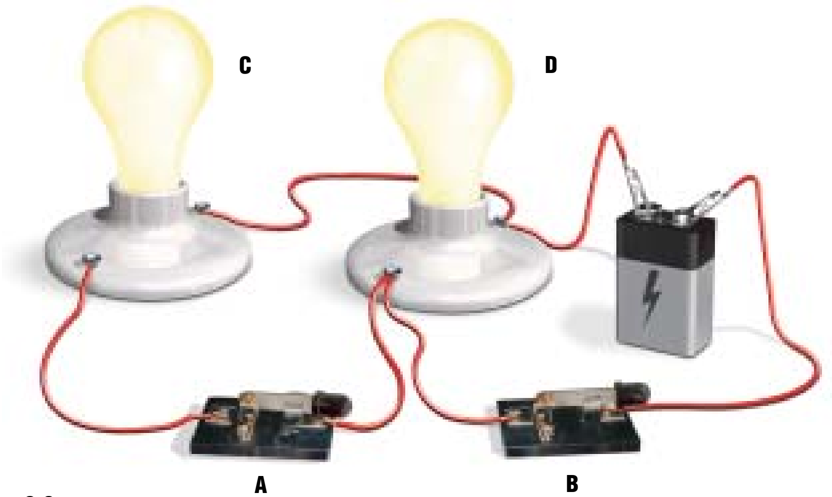
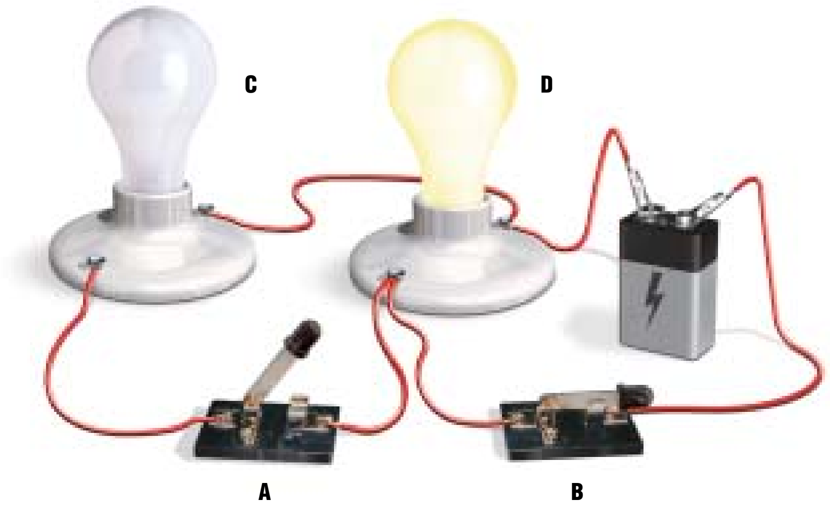


Figure 2.9
(a) Both switches are closed, so the current flows through both bulbs.



(b) Switch A is open, so the current cannot flow through bulb C.

Check and Reflect

Key Concept Review

1. What is the difference between a conductor and an insulator?
2. What is a resistor?
3. How does a switch control current flow?
4. How might a polygraph machine indicate someone is lying?

Connect Your Understanding

5. Why do some substances conduct while others do not?
6. Use a labelled diagram to explain how electrons behave in a conductor when:
   a) no voltage is applied
   b) voltage is applied
7. You have two wires made of two different metals (metal A and metal B). Both wires are the same thickness and length. In one circuit, you use the metal A wire. In another identical circuit, you use the metal B wire. The metal A wire gets hot, while the metal B wire does not. Explain.
8. A friend insists that using an electric drill in his flooded basement is safe because, he says, "Water doesn't conduct electricity." What would you say to your friend?

Extend Your Understanding

9. You have built a fountain for your backyard pond. How might you control the pump speed so that the water doesn't spray too high or too low?
10. Wood burning is a popular hobby. Would a wood-buring tool work well if its heating element had a very high resistance? Explain your answer.

Figure 2.10 Wood burning

Careers and Profiles

Computer Network Technician

A computer network technician helps computers communicate. This job involves dealing with many computers, electronics systems, and wires.

A computer network technician must have a good understanding of switches and wiring. You have to run new wires to connect computers to the network, and you have to understand computer operating systems in order to configure computers to the network properly. You have to be a good troubleshooter in order to find components that are malfunctioning in a network. Your job might include maintaining the computers and wiring for a local area network (LAN) in an office. In critical networks, you also maintain redundant systems. These are special computers that can run the network if the main computer fails.

Figure 2.11 Computer network technician at work

1. How does this job affect how much work other people do?
2. What kind of training would you need to be a computer network technician? Is this the type of career that would sometimes require extra training? Why or why not?
3. Does a computer network technician sound like an interesting career? Why or why not?

infoBIT

Another Measure of Electricity

Electrical charge is measured in coulombs, named after the French scientist Charles A. Coulomb. In the late 1700s, Coulomb measured the electrical force that charged objects exerted on each other. One coulomb is a large amount of charge—it equals 6.25 billion billion electrons.

2.2 Modelling and Measuring Electricity

So far in this section, you have learned many different terms to describe electrical current. Voltage, current, resistance, conductors, and cells all describe different aspects of electron flow. But all these terms can be confusing. Since electrons "flow" through conductors and resistors, a model using water can be helpful for understanding electricity.

Like flowing water, electricity must come from a source. Like water smashing into rocks in rapids, electricity encounters resistance. The more water, the more powerful the current in a river. The more electrons, the more powerful the current is in a conductor.

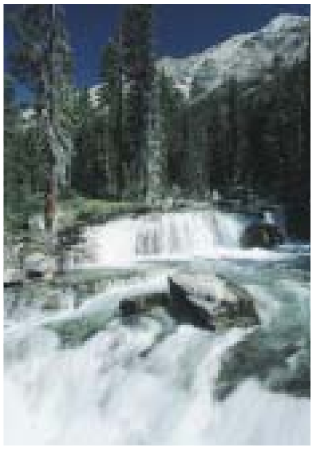


Figure 2.12 The flow of this Rocky Mountain stream is like the flow of electricity.

For both water and electricity, the source must be constantly replenished for flow to continue. Through the water cycle, snow is deposited on the mountain in Figure 2.12. The melting snow keeps the stream flowing. For electricity, a source such as a generator or cell keeps the electricity flowing from a negatively charged terminal to a positively charged one.

If the snow all melted away, the water flow would stop. If the generator is shut down or when the cell is used up, the electricity stops flowing.

***QUICK*LAB**

Funnel Power

Purpose

To build a model that represents different amounts of current and resistance in a circuit

Procedure

1. Set up the ring stand, beaker, tubing, and the smaller funnel as shown in the cartoon.
2. Have your partner start the timer as you start to pour 150 mL of water into the funnel quickly and smoothly. When all the water is in the beaker, stop the timer. Record the time.
3. Repeat step 2 with the larger funnel and tubing. Record the time.

Question

4. Explain how your results can serve as a model of current and resistance.

Materials & Equipment

- 2 funnels with different-size drain holes
- 2 equal lengths of tubing of different diameters to fit on the two funnels
- beaker
- water
- ring stand
- timer

MODELLING VOLTAGE

Unless there is a change in elevation, water doesn't flow—it simply sits in a pool. If you pump water up a hill, it gains gravitational potential energy, and then flows back down. In a similar way, a cell, battery, or generator "pumps" electrons to a point with a higher electric potential (voltage). Electricity will not flow without a difference in electrical potential, just as water does not flow without a difference in gravitational potential energy.

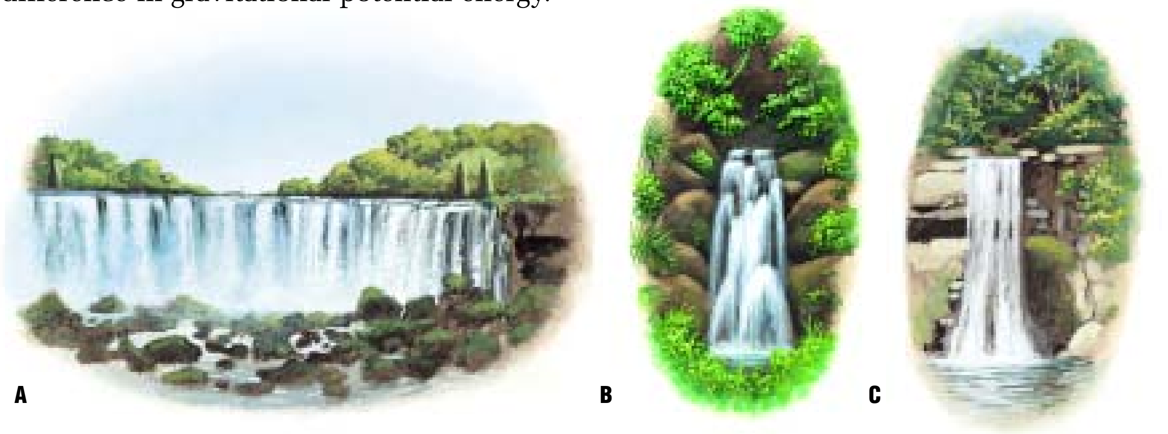


Figure 2.13 Waterfalls can model current, voltage, and resistance in a circuit. Waterfall A has a large flow of water. Waterfalls B and C are the same height, but B has more rocks that slow the flow. As an electrical circuit, waterfall A would have the greatest flow of current. Waterfalls B and C would have similar voltages, but B has greater resistance, and therefore less current flow.

The water in a garden fountain might be only a metre from the ground, while the water in a town's water tower might be 50 metres from the ground. The water from the water tower has much more gravitational potential energy and flows to the ground with greater force. Similarly, the high-voltage electrons from a generating station have more electrical potential energy than low-voltage electrons from a flashlight battery.

MODELLING RESISTANCE AND CURRENT

The flow of water in pipes is another useful model of electricity. Suppose you were using a reservoir to provide irrigation water for a field. You have to decide what size of pipes to use to drain the reservoir. A pipe with a small diameter might be easier to hook up. However, the longer and thinner a pipe is, the more resistance it has to the flow of water. A pipe with a bigger diameter has less resistance, which allows a greater flow of water.

Similarly, the amount of resistance in a circuit affects the electrical current. For any given voltage, current decreases if you add resistance. As with water flow, you get the least resistance with a short, wide path with no obstructions. The shorter and thicker the wire, the less resistance it creates for electrons. The flow of current will be reduced if it has to pass through a resistor.

Figure 2.14 Resistance in a stream or pipe reduces the flow of water.

Ohm's Law

Figure 2.15 Georg Simon Ohm

German scientist Georg Simon Ohm made exciting electrical discoveries in the early 1800s. He experimented with many different substances, and in 1826, he was able to prove a mathematical link between voltage (V), current (I), and resistance (R). The unit of resistance, the ohm, was named in his honour. **Ohm's law** states that as long as temperature stays the same:

- the resistance of a conductor stays constant, and
- the current is directly proportional to the voltage applied.

In other words, if you increase the voltage in a circuit, the current also increases.

Ohm's law also covers changes in resistance. If the voltage stays the same, but a resistor of greater value is used, then the current decreases. This table shows how to use Ohm's law.

Ohm's Law

Quantity	Symbol	Unit	Calculated with Ohm's Law	Measured with
Voltage	V	volts (V)	$V = I \times R$	voltmeter
Current	I	amperes (A)	$I = \frac{V}{R}$	ammeter
Resistance	R	ohms (Ω)	$R = \frac{V}{I}$	ohmmeter

math Link

In a circuit where voltage is kept constant, what happens to current if resistance is doubled? Quadrupled?

Applying Ohm's Law

The simple math of Ohm's law is a powerful tool for those who design or analyze circuits. As long as two of the values are known, the third one can be calculated. This means it is possible to calculate the value of an unknown resistor, or figure out the value of resistor needed to obtain a particular current.

Example

An electric stove is connected to a 240-V outlet. If the current flowing through the stove is 20 A, what is the resistance of the heating element?

Steps to Solving the Problem	Information and Solution
1. Identify known quantities.	current (I) = 20 A, voltage (V) = 240 V
2. Identify the unknown quantity.	resistance (R)
3. Use the correct formula.	$R = \frac{V}{I}$
4. Solve the problem.	$R = \frac{V}{I} = \frac{240\text{ V}}{20\text{ A}}$ $\boldsymbol{R = 12\ \Omega}$

While Ohm's law is a good tool for circuit analysis, it's not perfect. If the temperature of a resistor changes, its resistance changes as well. Generally, resistance is lowest when a conductor is cool. As the temperature increases, resistance increases. For example, a filament in a light bulb often has 10 times its normal current flowing through it at the instant it is switched on. This current heats the filament white hot in a fraction of a second. The huge rise in temperature greatly increases the filament's resistance, which reduces the current flowing through it. As explained in subsection 2.1, this increase in resistance causes the filament to glow. Light bulbs sometimes "blow" when they are switched on because of the sudden temperature change and other forces caused by the large initial current.

SKILL PRACTICE

USING OHM'S LAW

1 A 30-V battery creates a current through a 15-Ω resistor. How much current is created?

2 A motor has an internal resistance of 40 Ω. The motor is in a circuit with a current of 4.0 A. What is the voltage?

3 A current of 625 mA runs through a bulb that is connected to 120 V. What is the resistance of the bulb?

USING TEST METERS

In subsection 1.2, you learned how a voltmeter is used to measure voltage. The voltmeter is just one of various types of meters used to measure electricity in a circuit. These devices use a small amount of current to move a needle across a specially calibrated scale or to display numbers on a digital readout. Meters are very useful, but they must be used properly to get accurate readings and avoid damage to their sensitive mechanisms.

Voltmeters

Recall that voltage is the potential *difference* between two points. To measure the potential difference across a cell, battery, resistor, or other device in a circuit, each terminal of the device must be connected to the appropriate positive or negative terminal of a voltmeter. Many electricians refer to the potential difference across a resistor or device as **voltage drop**. Note that meters used to measure small voltages are sometimes called **millivoltmeters**.

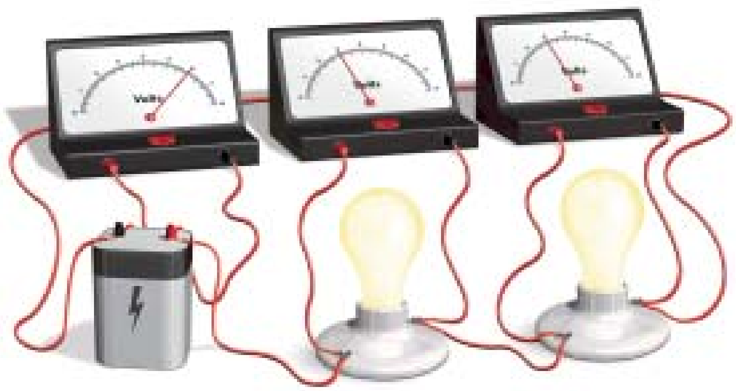


Figure 2.16 These voltmeters read the voltage difference across the items in this circuit.

Ammeters

Ammeters are used to measure electric current in amperes. Recall that current is the *rate of flow* of electricity in a circuit. It is a measure of how many electrons move past a point in a circuit each second. To measure this flow, an ammeter must be placed so that the current flows through it.

If a circuit consists of only one continuous loop, you can insert the ammeter between any two circuit components. Figure 2.17 shows an ammeter connected in a simple circuit. It could be attached at another place in the circuit and would still show the same reading. The current is the same at every point in the loop, so the ammeter can measure it anywhere. Meters used to measure small currents are sometimes called **galvanometers**.

SKILL PRACTICE

USING AMMETERS

Connect a battery, light bulb, and ammeter in a loop as shown in Figure 2.17. Record the reading on the ammeter. Now add another bulb to the loop. Record that ammeter reading. Repeat this until you run out of bulbs. Explain your observations.

Suppose you repeated this activity with two electrical cells connected end to end (positive to negative). Predict what the ammeter readings would be. Explain your answer. Repeat the experiment to see if your prediction is correct.

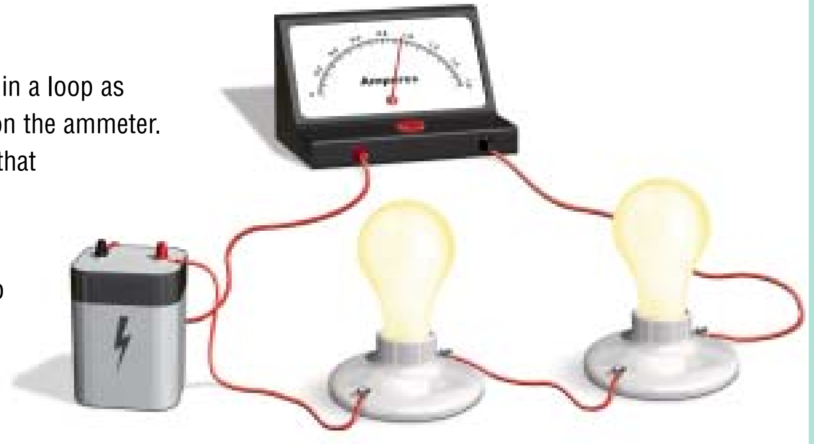


Figure 2.17 This ammeter will read the current for the circuit. The circuit shown has only one pathway, so the current is the same everywhere in the circuit.

Figure 2.18 Multimeters can be used to measure voltage, current, or resistance.

Multimeters

Often, meters are made with several different measuring circuits mounted in the same case. By turning a selector switch on the front of the case, you can set such **multimeters** to measure voltage, current, or resistance in a circuit. You must be careful that you have selected the right setting for the quantity you want to measure.

When you read a multimeter with a needle display, you must first find the scale that corresponds to the setting on the multimeter's selector switch. If the needle falls between numbers on this scale, you can estimate the last digit of your reading. For example, if the needle rests between 2 and 3 volts on the scale, but is slightly closer to the 2, you may estimate the reading as 2.4 volts. Digital displays do not require estimates. Some digital meters even allow you to select the level of precision (how many digits are displayed). Meters range from extremely precise instruments to simple, inexpensive testers that are accurate to only ± 5% of a full-scale reading.

ACTIVITY D-4

Inquiry

WHAT'S THE RESISTANCE?

The Question

Do different materials have different values of electrical resistance?

Materials & Equipment

- D-cell and holder
- 10-cm length of copper wire
- 10-cm length of Nichrome wire
- 10-cm length of solid graphite (pencil lead)
- 10-cm length of rubber tubing
- optional: 10-cm lengths of various other materials
- connecting wires
- voltmeter
- ammeter or current sensor
- ruler
- calculator

Caution!
The wires may get hot.

Procedure

1. In your notebook, set up a table for recording your data. The table should include the following headings: Substance, Length connected (10 cm or 1 cm), Voltage (from step 2), Current, and Resistance. In the "Resistance" column you will calculate the resistance for each observation.
2. Use connecting wires to connect each end of a D-cell to a terminal on a voltmeter. Record the voltmeter reading in your table. Disconnect the voltmeter.
3. Connect one wire from the D-cell to a terminal of an ammeter. Attach another connecting wire to the other terminal of the ammeter.
4. Clip the free ends of the connecting wires onto the ends of a 10-cm length of pencil lead. Record the reading on the ammeter.
5. Move the clips on the pencil lead so that they are only 1 cm apart. Record any change in the reading on the ammeter.
6. Repeat steps 4 and 5 for the other lengths of substances that you have.

Analyzing and Interpreting

7. Use Ohm's law ($R = V/I$) to calculate the resistance for each current recorded in your table.
8. Which substance had the greatest resistance? Explain any differences in resistance among the substances.
9. What was the effect of moving the connecting wires so that the current travelled through a shorter length of the conductor? Explain.
10. How precise were your measurements? Were there any sources of error that could affect the accuracy of your results?

Forming Conclusions

11. Write a summary that answers the question: Do different materials have different values of electrical resistance? Use your data to support your answer.

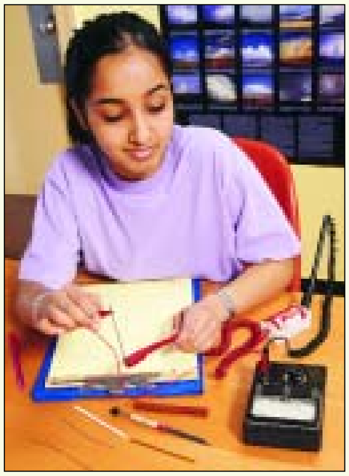


Figure 2.19 Determining resistance

Applying and Connecting

You have probably seen a computer plugged into a surge protector instead of directly into a wall socket. Surge protectors protect sensitive electronic equipment from occasional sudden increases in voltage. These devices rely on special conductors that have variable resistance. If voltage is at normal levels, the current flows normally through the circuit. But if voltage is too high, the resistance of the conductor drops. This allows the potentially dangerous current to be conducted away from the normal circuit to a safety ground wire.

Extending

Alberta homes have to cope with long, cold winters. Sometimes, the water pipes of homes will freeze causing considerable damage. If you had to construct a flexible wrap that you could plug in and wrap around water pipes to keep them warm, what materials would you use? Explain.

Figure 2.20 Resistors come in many shapes and sizes. Remember that the type of material affects the resistance.

Types of Resistors

A wide variety of resistors are made for different applications, especially in electronics. For example, radios and televisions contain dozens of different resistors. Resistors are available with values covering the whole range between conductors (very low resistance) and insulators (very high resistance).

Resistors can be made with a number of techniques and materials, but the two most common types are wire-wound and carbon-composition. A wire-wound resistor has a wire made of heat-resistant alloy wrapped around an insulating core. The longer and thinner the wire, the higher the resistance. Wire-wound resistors are available with values from 0.1 Ω up to 200 kΩ. The wire for a 200 kΩ resistor is very thin.

Carbon-composition resistors are made of carbon mixed with other materials. The carbon mixture is moulded into a cylinder with a wire at each end. By varying the size and composition of the cylinder, manufacturers produce resistances from 10 Ω to 20 MΩ. Moulded carbon resistors are cheaper to make than wire-wound resistors, but less precise.

*re*SEARCH

Superconductors

Superconductors may bring radical changes in electronics and power transmission. Find out how superconductors might change the world of electrical technology. Prepare a multimedia presentation to summarize your research. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. How is current related to voltage in a circuit?
2. How is current related to resistance in a circuit?
3. What is the difference between a galvanometer and a multimeter?
4. What does the term "voltage drop" mean?

Connect Your Understanding

Use the Ohm's law table on page 306 to answer questions 5 to 9.

5. A bulb of 15-Ω resistance is in a circuit powered by a 3-V battery.
   a) What is the current in this circuit?
   b) What would the current be if you changed to a 45-Ω bulb?
6. A digital recorder plugged into a 120-V outlet has an operating resistance of 10 000 Ω. How much current flows in this device?
7. An electric heater draws 10 A from a 120-V source. What is the heater's resistance?
8. A current of 1.5 A flows through a 30-Ω resistor that is connected across a battery. What is the battery's voltage?
9. A current of 12 A flows through a vacuum cleaner motor that is plugged into a 120-V source. What is the internal resistance of the vacuum motor?

Extend Your Understanding

10. Use the waterfall model to explain flowing electricity. Make sure to include the terms voltage, current, and resistance in your description.

2.3 Analyzing and Building Electrical Circuits

The toy robots in Figure 2.21 have ingenious circuits. The most economical way to connect all the components in a circuit is in a simple loop. But these circuits must be designed so that one component does not depend on the others. For example, it would be frustrating to the user if the whole device stopped working simply because one small light bulb burnt out. With careful attention to circuit design, engineers make sure these devices can perform the tasks that the user wants.

Figure 2.21 These toy robots are controlled by electrical circuits.

QUICKLAB

Flashlight Design

Purpose

To explore circuits by designing a simple flashlight

Procedure

1. Draw a diagram to show how you think the electrical circuits inside an ordinary flashlight are set up.
2. Use cells, connecting wires, switches, and bulbs provided by your teacher to build your own model flashlight based on the diagram you've made.

Question

3. Suppose you had to design an emergency flashlight with a light at each end. How would you add the second bulb to your flashlight without making the first bulb dimmer?

Materials & Equipment

- dry cells
- connecting wires
- switches
- bulbs and holders

Circuit Drawings

Engineers and designers of electrical circuits use special symbols that show the components and connections clearly. These symbols make it easier to plan and analyze a circuit before you build it. A drawing made with these symbols is often called a **schematic** or **schematic diagram**.

Parts of a Circuit

Schematics can sometimes seem complicated, but all circuits have four basic parts: sources, conductors, switching mechanisms, and loads.

- A source provides energy and a supply of electrons for the circuit.
- A conductor provides a path for current.
- A switching mechanism controls current flow, turning it on and off, or directing it into different parts of the circuit.
- A load converts electrical energy into some other form of energy.

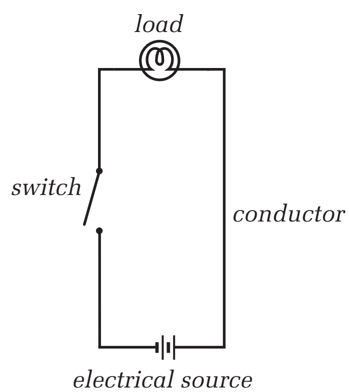
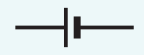
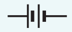


Figure 2.22 The four basic parts of an electrical circuit

*info***BIT**

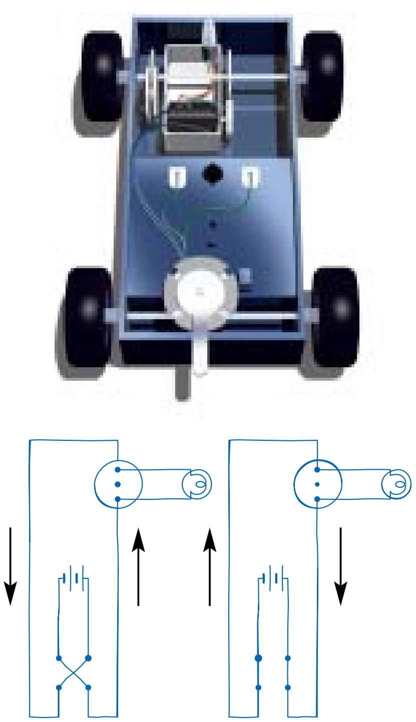
Incredible Shrinking Circuits

Before the 1950s, vacuum tubes were used to control current in electrical circuits. These were so bulky that early computers filled entire rooms. Vacuum tubes have been replaced by tiny components that make today's hand-held computers thousands of times more powerful than the old room-sized ones.

Symbol	Represents	Description
	conductor	conducts electricity through circuit
	cell	stores electricity (large bar is positive)
	battery	combination of cells
	lamp	converts electricity to light
	resistor	controls the amount of current in the circuit
	switch	opens and closes circuit—allows current to flow
	ammeter	measures amount of current in circuit
	voltmeter	measures voltage across a device in a circuit
	rheostat	variable resistor
	motor	converts electricity to mechanical energy
	fuse	melts if current in circuit is too high

Knowing the basic electrical symbols can help you analyze existing circuits. By studying the pathways of wires and components in a device, you can draw a schematic for the circuit. This drawing can make it much easier to understand where the current flows and how the device functions.

(a)



(b) forward (c) backward

Figure 2.23 A toy bulldozer and schematics for its circuit. Arrows show direction of current flow.

Circuit Analysis Example—Bulldozer

A student was curious about the toy bulldozer shown in Figure 2.23(a), so she decided to do a circuit analysis of it. She determined that the bulldozer moves forward when its switch is moved to the left and backward when the switch is moved to the right. In its middle position, the switch turns the bulldozer off. A bulb on top of the bulldozer lights up when it moves in either direction. Taking the bulldozer apart, the student determined that it has two loads, a motor and a bulb. She also found two 1.5-V cells that act as the source and a switching mechanism that appears to connect the ends of four wires. She carefully followed the conductors through the whole circuit and produced two schematics showing the circuits for forward and backward movement of the bulldozer. Note that, for clarity, conductors in schematic diagrams are drawn as straight lines, even though the wire may twist and turn in the device.

Parallel and Series Circuits

You may have noticed burned-out bulbs in decorative displays. In order for a bulb to operate, current must travel through it. Sometimes the bulbs are connected in a single string with the current running through each bulb in turn. That means the whole string goes out if any of the bulbs burns out or becomes loose in its socket. Circuits can be designed to avoid this problem.

Series Circuits

The circuit in which the current passes through each bulb in turn is called a **series circuit**. In a series circuit, there is only one pathway for the current, as shown in Figure 2.24. If that pathway is interrupted, the whole circuit cannot function. The other problem with series circuits is that adding components increases the total resistance of the circuit. This decreases the current. Thus, adding an extra bulb to a series string of lights makes all the bulbs dimmer. However, series circuits do have an important use. In household circuits, switches are wired in series with other components (e.g., wall plugs, lights). This makes it possible to turn off all the electricity in the circuit.

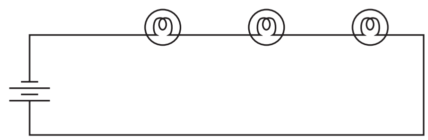


Figure 2.24 Series circuit—there is only one path for current.

Parallel Circuits

Many sets of decorative lights are not connected in series, but in parallel. **Parallel circuits** have a separate current path for each section of the circuit (Figure 2.25). In a parallel-wired string of lights, for example, each bulb has its own path to the current source. An interruption or break in one pathway does not affect the rest of the pathways in the circuit. Similarly, adding a new pathway with more resistors does not affect the resistance in any of the other pathways. In fact, adding extra resistors in parallel decreases the *total* resistance of the circuit. This might seem strange, but remember that adding more paths for the current to take means less total resistance. Think about how much less resistance there is when you drink through two straws instead of one.

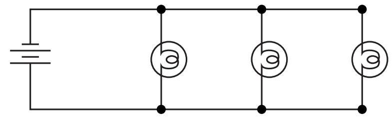


Figure 2.25 Parallel circuit—each component has its own path for current.

QUICKLAB

How Does That Toy Work?

Purpose

To determine the circuit design of an electronic device

Procedure

1. With a partner, carefully take apart the toy vehicle, noting all the parts of the electrical circuit.
2. Draw a schematic diagram for the toy vehicle. Label the loads, conductors, switches, and sources in your schematic. Have other students examine your toy and see if they agree with the schematic you have drawn.

Question

3. Can you design your own, unique toy vehicle? Draw a labelled picture for your toy vehicle and draw a schematic for its circuit.

Materials & Equipment

- an electric toy vehicle or an old or discarded electrical device
- basic tools

Caution!
Make sure your device is **not** plugged in.

Activity D-5

Problem Solving

Wiring a Secure and Safe Home

Recognize a Need

Home outdoor lighting that comes on automatically makes walking safer and deters burglars. How can you design circuitry for a home that includes an automatic exterior light?

Materials & Equipment

- connecting wires
- electricity source (batteries)
- battery holder
- bulbs
- switches
- photoconductor
- flashlight or lamp

Figure 2.26 Photoconductors

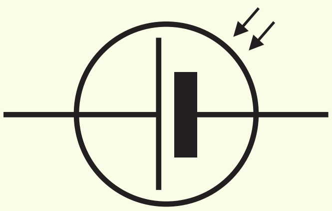


Figure 2.27 Photoconductor symbol

The Problem

You and your partner are charged with the task of designing the basic lighting circuit for the interior and exterior of a small home. The homeowner wants the circuit to include an outdoor light that comes on automatically when someone approaches. **Photoconductors** are devices that allow current to flow when they are exposed to light. Some photoconductors respond to the heat radiated by people or animals. In this lab, you will likely have a visible-light photoconductor and use a flashlight or a lamp to mimic an approaching person.

Criteria for Success

- Draw a schematic for a circuit that provides lighting for three rooms in a home, plus an outdoor light that will come on automatically. Your schematic should also include a method of controlling the electricity in the whole circuit—there must be a way to turn off the electricity to the circuit in order to make repairs or modifications safely.
- Build a circuit that represents the home lighting system you have designed.
  - ❍ The model circuit should have three room lights that can operate independently.
  - ❍ The model circuit's outdoor light should come on automatically (when tested with a flashlight).
  - ❍ The model circuit should have a switch that can successfully turn the electricity off or on for the entire circuit.

Brainstorm Ideas

1 Discuss and sketch designs for your lighting system. Keep in mind the criteria for success and convenience for the homeowner.

2 Consider the materials you have to work with. Remember that you must build what you include in your schematic. You will have access to general electrical supplies such as wires, bulbs, and switches. Do you have all the components you need?

3 Predict which of your designs will best meet the criteria for success.

Build a Prototype

4 Assemble the materials you will need to build your circuit model and construct it.

Test and Evaluate

5 When you have built your circuit, test it to see if it meets the criteria. If you used a visible light-activated photoconductor in your model, you can shine a light onto it to represent a person approaching the home.

Communicate

6 Have classmates examine and test your circuit. Examine the circuits your classmates have built, and suggest an improvement for one of their designs. If someone suggests a design improvement for your circuit, test it.

Applications of Series and Parallel Circuits

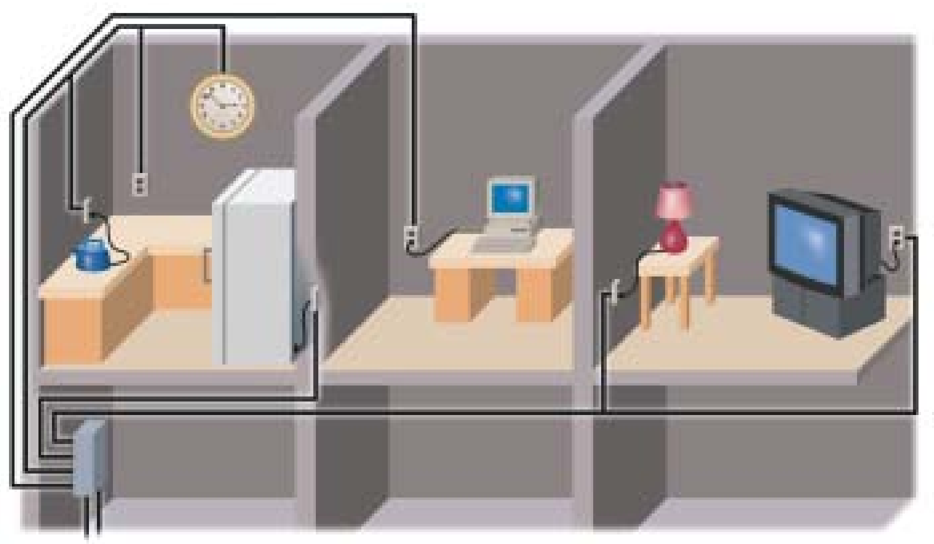


Figure 2.28 A typical home has many parallel circuits.

House Wiring

Household wiring is one of many applications that use parallel circuits. You wouldn't want the power to your refrigerator to go off if a bulb burnt out, would you? This could happen if you wired your lights and wall sockets in series instead of in parallel. However, as you read earlier, you must use a series circuit for switches. A switch in one branch of a parallel circuit controls only the devices in that branch. But a switch in series with all the branches controls all of them. It is an important safety feature to have switches wired in series because it is sometimes necessary to turn off the electricity in part or all of a home.

Microcircuits

Conventional switches are practical and convenient for a home. But for the tiny circuits in advanced electronics applications, **transistors** must be used instead. Transistors are often referred to as solid-state components because they are made of a solid material with no moving parts. Most transistors are constructed with three layers of specially treated silicon. These layers are arranged so that a small voltage through the middle layer controls a current between the outer layers. In this way, transistors can act as switches.

Microcircuits (also called **integrated circuits**) are made up of microscopic transistors and resistors. A microcircuit is exactly what its name suggests: a circuit on an extremely small scale. The latest microcircuits contain more than a million components in a square centimetre!

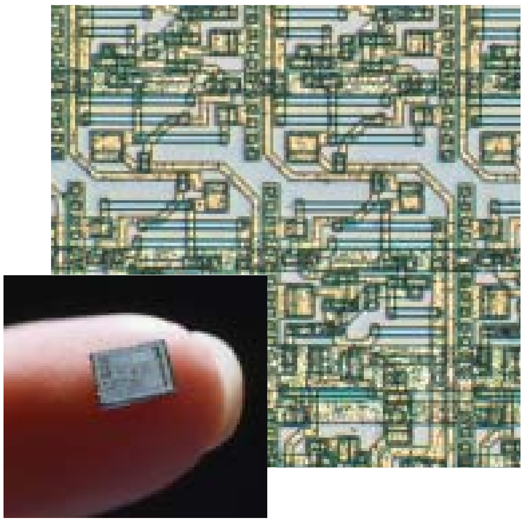


Figure 2.30 A microcircuit is often called a "chip" or "microchip."

reSEARCH

Diodes

Diodes are another type of solid-state component widely used in microchips and other circuits. Find out more about diodes and how they function.

Begin your search at www.pearsoned.ca/scienceinaction.

Summarize your research in a poster.

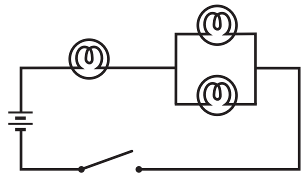


Figure 2.29 A combination circuit. The switch in this circuit can turn all the bulbs on or off.

Check and Reflect

Key Concept Review

1. What are the two types of electrical circuits? Draw a diagram of each type. Use the same components in each diagram.
2. What is a schematic? Illustrate the schematic symbols for a lamp, switch, rheostat, motor, fuse, and ammeter.
3. What is the difference between a cell and a battery in a schematic diagram?
4. How does resistance change as you add bulbs to a series circuit? Explain your answer.
5. What happens to all the bulbs in a parallel circuit when one bulb burns out? Explain your answer.

Connect Your Understanding

6. Is the wiring in a home likely to have series or parallel circuits? Explain your answer.
7. Examine circuits A and B in Figure 2.31.
   a) In which circuit will the bulbs not light up when the switches are closed?
   b) What can be done to correct the problem?

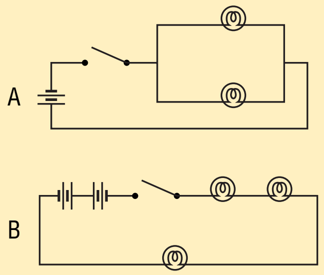


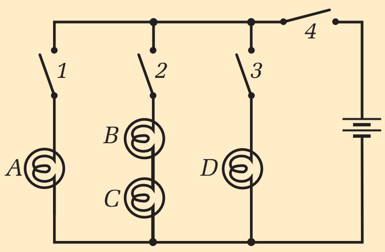
Figure 2.31 Circuits for question 7

8. What are the differences between the circuits you find in your house and the circuits on a microchip in a computer?
9. Why are motors, lamps, and other resistors considered "loads" in electrical circuits?

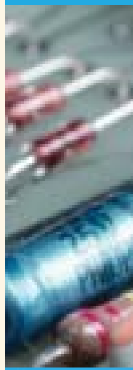
Extend Your Understanding

10. You have been asked to design a toy that looks like a dancing chicken. The toy must have an on/off switch and a motor that operates whenever a light shines on the toy. Draw a schematic for the toy.
11. The circuit in Figure 2.32 has four bulbs (A–D) and four switches (1–4). Use Figure 2.32 to answer the following questions:
    a) Which switch(es) should be closed to light bulbs A and D only? Explain.
    b) Which switch(es) should be closed to light bulb A only? Explain.
    c) Which switch(es) should be closed to light bulbs B and C only? Explain.
    d) How would you operate this circuit so that you could turn all the lights on and off with a single switch?
    e) Is it possible to operate bulbs B and C independently of each other? Explain. If not, suggest a change to the circuit that would make this possible.

Figure 2.32 Circuit for question 11



SECTION REVIEW



Assess Your Learning

Key Concept Review

1. Three quantities can be used to describe the flow of electricity in a circuit. Name each quantity, the unit of measurement, and the device used to measure it.
2. A student measures the current in a circuit as 0.50 A. The circuit has two resistors connected in series: one is 110 Ω and the other is 130 Ω. What is the voltage in the circuit?
3. A firetruck has a searchlight with a resistance of 60 Ω which is placed across a 24-V battery. What is the current in this circuit?
4. A table lamp draws a current of 200 mA when it is connected to a 120-V source. What is the resistance of the table lamp?

Connect Your Understanding

5. You are given an unmarked resistor of unknown value. You have a selection of electronics equipment, including connecting wires, cells, and meters. Describe how you would determine the approximate value of the resistor.
6. Draw a circuit schematic that contains two motors and a lamp, all connected in parallel. Include two switches in this schematic: one to operate the lamp and one to control the whole circuit.

Extend Your Understanding

7. Explain how the person drinking a milkshake through a straw in Figure 2.33 could be used as a model for electrical current in a resistor.
8. You find an old string of decorative lights in your grandparents' attic. The wiring appears safe, so you buy new bulbs for the string and screw them in. But none of them work when you plug in the string. Explain the likely cause of this problem.
9. Draw a circuit schematic for a battery-operated, variable-speed electric fan. What makes it possible to vary the speed of the fan?

Figure 2.33 Question 7: Drinking a milkshake through a straw

Focus On SCIENCE AND TECHNOLOGY

The products of technology are devices, systems, and processes that meet given needs and wants. For example, conductors, insulators, and resistors in your home control electricity used in lights, appliances, and other devices.

1. Describe two devices or systems you read about in this section.
2. What needs or wants were these devices designed to meet?
3. Name other devices or systems that meet these same needs. Why do you think different devices and systems are developed to meet the same needs?

3.0 Devices and systems convert energy with varying efficiencies.

Key Concepts

In this section, you will learn about the following key concepts:
- forms of energy
- energy transformation
- generation of electrical energy
- energy transmission
- measures and units of electrical energy

Learning Outcomes

When you have completed this section, you will be able to:
- identify, describe, and interpret examples of mechanical, chemical, thermal, and electrical energy
- describe evidence of energy transfer and transformation
- identify forms of energy inputs and outputs
- apply appropriate units, measures, and devices in determining and describing quantities of electrical energy
- construct, use, and evaluate devices for transforming mechanical energy to electrical energy and electrical energy to mechanical energy
- evaluate modifications to electrical devices
- apply the concepts of conservation of energy and efficiency to the analysis of energy devices
- compare energy inputs and outputs of a device, and calculate its efficiency
- describe techniques for reducing energy waste in common household devices

Energy is all around us in many different forms—light from lamps, sound from stereos, heat from furnaces and stoves. Yet we rarely think about how much energy we use in a day. It has been estimated that it would take 2800 hours of strenuous manual labour to produce as much energy as a typical Canadian uses daily. You would need a team of 350 people working for eight hours straight to supply the energy for just one person.

In this section, you will learn about four common forms of energy—chemical, electrical, mechanical, and thermal—and how they can be transformed into other forms. This will help you understand and measure energy inputs and outputs, and calculate the efficiency of devices and systems. You will also use this knowledge when you consider ways to reduce energy wasted by household devices.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Energy Forms and Transformations

Figure 3.1 Energy transformations make this work possible.

When we are exhausted we might say that we don't have the energy to do any more work—we know that work requires energy. In fact, the scientific definition of **energy** is the ability to do work.

In Figure 3.1, several kinds of energy are being used to do work. The lawnmower's motor is using electrical energy to spin the cutting blade, but the lawnmower will not move forward unless it is pushed. Chemical reactions in the muscles of the person pushing the lawnmower provide the energy to move it across the lawn. The chemical energy from her muscles is converted into the motion or mechanical energy of the lawnmower. Chemical energy is also converted to thermal energy as her muscles strain to push the lawnmower.

The photo shows examples of four common forms of energy and the transformations that occur between them. The following chart can help you understand these different forms of energy.

Four Common Forms of Energy

Energy Form	Description
Chemical Energy	The energy stored in chemicals. This is a form of potential or stored energy. This energy is released when chemicals react.
Electrical Energy	The energy of charged particles. Electrons are negatively charged. Electrical energy is transferred when electrons travel from place to place.
Mechanical Energy	The energy possessed by an object because of its motion or its potential to move. A thrown baseball has mechanical energy because of its movement and its potential to fall.
Thermal Energy	The total kinetic energy of all the particles in a substance. The faster a particle moves, the more kinetic energy it has. Compare two cups holding equal amounts of water: the one containing more thermal energy will feel warmer.

infoBIT

The Joule

Englishman James Joule (1818–1889) contributed greatly to our understanding of energy by proving that both mechanical work and electricity can produce heat and vice versa. In recognition of the importance of his research, scientists named the unit of energy the joule (symbol J).

GIVE IT A TRY

GOING SHOPPING

Examine the photo of the shopper in Figure 3.2, and answer the following questions:

- The shopper is using his muscles to push the grocery cart. What energy transformation is involved?
- Thermal energy is constantly produced by chemical reactions in our bodies. What transformation or transfer takes place when we are in an environment that is cooler than our bodies?
- The wheelchair is powered by a battery. What energy transformation takes place in the wheelchair?
- What form of energy does the wheelchair have when it is rolling?
- Suppose the battery fails and the wheelchair must be pushed by hand. What energy transformation would take place?

Figure 3.2 Every activity involves energy transformations.

CHEMICAL ENERGY

You have probably felt weak and tired when you have gone for long periods without a meal. This results from a lack of energy-producing molecules in your bloodstream and cells. **Chemical energy** is the energy that is found in chemicals, including food. A common molecule used for the production of energy in humans is glucose, a type of sugar (Figure 3.3). Your cells use glucose molecules and a series of chemical reactions to produce thermal energy to keep you warm and mechanical energy so that you can move.

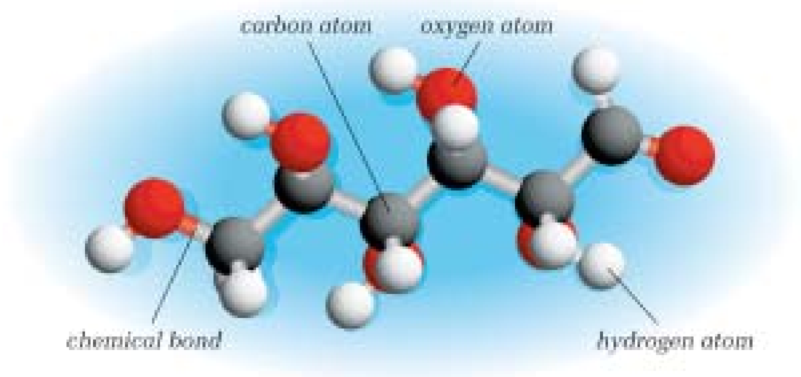


Figure 3.3 Glucose molecules are used in the production of energy for your body.

Chemical energy can be transformed to other forms of energy as well. For example, when you use a battery-operated CD player, you are transforming chemical energy into other forms. Recall from earlier lessons that a dry cell contains chemicals that react to produce electrical energy. The CD player transforms this electrical energy into mechanical and sound energy.

Another example of a transformation involving chemical energy is the use of explosives to demolish large buildings. These buildings must be brought down quickly to save money and time, but they must also be brought down safely. Carefully placed and well-timed dynamite explosions are often the best choice for the task. The chemical energy in the dynamite is rapidly released to provide the mechanical energy that demolishes the building.

Figure 3.4 Part of the mechanical energy in a building demolition is transformed from the chemical energy of explosives. Much of the energy in the demolition comes from the gravitational potential energy of the building itself. The collapse of the support columns triggers the release of this energy.

Transformations Involving Chemical and Electrical Energy

You can use various devices to transform electricity into other forms of energy. Depending on the electrical device, electricity can be transformed into any form of energy you require, such as heat, light, sound, or movement (mechanical energy).

Examples of Devices That Convert Energy from One Form to Another

Input Energy	Device	Output Energy
electrical	toaster	thermal
chemical	flashlight	electrical, then light and thermal
electrical	blender	mechanical
chemical	battery-operated clock	electrical, mechanical, sound

ACTIVITY D-6

Problem Solving

TRANSFORMING HEAT INTO ELECTRICITY

Recognize a Need

There are locations where it is impossible or inconvenient to measure temperature with an ordinary thermometer; for example, inside a car engine or a baker's oven. One way to keep track of temperatures in such locations is to convert some of the heat into electricity and then use that electricity to gauge the temperature.

The Problem

You have been asked to design a method of monitoring the temperature inside a kiln in a pottery studio. The potter has built a kiln but needs a way of measuring the temperature inside to ensure that the pottery is fired properly. You will be testing a **thermocouple**, a simple device that can convert heat to electricity.

Criteria for Success

- You must produce a sketch to show how you could use a thermocouple to measure the temperature inside a very hot, closed environment, such as a kiln.
- You must prove that your thermocouple device is capable of converting heat into electricity and that it will work at high temperatures.

Brainstorm Ideas

1 Discuss how to convert electricity produced by a thermocouple into a display of temperature. Keep in mind that the system should be convenient to use and read.

Test and Evaluate

Steps 2 to 7 can be done as a teacher demonstration.

2 Use wires to connect the ends of the thermocouple to the voltmeter.

3 Light the Bunsen burner and rotate the barrel to obtain a blue flame.

4 Hold the end of the thermocouple in the beaker of ice water. Observe and record the reading on the voltmeter.

5 Using tongs, hold the very tip of the thermocouple still in the bottom of the flame. Observe and record the reading on the voltmeter.

6 Return the thermocouple to the ice water, again recording any reading on the voltmeter.

7 Repeat steps 4 to 6 at least three times. Each time hold the thermocouple in a different part of the flame, such as middle, side, or top.

Communicate

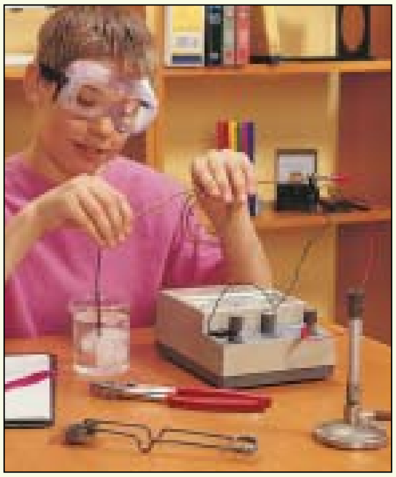
8 What is the relationship between the voltage produced by the thermocouple, its position in the flame, and temperature?

9 Why do you think the device used to produce electricity in this activity is called a "thermocouple"?

10 Do your results indicate that the thermocouple will be appropriate for your design for measuring the temperature in a kiln? Explain.

Materials & Equipment

- thermocouple
- beaker
- Bunsen burner
- heat resistant tongs or pliers
- ice water
- connecting wires
- millivoltmeter



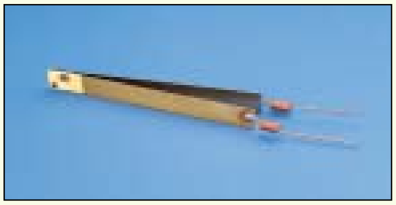


Figure 3.5 Two types of thermocouples

Caution!
Be very careful when working with open flames.

Transformations Between Thermal and Electrical Energy

A **thermocouple** is a device that can convert thermal energy to electrical energy. It consists of two different metals joined together that conduct heat at slightly different rates. When the metals are heated, this difference in conduction results in electricity flowing from one metal to the other. The temperature affects the amount of electricity produced, so you can use a thermocouple as a thermometer.

Thermocouples are very useful for measuring temperatures in areas that are difficult to access or that are too hot for a liquid-filled glass thermometer. For example, some Alberta farmers hang thermocouple cables in their grain bins. The amount of electricity the cable produces indicates whether the grain is getting too hot. This can happen if the grain is too moist.

Devices such as heaters and ovens do the exact opposite of a thermocouple. They convert electrical energy into thermal energy. Think of the heating element in the oven. The energy of the electrical charges is transferred to the atoms of the metal that the charges flow through. The metal heats up and warms the oven. Changes in thermal energy can be measured by keeping track of the temperature of the substance.

reSEARCH

Ocean Thermal Energy Conversion (OTEC)

Scientists are researching ways to use the ocean's natural thermal differences to generate electricity. The temperature difference between the warm surface and cold depths can be 20°C or more. This difference can be used to make electricity through ocean thermal energy conversion (OTEC). Find out how OTEC works. Use labelled diagrams and flowcharts to summarize your research. Begin your information search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is energy?
2. What energy transformations take place in each of the following devices?
   - electric kettle
   - battery-operated toy car
   - electric blanket
   - cordless telephone
3. What does a thermocouple do?
4. What is thermal energy?
5. What is the difference between mechanical and chemical energy?

Connect Your Understanding

6. a) What form of energy is found in sugar?
   b) How is that energy used in your body?
7. A model rocket uses a flammable fuel to power its flight into the air. What energy transformation takes place in the rocket?
8. In what way is an electric oven the opposite of a thermocouple?

Extend Your Understanding

9. Why is a thermocouple a good device for indicating the temperature in a car engine?

Figure 3.6 Hans Christian Oersted

3.2 Energy Transformations Involving Electrical and Mechanical Energy

Motors have a place in many of the electrical devices that we use every day. The beginnings of this important energy converter—the motor—can be traced back to the early 1800s. In 1820, Danish scientist Hans Christian Oersted conducted a famous demonstration in which he deflected a compass needle with a current-carrying wire. A compass needle is magnetic. If a nearby electrical current affects it, there must be some relationship between electricity and magnetism. Oersted had discovered that current flowing through a wire creates a magnetic field around the wire.

*info***BIT**

Vacuum Cleaner

Vacuum cleaners work with the help of an electric motor. The motor has a fan attached. When it spins, the blades of the fan force air out, which creates suction inside the vacuum cleaner. Air from the room forces its way into the vacuum, carrying dirt with it.

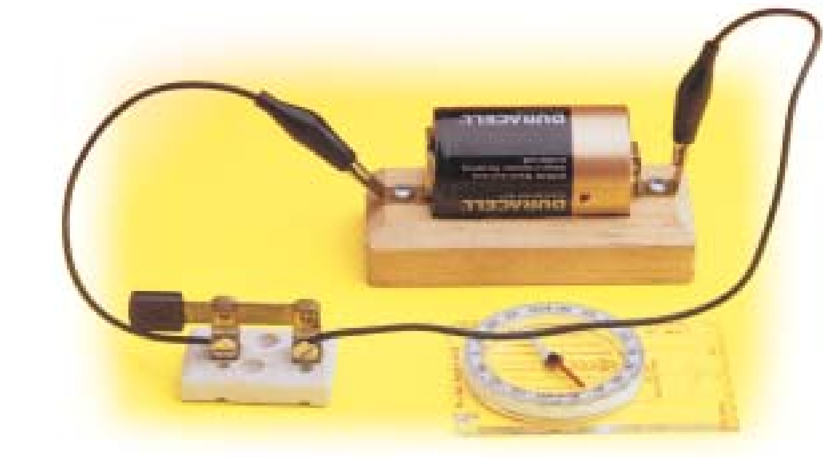


Figure 3.7 Electricity flowing through the wire causes the compass needle to deflect.

Eleven years later, Michael Faraday constructed a device that used electromagnetic forces to move an object. The design was crude and produced little power, but it proved that electricity could produce continuous motion. In Faraday's device, a hanging wire circled around a fixed magnet. A pool of mercury maintained the connection to the moving wire. We now know that mercury is highly toxic, so an open container of mercury would never be used today. Faraday also made a device in which a magnet rotated around a fixed wire. Faraday's devices led to the development of the electric motors that we use.

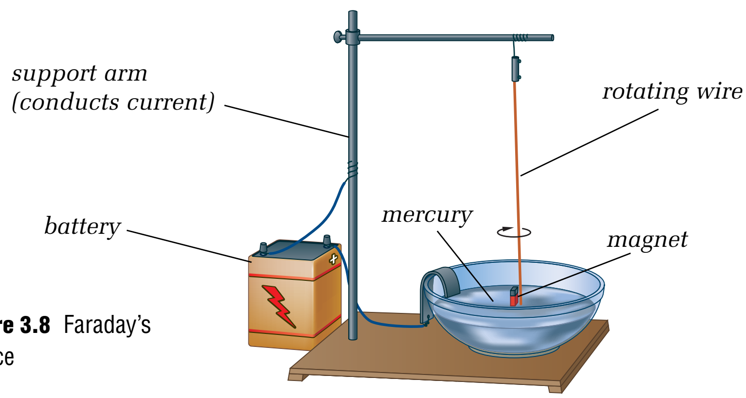


Figure 3.8 Faraday's device

Electric Motors

Early experimenters found that they could make a strong **electromagnet** by winding current-carrying wire into a coil (usually around an iron core). They also found that an electromagnet will move to line up with the magnetic field from a nearby permanent magnet. This is the same way that two permanent magnets attract each other.

How do you keep an electromagnet spinning in a magnetic field? The trick is to switch the direction that the current travels through the coil just as it aligns with the magnetic field of the permanent magnet. Reversing the current reverses the polarity (the north and sounds ends) of the electromagnet. It will then continue turning in order to align the opposite way. Changing the polarity of the electromagnet every half turn causes the electromagnet to be continuously pushed and pulled by the permanent magnet.

Many electric motors use a **commutator** and **brushes** to reverse the flow of electricity through the electromagnetic coil. The commutator is a split ring that breaks the flow of electricity for a moment and then reverses the connection of the coil (see Figure 3.10(a)). When the contact is broken, so is the magnetic force. But the **armature** continues to spin because of its momentum. (The armature is the rotating shaft with the coil wrapped around it.) As a result of the spinning, the commutator reconnects with the brushes. The magnetic force on the coil keeps it spinning continuously (Figure 3.10(b)). The brushes are usually bars of carbon pushed against the metal commutator by springs. They make electrical contact with the moving commutator by "brushing" against it.

Figure 3.9 An electromagnet is made by winding a current-carrying wire around a metal core.

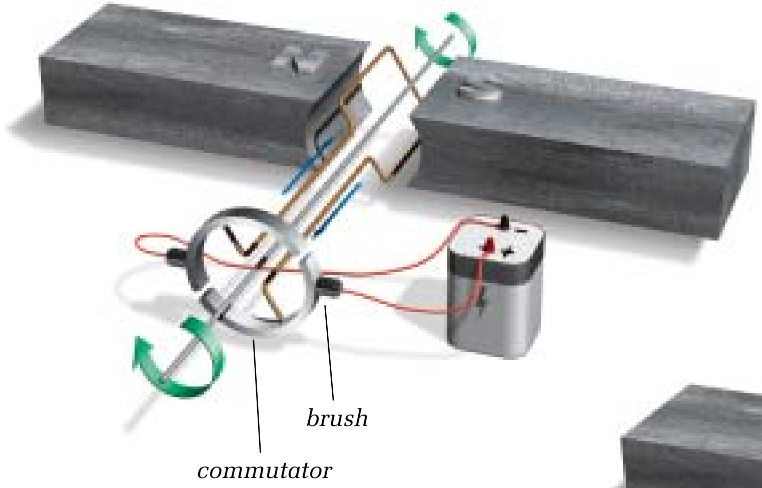


Figure 3.10(a) Current flowing through the wire coil creates a magnetic field around the wire. This interacts with the permanent magnets, making the coil spin.

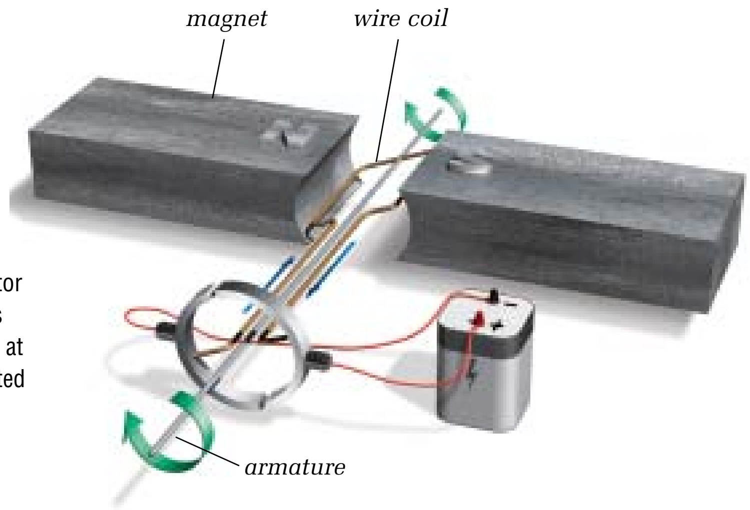


Figure 3.10(b) As the coil spins, the commutator changes position so that its other half contacts the other brush. This reverses the current flow at just the right time. The magnetic force is directed on the coil to keep it spinning.

Activity D-7

Problem Solving

Get Your Motor Running

Recognize a Need

A toy manufacturer has developed a motor-building kit. Before they can market it, they need to know if their kit is suitable for both beginners and more advanced hobbyists.

Materials & Equipment

- 1.5-V D-cell
- 1 m of thin enamel-coated wire (22-28 gauge)
- paper clips
- tape
- sandpaper
- empty film canister
- circular magnet

Figure 3.11 Building a simple motor

The Problem

The toy manufacturer would like you to test the kit. They would also like you to write instructions for users on how to alter the motor so that it will spin at different speeds and in the opposite direction. The manufacturer has encouraged you to design your own motor, if you wish, and write building instructions for it.

Criteria for Success

- Build a functioning electric motor with simple materials. Do your best to complete as many of the following tasks as you can. Each level is more difficult as you go from level 1 to level 5.
  - ❍ Level 1: your motor shows movement
  - ❍ Level 2: your motor can turn a half-turn to a full-turn
  - ❍ Level 3: your motor can spin continuously
  - ❍ Level 4: your motor can be adjusted to spin at different speeds
  - ❍ Level 5: your motor can spin in different directions

Brainstorm Ideas

TOOLBOX

1. Before you begin, read Toolbox 3 about the problem solving process.
2. Make a sketch of what your motor will look like when it is completed. Show it to your teacher for approval.
3. Consider the materials you have to work with. You have to build a working model that must be easy to adjust.

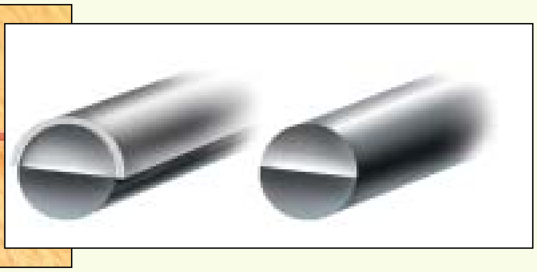
Build a Prototype

4 Assemble the materials you need and construct your motor. If you wish, you may instead build the toy manufacturer's motor design by following steps 5 through 8.

5 Use the film canister to wrap the length of wire into a coil. Leave 5 to 6 cm of wire free at each end of the coil. To keep your wire coil from unwinding, wrap the free ends around the coil a few times, as shown in Figure 3.12(a).

6 Use sandpaper to remove the enamel coating from one end of the wire. Then hold the coil on edge and sand off the enamel coating from only the bottom half of the other end of the wire. Figure 3.12(b) shows the wire's ends. When you are done, your wire coil should look like the one in Figure 3.10(a). This is your motor's armature.

Figure 3.12(a) The motor's armature



(b) The finished ends of the wire

7 Bend two paper clips so that they can support the wire coil and be attached to the ends of the D-cell. Use tape to hold the bent paper clips in contact with the metal ends of the cell, as shown in Figure 3.11. Attach the circular magnet to the D-cell as shown in Figure 3.11.

8 Place the coil so that it rests on the clips. Give the coil a small push to see if it will spin. Adjust these components to minimize friction and get the loop spinning as smoothly as possible.

Test and Evaluate

9 When your motor is complete, test it to see if it meets some or all of the criteria for success listed on the previous page. Make adjustments as necessary. Record what you have done and the adjustments you have made.

Communicate

10 Explain why the coil of wire in your motor spins.

11 Did your coil spin better in one direction than another? Explain why it did or did not.

12 Suggest two ways that you could change the design of your motor to make it function better. Make these changes and test your motor again.

13 Have your classmates examine and test your motor. Examine the motors of your classmates and suggest modifications that could improve their designs. If someone suggests a design improvement for your motor, test the suggestion.

14 Write clear instructions on how to build a motor like yours. Include advice on how to make adjustments like the ones you made. Use diagrams wherever they would be helpful. To see if your instructions are easy to follow, have another student or group read them. Revise your instructions as necessary to make them clearer.

Figure 3.13 Turning a steering wheel is similar to the turning of the armature in a motor.

The Steering Analogy

The commutator's role in helping the armature to spin continuously can be hard to understand. Imagine trying to turn a steering wheel. You put both hands on the wheel and turn. Can you keep turning without letting go? You can't because your hands must release and return to their starting position in order to keep turning the wheel.

If you could not let go, you could only turn the wheel one-half turn, then you'd be stuck. The same problem occurs with the motor. Without the split-ring commutator, the armature would turn only one-half turn, then it would stop, locked into place by magnetic attraction.

*QUICK*LAB

St. Louis Motor

A St. Louis motor is designed to show how an electric motor works.

Materials & Equipment

- St. Louis motor

Purpose

To identify the parts of a St. Louis motor and examine its operation

Procedure

1. Draw a diagram of the motor, identifying all the parts: wire coil, brushes, commutator, magnets, and armature.
2. Use connecting wires and a battery to supply electricity to your motor. Start the motor by giving it a spin. Turn off the lights in the room and observe the commutator closely.
3. Alter the position of the magnets in the motor to move them closer, then farther away from the armature. Carefully observe the armature.

Questions

4. Explain what you observed in step 2.
5. Explain what you observed in step 3.

Direct and Alternating Current

Some motors run on **direct current** (DC). It's called "direct" current because the electricity flows in only one direction. Many devices such as mp3 players, computers, cell phones, and calculators also use DC. The electricity in your household circuits is **alternating current** (AC). It's called "alternating" because it flows back and forth 60 times per second. Plug-in devices that require DC come with their own power supplies. The power supply converts the power company's 120-V AC to DC and supplies the voltage that the device requires.

Transformers

Power companies generate AC because, with AC, they can use **transformers** to change the amount of voltage with hardly any energy loss. Voltage change is necessary because the most efficient way to transmit current over long distances is at high voltage. Some transmission lines carry current at 500 000 V. These high voltages must be reduced before the current can be used in your home.

Figure 3.14 shows how this is done. The current-carrying wire is wrapped around one side of an iron ring called a core. This is the primary coil. A secondary coil is wrapped around the other side of the core. The AC current flowing through the primary coil creates an alternating magnetic field. This induces a current in the secondary coil. If the number of loops in the two coils is different, the voltage is transformed down (Figure 3.14(a)) or up (Figure 3.14(b)).

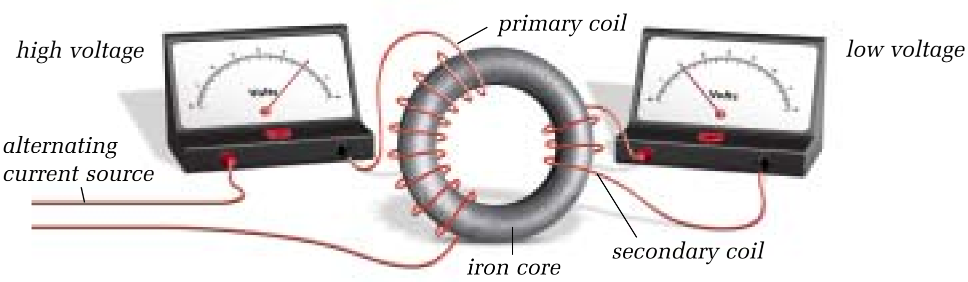


Figure 3.14(a) A step-down transformer reduces voltage.

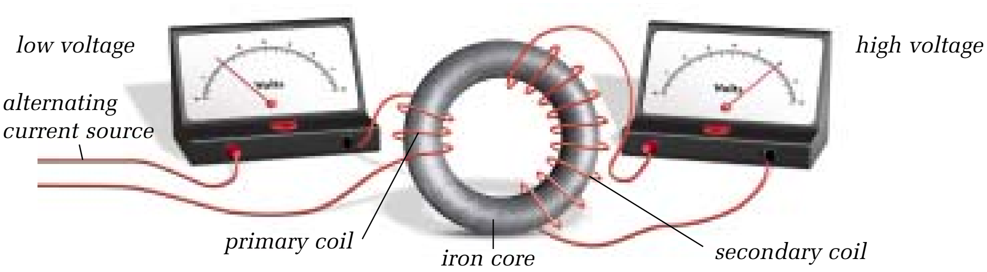


Figure 3.14(b) A step-up transformer increases voltage.

Generating Electricity

In 1831, Michael Faraday made one of the most significant electrical discoveries: **electromagnetic induction**. He demonstrated that electrical current could be generated by moving a conducting wire through a magnetic field. Faraday moved a magnet back and forth inside a coil of wire that was connected to a meter that could detect small electric currents. His discovery changed the world by introducing a way to generate a steady supply of large amounts of electricity.

The hand-held generator in Figure 3.15 moves a coil of wire past permanent magnets. As long as you keep turning, electricity will be produced. The faster you turn, the more current is generated. The same principle of electromagnetic induction is used in large-scale power plants. Massive coils of wire rotating in huge generators produce enough electricity to power whole cities. Such generators provide the electricity we use every day.

reSEARCH

A Wind-up Radio

This radio runs on muscle power. The crank winds a spring. As the spring unwinds, it turns a small generator that produces electricity to run the radio. Find out why engineers thought it would be impossible to build a wind-up radio. Prepare a report about the radio and include a diagram to show how it works. Explain how this invention is helping people in developing countries. Begin your information search at www.pearsoned.ca/scienceinaction.

Spring-powered radio

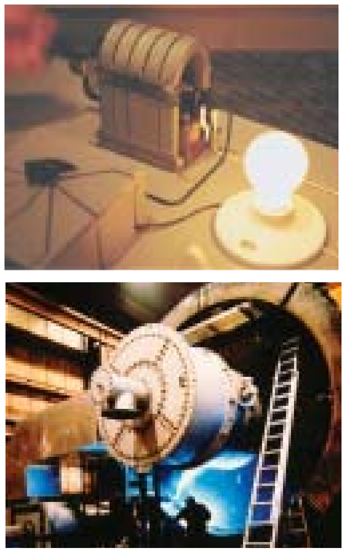


Figure 3.15 Both generators have coils that rotate in a magnetic field.

ACTIVITY D-8

Experiment **on your own**

GENERATING ELECTRICITY

Before You Start

You know that electricity can be transformed into mechanical energy by a motor. The reverse is also true. Transforming mechanical energy into electrical energy can be done with a generator. The generator consists of a rotating coil, magnets, and a device to create the turning motion. For example, the turning motion from a wind turbine or water wheel can turn the coil. The turning of the coil through a magnetic field creates, or induces, a voltage. This voltage can be measured with a voltmeter. In this experiment, you will build and modify a generator to induce the highest possible voltage.

The Question

How can mechanical energy be converted to electrical energy?

Design and Conduct Your Experiment

TOOLBOX

1 In your group, brainstorm the materials and equipment you will need to build your generator.
2 List any safety concerns that you need to consider.
3 Develop a plan to build your generator. Show your plan to your teacher for approval.
4 Build your generator.
5 Test your generator to see if it can produce a voltage. You may want to read Toolbox 3 on problem solving to help you improve your design. Remember you will probably need to make several modifications to your design before it works.
6 Once your generator is working, create a hypothesis about the effect of modifying your generator to create a higher voltage.
7 Modify your generator.
8 Compare your results with your hypothesis. Was your hypothesis correct? If not, how would you explain your experimental results?

Figure 3.16 Building a generator

9 Compare your results with those of your classmates. Were your results similar? If there were differences, explain them.
10 Compare your experimental procedure with your classmates' procedures. Identify some strengths and weaknesses of the different ways of collecting and displaying data.
11 Are there any questions or problems that came up during your experiment that would take more investigation to answer? Outline how you would design an experiment to look into these questions or problems.

Generating DC and AC

A DC generator is structurally the same as a DC motor like the one in Figure 3.10—the spinning armature produces electricity. If you run electricity through a DC generator, it will spin like a motor.

An AC generator is slightly different. The central axle of an AC generator has a loop of wire that is attached to two slip rings. Recall that when a wire moves in a magnetic field, current is generated in the wire. Examine Figure 3.17 carefully. You can see that as the axle and loop of wire turn, one side of the loop moves up, and the other side moves down through the magnetic field. When the wire moves up between the magnets, current flows one way in the wire. But when the wire moves down, the current moves in the other direction. This is how the current switches back and forth in the wire with each complete turn of the loop.

The slip rings attached to the wire loop ends conduct the alternating current to the circuit through brushes. The brush and slip ring arrangement allows the whole loop to spin freely. In large AC generators, such as those in a power station, many loops of wire are wrapped around an iron axle-core.

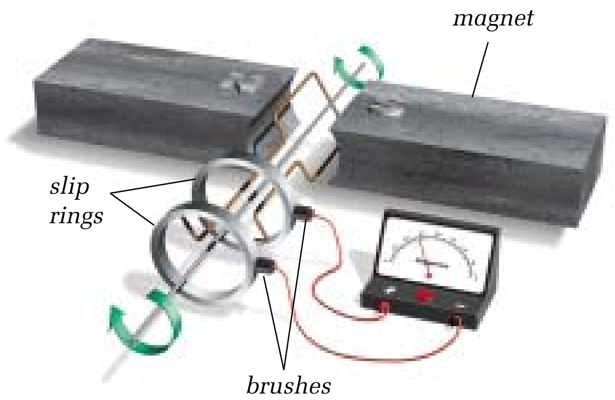


Figure 3.17 The central axle of an AC generator has a loop of wire that is attached to two slip rings.

Check and Reflect

Key Concept Review

1. What is meant by the term "polarity"?
2. Use words and a drawing to describe how to construct a simple electromagnet.
3. Explain the function of the permanent magnets in an electric motor.
4. Describe Faraday's contributions to the development of the motor and the generator.

Connect Your Understanding

5. *A generator stores electric current.* Explain why you agree or disagree with this statement.
6. How are electricity and magnetism related?
7. The permanent magnets of a motor are replaced with more powerful ones. What effect do you think this would have on motor rotation? Explain.
8. Suppose a classmate constructed an electric motor with a solid commutator. That is, the commutator has no split. This solid commutator is in constant contact with the motor brushes. Would this motor design work? Explain why or why not.

Extend Your Understanding

9. You are lost with a group of friends in the deep woods. You notice that the group leader is determining direction with a compass that is taped to the top of his flashlight. Explain why this is a concern.
10. *A motor and a generator are the same thing.* Explain why you agree or disagree with this statement.

Figure 3.18 Cars powered by batteries (top) and hydrogen (bottom)

3.3 Measuring Energy Input and Output

We use energy in every aspect of our daily lives—driving to work or school, heating our homes, preparing our food, watching television. Sometimes, we can choose which kind of energy we will use. For example, we could use electricity, gasoline, natural gas, propane, or hydrogen to power a vehicle. But how do we know which is best? To determine that, we need to measure the types and amounts of energy going into and coming out of the devices we use.

Power

Power is the rate at which a device converts energy. The unit of power is the **watt** (W), named for the Scottish inventor and engineer, James Watt. A watt is equal to one joule per second. The faster a device converts energy, the greater its power rating.

For an electrical device, the power is the current multiplied by the voltage. Mathematically, the relationship between power (P), current (I), and voltage (V) is $P = I \times V$ (watts = amperes × volts). Think of our model using waterfalls. The power of a waterfall is equal to the amount of water flowing times the difference in potential energy between the top of the falls and the bottom. This is just like current flow times potential drop in a circuit.

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Garbage In... Energy Out!
Some cities burn garbage to generate electricity. Tokyo has a waste-to-energy plant that burns 1800 t (tonnes) of garbage a day to produce 50 MW (megawatts) of electrical power.

Example

A hair dryer has a power rating of 1000 W. It is plugged into a 120-V outlet. What is the current flowing through the hair dryer?

Steps to Solving the Problem	Information and Solution
1. Identify known quantities.	power (P) = 1000 W, voltage (V) = 120 V
2. Identify the unknown quantity.	current (I)
3. Use the correct formula.	$I = P/V$
4. Solve the problem.	$I = P/V = 1000\ \text{W}/120\ \text{V}$
	$\mathbf{I = 8.33\ A}$

Most small appliances in your home have a power rating of 1500 W or less. An electric stove might have a power rating of 7000 W, while the rating for a calculator could be only 0.4 mW.

Figure 3.19 You may be able to determine a product's power rating from its label.

ENERGY

You can use the power rating of a device to determine the amount of energy the device uses. Recall that power is the rate at which a device converts energy. You can find the amount of energy converted by multiplying this rate by the length of time the device operates. The energy consumption of an electrical device is its input power multiplied by the time the device is used: $E = P \times t$. Recall that energy is measured in joules (watts $\times$ seconds).

Example

A microwave oven has a power rating of 800 W. If you cook a roast in this oven for 30 min at high, how many joules of electrical energy are converted into heat by the microwave?

Steps to Solving the Problem	Information and Solution
1. Identify known quantities.	power $(P) = 800$ W , time $(t) = 30$ min
2. Identify the unknown quantity.	energy (E)
3. Use the correct formula.	$E = P \times t$
4. Solve the problem.	$E = P \times t = 800\ \text{W} \times 30\ \text{min}$ $E = 800\ \text{J/s} \times 30\ \text{min} \times 60\ \text{s/min}$ $\mathbf{E = 1\ 440\ 000\ J = 1.4\ MJ}$

Kilowatt Hours

It doesn't take common electrical devices long to consume a large number of joules. For this reason, the **kilowatt hour** is often used as a unit for energy. The energy calculation is the same, except that hours are substituted for seconds, and kilowatts (kW) are substituted for watts. For the microwave oven in our example, the calculation would be $E = 0.8\ \text{kW} \times 0.5\ \text{h} = 0.4\ \text{kW·h}$.

Electricity meters measure the energy used in kilowatt hours. The electric company then bills you for every kilowatt hour used. This cost can add up—a Canadian family's energy bill can be over $100 a month.

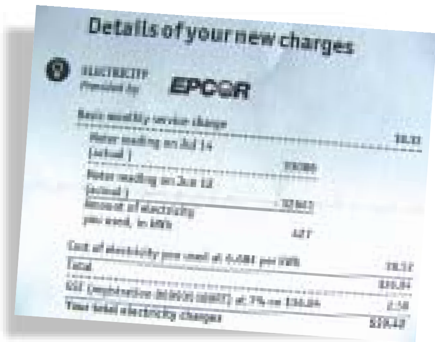


Figure 3.20 An energy bill for a household shows the amount of electricity used in kilowatt hours.

SKILL PRACTICE

POWER PRACTICE

Use a list from your teacher or use electrical devices at home to look at power ratings. Be careful! Unplug an electrical device before you handle it. Look at items such as light bulbs, curling irons, coffee makers, and clock radios. Record as many ratings as you can in a chart.

On some items, you may find voltage and current listed instead of power. In these cases, calculate the power rating of the device.

Estimate the amount of time that each device is used in a month in your home or in a typical home, then calculate the amount of energy it consumes.

Activity D-9

Problem Solving

Circuit Assessment

Recognize a Need

You have been approached by a couple who have just purchased a small, old recreational vehicle (RV). The RV has a few electrical components they would like to test. The couple want a tutorial on how to measure voltage, current, and power in a circuit. When you ask the couple whether the RV is wired in series or in parallel, they aren't sure.

Materials & Equipment

- cells or batteries
- cell holders
- motors
- bulbs and holders
- switches
- connecting wires
- voltmeters and ammeters, or multimeters

Figure 3.21 Materials you could use to demonstrate circuit analysis

The Problem

Build model series and parallel circuits to show how to assess the following:

- voltage across each item in a circuit
- current in each branch of a circuit
- power usage by each component

Criteria for Success

TOOLBOX

- You must build an operating example of a series and a parallel circuit. Each circuit should have three components in addition to a voltage source. You can reuse components from one circuit when building the next.
- You must test all components in each circuit for voltage drops. You must also measure the current in each circuit. Keep in mind that you must check each branch in the parallel circuit. (Review section 1.2 for proper use of voltmeters and section 2.2 for proper use of ammeters.) You must calculate the power used by all load components in each circuit.
- You must report your results in tables and graphs that clearly illustrate the difference between the two circuits you have analyzed. (See Toolbox 7 for information on graphing.)

Brainstorm Ideas

1 You will be working in teams. As a team, brainstorm possible approaches to solving the problem and providing the required analysis. Once you have decided on the best procedure, proceed to the next step.

Build a Prototype

2 Draw a schematic for the series and the parallel circuits you will build. Note on your drawings where you will be connecting your voltmeter and ammeter. Make a rough plan of the table(s) and graph(s) you will use to report your results and calculations. Show your design to your teacher for approval.

3 Assemble your materials and build your circuits.

Test and Evaluate

4 Test your circuits to ensure they are working. Then use meters to take the measurements you have designated in your sketches. Record all voltage readings, current readings, and power calculations, and present them in a table. Draw the graph(s) to compare your results for the two circuits.

Communicate

5 How did the power used by the components in the two circuits compare? Can you explain any differences?

6 Look at the circuits and results produced by classmates. Are their results similar to yours? If they are different, can you explain why?

7 Suggest one improvement to your procedure.

Figure 3.22 Even a water system dissipates energy because of friction.

Energy Dissipation

Scientists have found that energy cannot be created or destroyed. Energy does not just appear or disappear—it can only be transformed from one form to another. This fundamental principle is known as the **law of conservation of energy**. However, we usually find that the output energy of a device or system is smaller than the input energy, sometimes much smaller.

Most often, the missing energy is lost or dissipated as heat. For example, when you heat a beaker of water on a hot plate, the hot plate transfers some heat to the surrounding air instead of to the water. The hot plate also radiates heat to any other objects nearby, including you. All heating devices lose some heat to their surroundings.

Mechanical systems also dissipate energy to their surroundings. However, their heat losses may be less obvious than those in heating devices. Suppose you were using an electric motor to pump water from a well or river to irrigate a crop. You might find that the motor used 100 kJ of electrical energy for every 75 kJ of work done raising water up to the field. The other 25 kJ of energy is "missing."

Let's examine your pumping system. You can hear it running, so a bit of mechanical energy is being dissipated as sound. If the motor has been running for a while, it will be warm, perhaps even too hot to touch comfortably. Current flowing through the wires in a motor always produces some heat, and the friction between the moving parts generates heat as well. There is also friction between the moving parts in the pump and between the water and the walls of the pipe. The heat generated by this friction warms the water and pipe slightly, then dissipates into the surroundings. All of the "missing" input energy has been transformed into energy you cannot use.

In fact, all mechanical systems dissipate some energy, so their usable output energy is always less than their input energy.

*info***BIT**

Heat from Lighting

The heat from lights is not always wasted. During the winter, the heat from lighting helps keep buildings warm. In fact, some office buildings with extra insulation and specially designed ventilation systems can capture enough heat from lighting that they don't need furnaces.

UNDERSTANDING EFFICIENCY

The **efficiency** of a device is the ratio of the useful energy that comes out of a device to the total energy that went in. The more input energy that a device converts into useable output energy, the more efficient the device is. Efficiency is usually calculated as a percent:

$$\text{percent efficiency} = \frac{\text{joules of useful output}}{\text{joules of input energy}} \times 100$$

For example, let's look at the input and output energies of an ordinary incandescent light bulb, as shown in Figure 3.23. The percent efficiency of an incandescent light bulb is 5 J/100 J × 100 = 5. In other words, only 5% of the energy used by the bulb becomes light energy. Light bulbs transform the remaining 95% of their input energy into heat, which is often wasted. This heat is put to use in toy ovens where a single light bulb is used to bake a small cake.

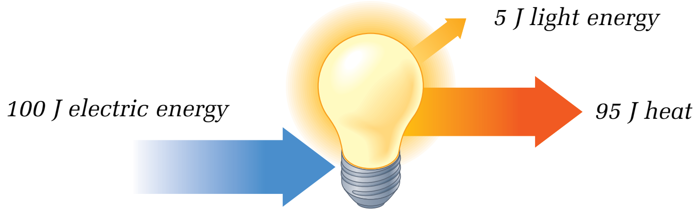


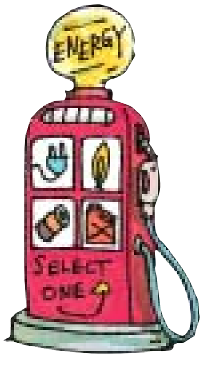
Figure 3.23 Most of the energy transformed by a light bulb is wasted.

SKILL PRACTICE

COMPARING INPUT AND OUTPUT ENERGIES

This table lists energy measurements from experiments on energy-converting devices. For each device, calculate the percent of its input energy that it converts to useful output energy. Which device is the most efficient? Which is the least efficient? What do you think causes the difference between the most and the least efficient?

Device	Input Energy	Useful Output Energy
Gasoline-powered sport utility vehicle	675 kJ	81 kJ
Gasoline-electric hybrid vehicle	675 kJ	195 kJ
Mid-efficiency natural-gas furnace	110 MJ	85 MJ
Electric baseboard heater	9.5 kJ	9.5 kJ
Alkaline dry cell	84.52 kJ	74.38 kJ
Fluorescent light	12.5 kJ	2.75 kJ
Incandescent light	780 J	31 J



Activity D-10

Problem Solving

Kettle Efficiency

Recognize a Need

In the world of advertising, products are promoted in a variety of ways to convince consumers to buy them. Sometimes claims that products can do certain things may seem false or exaggerated. A manufacturer can claim that its product is very efficient, but how can you be sure that their claim is true?

The Problem

A consumer-product magazine wishes to determine if the efficiency claims for a particular electric kettle are true. You have been hired by the editor of the magazine to test the efficiency of the kettle.

Criteria for Success

- Design a procedure that will measure the amount of electrical energy consumed by the kettle while heating water (energy input).
- Design a procedure that will measure the amount of energy gained by the water (energy output).
  Note: The amount of energy gained by water can be calculated using the following formula. For water, 1 mL = 1 g.
  E = mass of water in grams $\times$ 4.19 $\times$ change in temperature in °C = energy in joules
- Carry out your procedure and calculate the efficiency of the electric kettle.

Brainstorm Ideas

1 Write out the steps of a procedure and calculations you will perform that will allow you to successfully determine the efficiency of the kettle. (Hint: Do not allow the kettle to boil the water—it is very difficult to measure the heat gained by steam that has escaped.)

2 Have your procedure approved by the teacher.

Test and Evaluate

3 Conduct your procedure.

4 Record all the data you have collected and use it to calculate the efficiency of the kettle.

5 If your teacher has supplied other water-heating devices (such as a coffee maker or hot plate), use your procedure to calculate the efficiency of these devices as well.

6 List possible sources of error in your measurements. Estimate how accurate your calculations are.

Communicate

7 Report your efficiency results for the kettle (and any other devices you tested). Compare your results with those obtained by others in the class.

8 Would you make any changes to your procedure to increase the reliability of your results? Explain your answer.

9 Could your procedure be safely altered to determine the efficiency of other heating devices not meant for heating water, such as a blow dryer? Explain.

Materials & Equipment

- electric kettle
- timer
- thermometer
- 500-mL beaker
- graduated cylinder

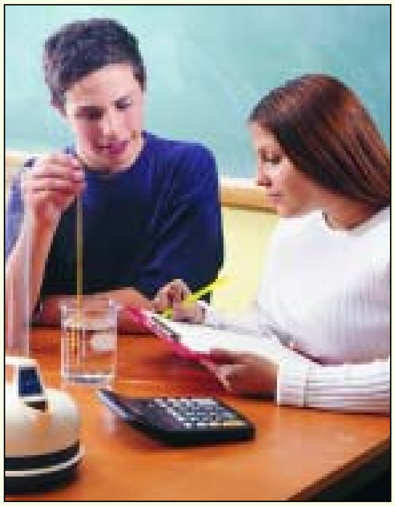


Figure 3.24 Determining the efficiency of an electric kettle

Caution!
Hot water and steam can burn.

Figure 3.25 In a fluorescent tube, an arc through mercury vapour produces ultraviolet (UV) light. The tube's fluorescent coating absorbs the UV light and re-emits it as visible light.

Comparing Efficiencies

By comparing efficiencies of devices, we can judge both their energy cost and their environmental impact. For example, fluorescent lights are about four times more efficient than incandescent lights. Although fluorescent tubes also produce more heat than light, they transform about 20% of their input energy into light. Thus, they require much less energy to produce the same amount of light as incandescent bulbs.

Arc-discharge lamps are even more efficient. they produce light by passing an electric arc through a vapour of a metal such as mercury or sodium. Most cities use these high-efficiency lamps for streetlights.

New technologies are also improving the efficiency of motor vehicles. Hybrid gasoline-electric cars can be twice as efficient as gasoline-powered vehicles. The hybrid uses a smaller gasoline engine and an electric motor that provides extra power when needed. Sometimes the electric motor powers the car by itself. It even operates as a generator when the car is slowing down, producing electricity to recharge the batteries.

Check and Reflect

Key Concept Review

1. What is the difference between energy and power?
2. What energy conversions take place in an electric motor?
3. What is the law of conservation of energy?
4. A vehicle is only 15% efficient. What happened to the other 85%?
5. Compare the energy efficiency of incandescent and fluorescent bulbs.

Connect Your Understanding

6. You bake a potato in a 1200-W toaster oven for 25 min. How many joules of electricity did the toaster oven use? How many kilowatt hours did it use?
7. A colour TV draws 1.5 A when connected to a 120-V outlet. What is the power rating of the TV set?
8. A diesel truck produces 47.5 kJ of useful output energy from 125 kJ of diesel fuel. What is the truck's efficiency?
9. A small tractor is 12% efficient at producing useful output from input fuel. How many joules of input fuel energy will this tractor need to produce 1000 J of useful output?

Extend Your Understanding

10. Explain the advantage of operating a motor vehicle that is 20% efficient instead of one that is 10% efficient.
11. Two identical resistors connected in series use a total of 2 W of power. How much power would these resistors use if they were connected in parallel?

reSEARCH

Halogen Lamps

Halogen lamps produce about 50% more light than ordinary incandescent bulbs using the same amount of power. Find out more about halogen lamps. What are their advantages and disadvantages? Write a brief report providing advice to buyers of these lamps. Begin your search at www.pearsoned.ca/scienceinaction.

3.4 Reducing the Energy Wasted by Devices

Figure 3.26 An energy-efficient washing machine is designed to wash more clothes with less water.

Having to do laundry is a real drag. Spending your afternoon washing, drying, and folding laundry is bad enough, but how about paying too much for it, too? Appliances such as washing machines and dryers are designed for specific tasks and most perform them well. However, appliance designers did not always consider energy consumption. The washer in Figure 3.26 is a new design that uses much less energy than traditional washers. The energy-efficient design uses less electricity, washes more clothes per load, and uses less water. This reduces the energy needed to pump and heat water for laundry.

Every bit of electrical energy that flows into your home costs money. The energy that you use must be generated somewhere, and all generation and transmission methods affect the environment in some way. Lower energy demand means fewer power plants need to be built. This would avoid greater impact on the environment and major construction costs. These are good reasons to reduce energy consumption whenever possible.

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Overdrying

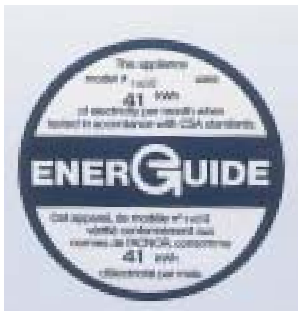
Millions of dollars of energy are wasted each year running clothes dryers to heat clothes that are already dry. Overdrying does nothing for your clothes. Overdrying creates static "cling" and contributes to shrinking and fabric damage. The solution? Cut down on drying time. Your clothes and electric bill will look a lot better!

GIVE IT A **TRY**

Shopping for Appliances

All large appliances sold in Canada must have an EnerGuide label that clearly states how much energy that appliance will use in a month of average use. This amount might not accurately represent how you will use the machine. However, it does allow you to compare the energy consumption of different brands and models.

Go to an appliance store and compare EnerGuide labels on electrical appliances such as refrigerators and dishwashers. Find out which models and brands use the most energy and which use the least.



Limits to Efficiency

Although it is possible for an electric heater to be 100% efficient in converting electricity to heat, devices that convert electricity to other forms of energy can never be 100% efficient. Any sort of movement generates a certain amount of thermal energy that is not useful output. Moving parts create friction within a system. Consider the many moving parts and points of friction in a typical combustion engine. Figure 3.27 shows just a few. This friction is one cause of energy loss in these engines. The largest energy losses result from hot exhaust and heat transferred to the cooling system.

Electric motors, like the one in Figure 3.28, have few moving parts. In some motors, the armature is the only moving part. Also, it is easy to put bearings at each end of the armature shaft to minimize the friction between the spinning shaft and the rest of the motor.

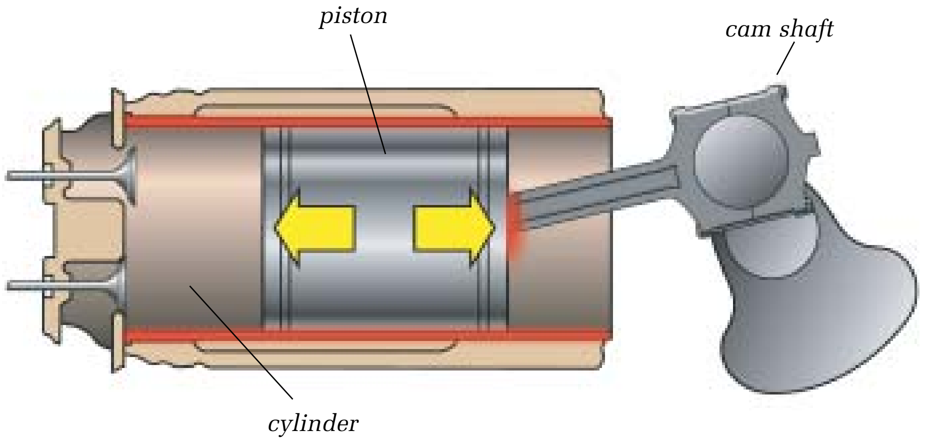


Figure 3.27 The pistons in a combustion engine move inside cylinders and create friction (indicated in red) as they stroke back-and-forth. Many other moving components in the engine create friction. Lubricants and component design can minimize the friction in these engines.

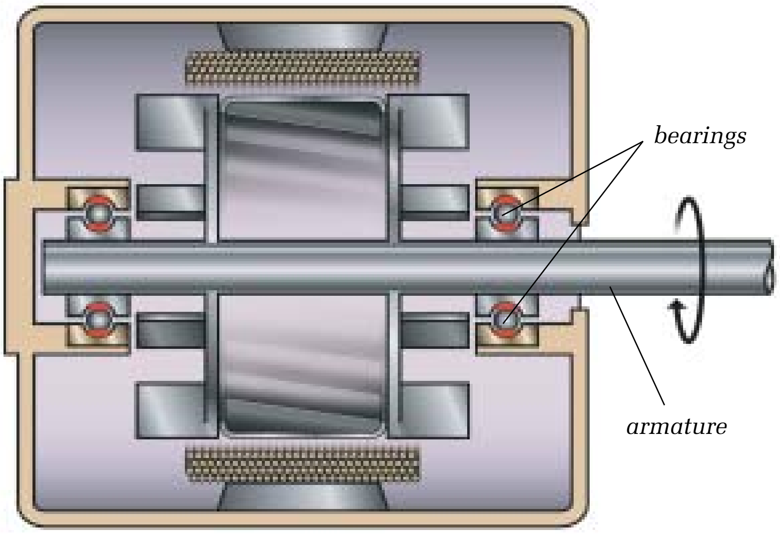


Figure 3.28 An electric motor has few moving parts and much less friction than a combustion engine.

ACTIVITY D-11

Decision Making

WHAT CAN WE DO TO INCREASE EFFICIENCY?

The Issue

Our day-to-day lives involve the use of many energy-converting devices. In what ways can you increase efficiency and reduce the amount of energy that you use?

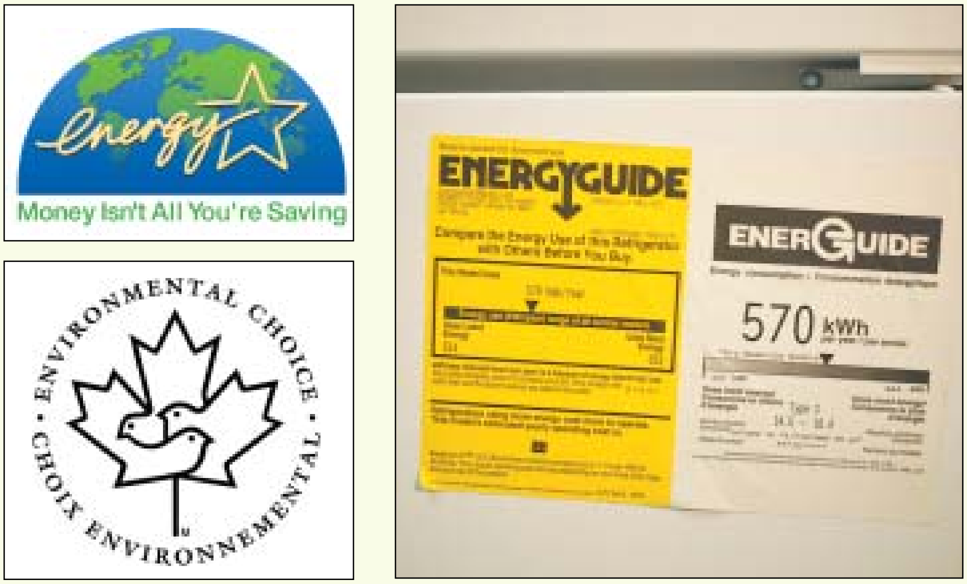


Figure 3.29 These labels can help you choose energy-efficient devices.

Background Information

Many energy choices are available to us in our daily lives. When choosing appliances, vehicles, or heating systems, we can look for more energy-efficient designs. Older equipment can be maintained, adjusted, modified, or replaced to increase efficiency. Don't forget to consider the energy it takes to make the changes you desire. For example, replacing a complete computer system for a gain in efficiency of 1% may not save energy because of the energy it takes to make a new computer.

1 Brainstorm a list of different ways you could increase the efficiency of the devices that you use daily. Also consider your purchase options when choosing new devices.

2 Research the energy savings impact of the items on your list.

Analyze and Evaluate

3 Choose the changes you would implement for maximum energy savings. Explain your reasons for the choices you have made.

4 Present your findings and recommendations for changes in a report to your classmates.

5 Compare your efficiency change recommendations with those of your classmates.

6 Are there any other changes you would recommend to Albertans as a group to increase the efficiency of energy usage?

reSEARCH

Cooking Tips

You can considerably reduce the amount of energy wasted in the kitchen by changing the way you use appliances. Research energy use for food preparation, and make a poster of "cooking tips" that can help reduce energy use in the kitchen. Begin your information search at www.pearsoned.ca/scienceinaction.

Increasing Efficiency

Increasing the efficiency of a device depends on its purpose. Many devices are made to convert electrical to mechanical energy, where the worst energy waste "offender" is friction. The easiest way to increase efficiency in these devices is to decrease friction as much as possible, for example, by using improved bearings and lubricants.

In devices where heat is produced, the major concern is heat loss from the system. Heat that escapes is waste heat which is not performing its task. Adding more insulation around the oven in a stove reduces the amount of heat escaping through the walls of the oven, so you will need less energy to keep the oven hot. Similarly, improving the insulation in the sides of the refrigerator reduces the amount of heat that transfers into the fridge. You need less energy to keep the fridge cold.

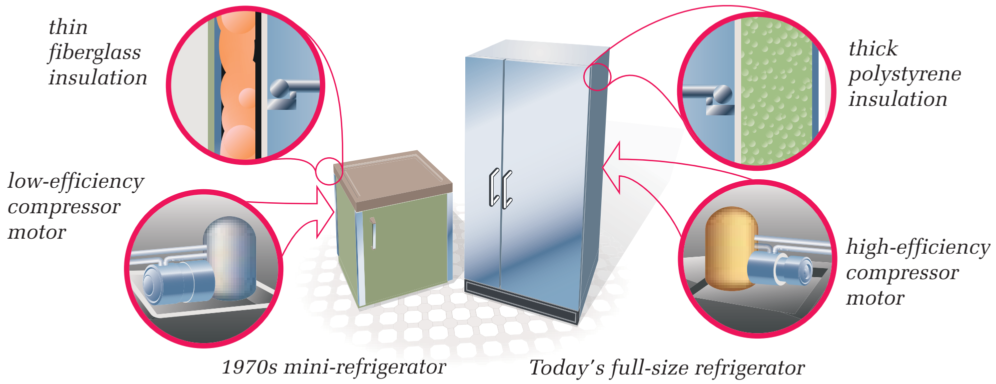


Figure 3.30 In the last 25 years, refrigerator efficiency has increased approximately 300%. The energy used to run a mini-refrigerator in the 1970s can run a full-size refrigerator today.

Check and Reflect

Key Concept Review

1. Give two reasons for reducing energy waste.
2. What is the purpose of the EnerGuide label on appliances?
3. How can a more efficient appliance benefit the environment?
4. Why are electric motors more efficient than combustion engines?

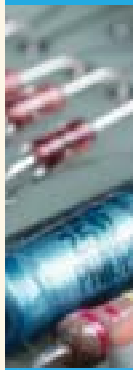
Connect Your Understanding

5. What causes most energy loss in devices designed to produce mechanical energy? What can be done to avoid it?
6. Is it always a good idea to discard low-efficiency devices? Explain your answer.
7. Explain how you might change the design of a typical gasoline-powered lawn mower to increase its efficiency.

Extend Your Understanding

8. An electric-assist bicycle has a rechargeable battery and electric motor that can be used instead of pedalling. What type of design features and maintenance suggestions would you recommend to keep an electric-assist bicycle operating at peak efficiency?

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. You overhear someone say, "An electric heater does the opposite of a thermocouple." Is this an accurate statement? Explain your answer.
2. What is the function of the brushes in an electric motor?
3. What is the function of the permanent magnets in an electric motor?
4. What energy transformations take place in the following devices: a dishwasher, a DVD player, a stereo speaker, and a hot-glue gun?

Connect Your Understanding

5. Two sisters own stereos. Joleen has a 40-W mini-system. Julianna has a large 120-W system. Is it possible for Julianna's system to use less energy in a month than Joleen's? Explain your answer.
6. A computer plugged into a 120-V outlet draws 3.0 A of current. How much power is the computer using?
7. A chemical laser in a research laboratory can fire for 10 s with a power of up to 10 MW. What is the maximum energy this laser would use when it fires?
8. A 330-W hot plate produces 38 kJ of thermal energy while operating for 2 min. What is the efficiency of this device?

Extend Your Understanding

9. You have designed and built an electric golf cart, but it goes only halfway around the course before running out of power. Describe modifications you could make to improve the range of your golf cart.
10. Your brother replaces the electric razor he purchased last year with a new, more energy-efficient model in order to save on his power bill. What does energy-efficient mean? Was this razor a wise purchase?

Focus On SCIENCE AND TECHNOLOGY

The goal of technology is to provide solutions to practical problems. One of the practical problems with using electrical technologies is how to improve efficiencies. Think about what you learned in this section.

1. Give two examples of practical problems related to efficiency that you read about in this section.
2. How were technologies used to solve these problems?
3. What knowledge from a related scientific field would a scientist or engineer need to develop these technologies?

4.0 The use of electrical energy affects society and the environment.

Key Concepts

In this section, you will learn about the following key concepts:

- energy transformation
- energy transmission
- generation of electrical energy
- energy storage
- renewable and nonrenewable energy

Learning Outcomes

When you have completed this section, you will be able to:

- identify and evaluate alternative sources of electrical energy, including oil, gas, coal, biomass, wind, waves, and batteries
- describe the by-products of electrical generation and their impacts on the environment
- identify example uses of electrical technologies and evaluate technologies in terms of benefits and impacts
- identify concerns regarding conservation of energy resources
- apply the concept of conservation of energy
- evaluate means for improving the sustainability of energy use

The world has a huge appetite for electrical power, but how do we meet this growing demand? Technology is not a limitation in generating large amounts of power or in getting it to where it is needed. A power-plant generator like the one above can produce up to a million kilowatts of electrical power.

The total output of all the electrical generators in Canada is more than 100 million kilowatts. All the world's power-generating facilities together produce about 3 billion kilowatts. Every second, enough electrical energy is produced to light a 100-W bulb for 951 years. In this section, you will learn more about the generation of electricity from different energy sources. You will also learn about the impact that electrical generation can have on the environment. You will consider how to balance the benefits of using electricity with the need to conserve energy resources.

4.1 Electrical Energy Sources and Alternatives

Worldwide, about 65% of all electric power is generated by burning oil, coal, or natural gas. These fuels are often called **fossil fuels** because they formed from the decomposition of prehistoric plants and animals.

Most of the fossil fuel used in power plants is coal. Coal is a reasonable choice in areas like Alberta that have large and easy-to-excavate deposits. However, mining coal or tapping deposits of oil or natural gas is only the first step toward generating electricity from fossil fuels.

infoBIT

Packed with Energy!
Coal contains a great deal of stored energy. Burning a single kilogram of Alberta coal will produce about 27 MJ of thermal energy. That's enough to boil about a third of a bathtub full of water.

Using Heat to Generate Electricity

How do we use coal to turn a generator? The coal is powdered, then blown into a combustion chamber and burned to release heat, as shown in Figure 4.1. The heat boils water and superheats the resulting steam to a high temperature and pressure. This high-pressure steam drives a large **turbine**. The turbine is a long shaft with many fan blades. Steam striking the blades turns the turbine. The turbine shaft rotates large electromagnetic coils in the generator to produce electricity. Oil or natural gas can be burned in the combustion chamber instead of coal.

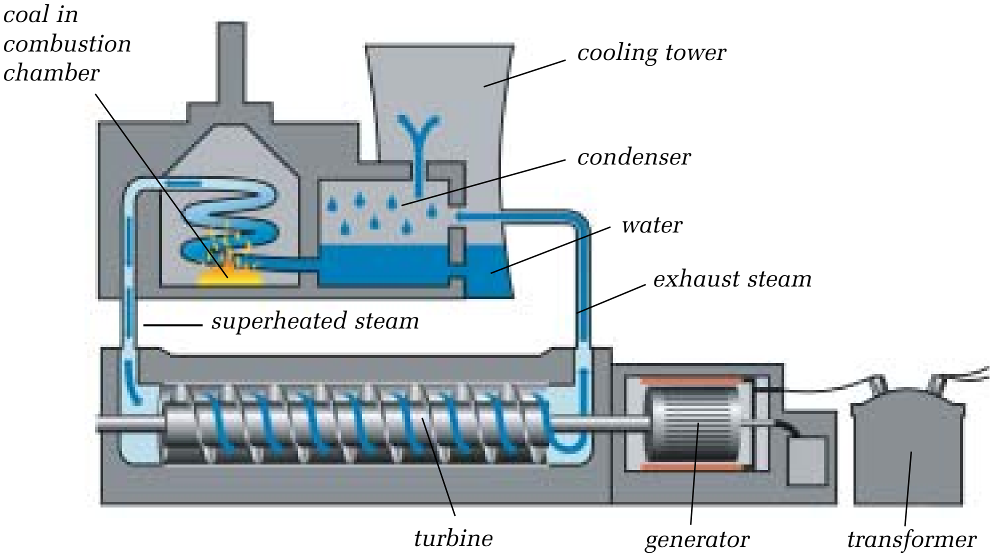


Figure 4.1 Coal-fired generating plant

Burning fossil fuels is not the only way to provide heat for a steam-powered generator. In Ontario, the United States, and parts of Europe, nuclear reactors are used extensively to produce steam in power plants. In a nuclear reactor, atoms of a heavy element, usually uranium, are split in a chain reaction. This splitting, known as **nuclear fission**, releases an enormous amount of energy.

Figure 4.2 Geothermal energy heats this hot spring.

Heat from Earth's core can also be used to generate electricity. In several places in the world, hot water and steam naturally come to the surface after having been heated by hot rock within Earth's crust. This is called **geothermal energy**. The steam is channelled through pipes and used to drive turbines. In some applications, water is injected back into the ground to take full advantage of the hot geothermal energy source.

Another interesting source of fuel is **biomass**. Biomass could accurately be described as garbage, but it's a particular type of garbage. Most cities and towns bury their biodegradable waste in landfills. When it decomposes, it produces combustible gases that can be collected and used as fuel for steam-driven generators. Yard clippings, dead trees, unused crops, and food-based garbage can also be burned to produce steam.

Some industrial processes, such as glass manufacturing, use very high temperature furnaces. The waste heat from the manufacturing process can be used to produce steam. This steam can then be used to drive a turbine to generate electricity. Fuel is burned in the manufacturing process to produce the heat in the first place, but no new fuel is needed to produce the electricity. Making double use of energy in this way is called **cogeneration**.

Using Water Power to Generate Electricity

About 20% of the world's electricity is generated by hydro-electric power plants. These plants capture the energy of falling water. Some hydro-electric plants, like the ones at Niagara Falls, use the flow from a waterfall, but most use a dam built across a river to store water in a reservoir. Water is directed through a channel called a penstock to a large paddle-covered turbine. The rushing water spins the turbine, which is connected to a generator in the same way as a steam-driven turbine.

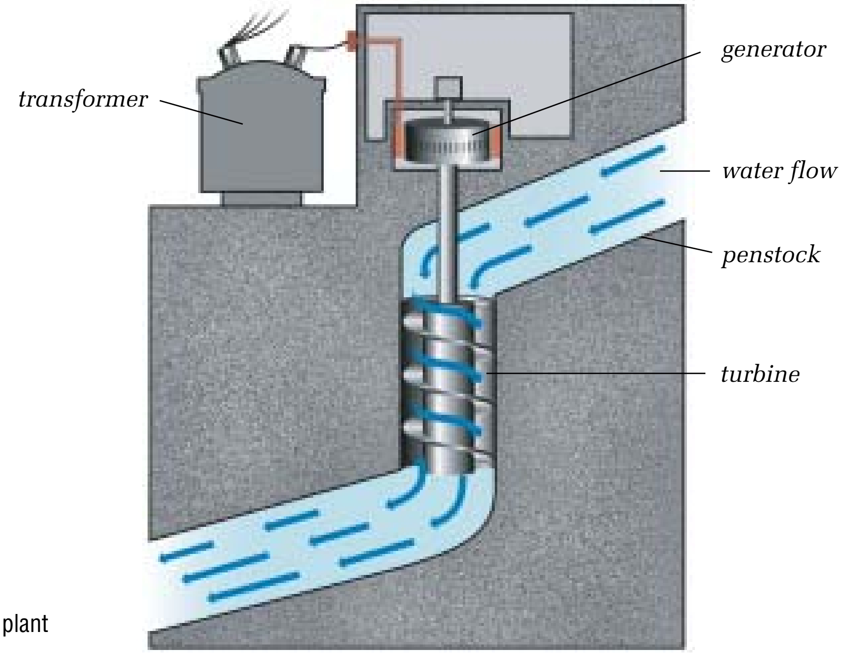


Figure 4.3 Hydro-electric plant

Alternative Energy Sources

Tides

Moving water from tides can also power turbines that run generators. Tidal power stations operate rather simply. When the tide comes in, the water is trapped in a reservoir and then let out past turbines. There are not many tidal power stations in the world because of the difficulty of finding suitable locations. One is located in Nova Scotia at the mouth of the Annapolis River. It takes advantage of the large tides in the Bay of Fundy. Waves can be used to generate electricity too. In one type of wave-power generating station, the up-and-down movement of the water drives a piston connected to a generator.

Figure 4.4 Windmills used to generate electricity at Cowley, Alberta

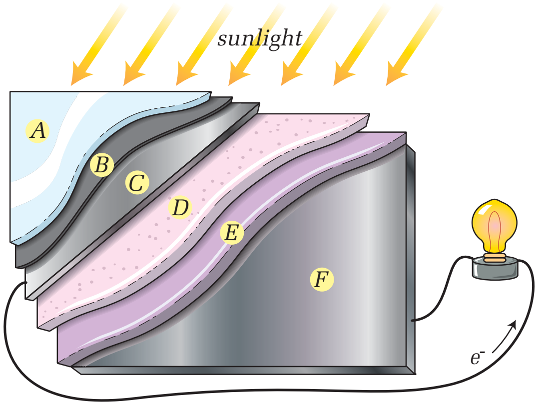
Wind

Wind energy can be harnessed to turn a shaft. For centuries, windmills used sails on the ends of shafts to provide power to grind grain and pump water. Modern windmills use more efficient designs with propeller-shaped blades. The amount of electricity a single windmill can generate is limited, but a number of wind-powered generators can be connected together in "wind farms" to produce larger amounts of electrical energy.

Sunlight

In 1839, French scientist Alexandre Edmond Becquerel soaked two metal plates in an electricity-conducting solution. When he exposed one of the plates to sunlight, he was able to detect a small voltage. Becquerel had discovered the photovoltaic effect and invented the first solar cell. Unfortunately, the voltage from his invention was too small to be useful as a source of power. In the 1950s, scientists began using silicon to make solar cells. Silicon-based solar cells are much more efficient at producing current. It is now common to find solar modules (several cells connected together) and arrays (several modules) used to power everything from calculators to spacecraft.

Figure 4.5 The International Space Station uses 2500 m^2 of solar cells to generate its electricity.



A Protective cover glass
B Antireflective coating to let light in and trap it
C Metal contact grid to collect electrons for circuit
D Silicon layer to release electrons
E Silicon layer to absorb electrons
F Metal contact grid to collect electrons from circuit

Figure 4.6 A solar cell consists of several layers. At the heart of the cell are two specially treated silicon layers that create current when in sunlight.

Batteries

Batteries are a convenient source of electricity for portable devices. However, large banks of batteries are rarely used because they are expensive and bulky. For example, an alkaline D-cell would light a 100-W light bulb for about 15 min. You would need a room full of batteries to run all the appliances in your house. Obviously, batteries are not practical for lighting whole cities.

Rechargeable batteries are widely used to provide backup power for emergency lights and computer systems. However, these batteries produce electricity only after they have been charged using electricity from an external source. Since rechargeable batteries are never 100% efficient, they actually use more electricity than they produce.

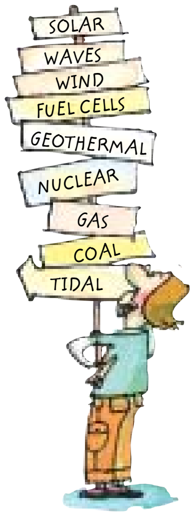
Recently, much research has been done to develop **fuel cells**. A fuel cell generates electricity directly from a chemical reaction with a fuel such as hydrogen. The hydrogen comes from sources such as gasoline or alcohol. More fuel is added as electricity is produced, so the cell is not used up as an ordinary cell would be. Larger fuel cells can be used to power electric vehicles. Smaller ones are being developed for use with portable devices such as laptop computers.

GIVE IT A **TRY**

ENERGY NEWS

Now that you've learned a bit about Earth's energy sources, it's time to dig deeper. All energy sources have advantages and disadvantages. Your task as a reporter is to find out more about two energy sources, and compare them. Compare any two of the following:

- wind
- nuclear
- geothermal
- waves
- solar
- natural gas
- fuel cells
- coal
- tidal
- biomass



Use your library or the Internet to find out more. If possible, interview an expert. On the Internet, begin your search at www.pearsoned.ca/scienceinaction.

- Compare as many factors as possible. For example, you could consider availability, cost, sustainability, environmental impact, applications (what the source can be used for), and safety.
- Prepare your findings in a report. In the spirit of "alternative" energy sources, consider alternative methods for presenting your report. You might design a poster, Web page, or a multi-media presentation. You could write an essay or make a videotape.

Activity D-12

Problem Solving

Harness the Wind

Recognize a Need

You have been contracted to design and build a windmill. It will be used in an exposed area that is windy all the time, although the strength of the wind varies. There are low winds lasting for several days but also periods of intense wind. Your client wants to use these winds to generate electricity.

The Problem

You must design a windmill that operates well in both low and high winds.

Criteria for Success

You must build a working model that meets the following criteria:

- Your model must be free-standing, although it can be anchored to the surface it sits on (for example, taped to a desk).
- The turning shaft of your windmill must be attached to the armature of a small electric motor so that when the windmill shaft turns, the motor armature turns. Although not specifically designed for the task, the electric motor will serve as a direct current generator.
- Your windmill must produce a detectable current. This can be determined by connecting the galvanometer to the leads of the generator (small motor).
- Your windmill must function in a stable manner when tested with a fan held at different distances to mimic low and high winds. Your teacher may give you more detailed criteria for testing with a specific fan.

Materials & Equipment

- a fan to test your windmill
- small electric motor with pulley
- connecting wires
- galvanometer (or milli-ammeter)
- materials to build your model

Figure 4.7 Designing a windmill

Brainstorm Ideas

TOOLBOX

1 With your team, brainstorm possible solutions. Once you have several solutions, choose the one you think will work the best to meet the criteria above. You may want to read Toolbox 3 to help you with the problem-solving process.

Build a Prototype

2 Create a plan of how you will build your windmill. Include a diagram and a list of the materials that you will need. Show your plan to your teacher for approval.

3 Assemble your materials and build your windmill. Remember that you may need to modify or change your design as your windmill progresses. Make sure to note any changes on the original design you submitted to your teacher.

Test and Evaluate

4 When you have built your windmill, test it to see if it meets the Criteria for Success. Identify any practical problems with your device. You may need to make changes to correct problems, and then repeat the tests.

Communicate

5 How well did your windmill function under varying wind conditions? If your windmill functioned better under one wind condition, explain why.

6 Evaluate your design for the factors listed below. For each factor, describe how well you think your device would work if it were built to full size.

a) reliability b) safety c) current generating efficiency

reSEARCH

Fusion

Fusion reactions occur in the Sun and provide all the energy for life on Earth. Scientists are investigating the potential of fusion as a limitless, pollution-free source of energy. Find out more about fusion. Make a chart comparing fusion with the nuclear energy we use today. Start your information search at www.pearsoned.ca/scienceinaction.

Renewable and Nonrenewable Energy

Alberta has substantial coal reserves, enough to last over two hundred years at current rates of consumption. However, coal is a **nonrenewable resource**—it cannot be replaced as it is used up. Alberta's other fossil fuel resources are also nonrenewable. Crude oil (petroleum), and natural gas will eventually run out. When the supplies of these fossil fuels are gone, they are gone forever.

In contrast, **renewable resources** can be renewed or replenished naturally in relatively short periods of time. Some are continually replenished. Wind energy, tidal energy, solar energy, geothermal energy, and biomass are resources that naturally renew themselves, so they can last forever. If tree harvesting is managed carefully, replanting can ensure that wood supplies for energy can last indefinitely. However, if wood is used faster than trees can be grown, then the renewable resource cannot meet energy needs indefinitely.

Check and Reflect

Key Concept Review

1. Describe the turbine's role in an electric generator.
2. Is it correct to say that the majority of the world's electrical demands are met with hydro-electric generators? Explain why or why not.
3. What is the difference between a renewable and a nonrenewable resource?
4. Look at Figure 4.6 on page 347. Describe how a solar cell produces electricity.
5. What is cogeneration? Give one example.

Connect Your Understanding

6. How can a river be used to produce electricity?
7. What do nuclear power plants and coal-fired power plants have in common?
8. What is biomass? How can it be used to create electricity?
9. Make a chart summarizing how tides, geothermal sources, sunlight, and wind can be used to produce energy.

Extend Your Understanding

10. Why don't power stations use batteries to generate electricity?
11. Residents of a remote community decide to use wood as their primary energy source. All the trees nearby are cut down and stockpiled for use in home heating and heating the boiler of the community's electrical generator.
    a) Is the community's energy source guaranteed to last indefinitely? Explain.
    b) What recommendations would you make to ensure that this community has a reliable long-term energy supply?

4.2 Electricity and the Environment

Every method of generating electricity affects the environment. Some methods create undesirable by-products. These by-products have negative effects on human health and the environment.

Figure 4.8 Burning fossil fuels produces air pollution.

Air Pollution

The burning of fossil fuels results in the release into the atmosphere of many problem-causing substances. For example, when coal burns, it leaves behind a powdery ash. Some of this ash is carried up the smokestack of the power plant and escapes into the atmosphere. This airborne ash is often referred to as **fly ash**. In Canada, air pollution produced by coal-burning plants has been reduced over the last 30 years by improved methods of cleaning the coal and capturing the fly ash. However, considerable amounts of fly ash still escape. This is a concern because the fly ash contains small amounts of mercury, a poisonous metal that can damage the nervous system.

Many other molecules are released into the air when coal is burned. Some of the most harmful are sulfur dioxide ($SO_{2(g)}$), nitrogen oxides ($NO_{x(g)}$), and carbon dioxide ($CO_{2(g)}$). Sulfur dioxide causes acid rain and contributes to air pollution. Nitrogen oxides are major causes of air pollution. Carbon dioxide in the atmosphere has been identified as a cause of global warming, which leads to climate change. You can learn more about these chemicals and their effects in Unit C: Environmental Chemistry.

Other Environmental Effects

Much of the coal used in power plants comes from strip mines. Strip-mining techniques are used when deposits are near the surface. Bulldozers clear the soil, and sometimes explosives are used to help clear any rock above the deposit. Large scoops collect the coal and load it into trucks that take the coal away for further processing. This type of mining removes all plants and animals from large areas of land. Although the land can be reclaimed by replacing the soil, the original natural environment usually is not fully restored.

Oil and gas wells can also affect the area surrounding them. Some deposits contain poisonous gases. Measures must be taken to prevent the release of these gases into the environment. Concentrations of chemicals in the environment around wells and plants are monitored for safety.

In electricity generation, steam turbines often release a great deal of warm water into nearby lakes and rivers. The resulting increase in water temperature alters the local freshwater ecology and can sometimes kill fish.

Figure 4.9 Strip-mining coal

*info***BIT**

Nuclear Waste Storage
Radioactive waste from nuclear power plants requires long-term storage. Canada's plans for storing this waste include placing corrosion-resistant containers in vaults deep within the Canadian Shield. These vaults will be 500 to 1000 m deep and will likely be in Ontario.

The mines and refineries that produce fuel for nuclear reactors can also damage the environment. The reactors create radioactive wastes that remain dangerous for thousands of years. Hydro-electric plants produce no pollutants, but their dams flood many hectares of land and alter the ecosystems of rivers. Wind farms and solar cell arrays require large tracts of land to generate practical amounts of energy. Also, the process for making solar cells creates some chemical pollution. The steam from geothermal plants produces a small amount of pollution. Generators using tidal or wave energy may disrupt the habitat for fish and other marine life. However, the "green" sources of energy—especially wind, tide, and geothermal—harm the environment much less than fossil fuels do.

Conserving Energy and Nonrenewable Resources

We know that reserves of oil and gas are decreasing, but it is likely that nonrenewable fossil-fuel supplies will last for your lifetime. So why bother trying to conserve energy? If demand for energy decreases, there is a lower demand for the resources that fuel electrical generating plants. Those pollution-producing plants that are already in operation would not need to operate at full capacity and may even be able to cease operation. The obvious benefit is less pollution, which is a good reason to try to use less electricity whenever possible. When your actions lead to a lower demand for natural resources, you are practising energy conservation.

You may not have to worry about fossil fuels running out in your lifetime. However, even temporary shortages can cause hardship and big price jumps. When fuel prices skyrocket, poorer countries cannot afford the energy they need.

Suppose you want to conserve fossil fuels and reduce pollution. You consider buying an electric car instead of one with a gasoline engine, but you know you have to look at more than just engine efficiency. Electric cars reduce the need for gasoline, which comes from oil. Burning less gasoline conserves oil reserves and reduces pollution. The electric car, however, must get electricity from somewhere for its rechargeable batteries. If a coal-fired plant supplies this electricity, you may not be saving fossil fuels or reducing pollution overall. However, if a hydro-electric plant or windmill farm supplies the electricity, fossil fuels will be conserved and pollution will decrease. Both personal and societal decisions must be taken into account when considering conservation.

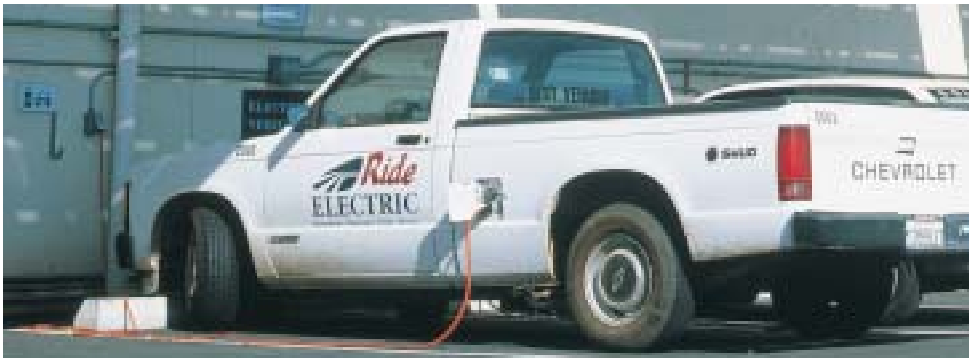


Figure 4.10 Does an electric vehicle conserve energy resources?

A Sustainable Future

Conserving energy means moving toward sustainability. **Sustainability** means using resources at a rate that can be maintained indefinitely. If we do not achieve *sustainable* energy use, future generations may not be able to support themselves. A sustainable approach sometimes requires a different way of developing resources. In the past, mineral and hydrocarbon deposits were used up as quickly as possible to earn money and satisfy consumer demand. We need to use our resources in a way that makes them available over a longer period. Sustainability may also mean no longer using nonrenewable resources because they cannot be maintained indefinitely.

We may never be able to achieve complete sustainability, but the decisions we make personally and as a society can move us closer to this goal. An example of a personal decision would be to take public transportation rather than driving your own vehicle. This saves fuel and reduces pollution. Decisions made with sustainability in mind sometimes involve compromise—a bus may not be as convenient as your own car. An example of a societal decision related to sustainability is the use of low wattage street lights. Some cities have installed these lights to reduce electricity consumption and light pollution. In this case, the drawback is that streets may not be as brightly lit.

reSEARCH

Acid Mine Drainage

The environmental effects of using coal start with its removal from the ground. The water that flows through mines and coal storage areas can become acidic. It may also contain dissolved metals. Research acid mine drainage. Prepare a brief report on its environmental effects and what is being done to reduce those effects. Start your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. How can oil wells affect the environment?
2. Do nuclear power plants produce by-products? If so, are they harmful?
3. What is fly ash? Why is it an environmental concern?
4. Explain why you agree or disagree with the following statement. *"Green" sources of energy such as solar and wind power have no environmental impact.*

Connect Your Understanding

5. What is the difference between energy conservation and energy sustainability?
6. Does replacing the soil removed by strip-mining restore the environment? Explain your answer.
7. Explain how each of the following actions affect energy sustainability:
   a) replacing a coal-fired power plant with several fields of solar arrays
   b) choosing a new refrigerator that is high efficiency
   c) carpooling with friends to drive to work
   d) replacing the incandescent bulbs in your home with compact fluorescent bulbs

Extend Your Understanding

8. A friend brags to you about her new electric car that uses rechargeable batteries as an energy source. She says, "My new car doesn't have an internal combustion engine, so no fossil fuels are needed to provide energy for it." Is this an accurate statement? Explain your answer.
9. In 1906, many steam-powered cars were on the roads. The record for the fastest steam car was approximately 206 km/h. A British team is now working to build a modern steam car that it hopes will travel over 300 km/h. While this car will be fast, will it conserve energy? Explain.

*info***BIT**

Less Luggage

A business traveller used to have to carry a cellular telephone, an organizer, and a laptop computer. Now digital wireless technologies let people on the road phone their offices and clients, manage their contact information and appointments, and connect to the Internet, all with a device small enough to fit in a pocket!

4.3 Electrical Technology and Society

Figure 4.11 Electrical technology lets us communicate at the speed of light.

In 1844, the first electrical communication took place with the help of Samuel Morse's invention, the telegraph, shown in Figure 4.11. Morse developed a code of dots and dashes (short and long electrical signals) to send messages down wires from one city to another. Today, electrical technologies continue to make fast and efficient communication possible. With the rapid development of personal computers in the 1980s and the Internet in the 1990s, we now have the ability to collect and transmit vast amounts of information.

Benefits of Electrical Technologies

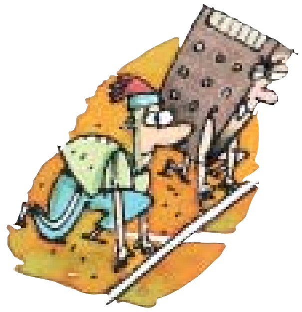
It would be a major understatement to say that electrical technologies have improved our standard of living. Most electrical devices and inventions came out of a desire for speed or convenience. Consider, for example, how the task of doing laundry has changed. Before the invention of the modern washing machine, it could take a whole day of hard work to complete the washing for an average family. Now, machines do the washing, rinsing, and drying, freeing people to do other things. In a similar way, many electronic devices help us to complete a variety of tasks more quickly and efficiently, and give us more time for other activities.

GIVE IT A TRY

NUMBER RACE

You will compare the time taken to do a calculation without and with a calculator.

Write an arithmetic problem requiring the addition and subtraction of 10 three-digit numbers. Trade your problem with someone else, then time each other on how long it takes to do the calculations the good old-fashioned way—by hand. Now time each other doing the calculations using an electronic calculator.



- In what way is an electronic device better for doing calculations? In what way is it worse?
- Design a similar test for processing words instead of numbers.

DRAWBACKS OF ELECTRICAL TECHNOLOGIES

More technology means that more resources are needed to manufacture and operate devices. This can make sustainability more difficult to achieve. And as technology progresses, it leaves behind obsolete devices. These devices are usually discarded as waste, so they add to problems with solid waste disposal. Some technologies may also be too expensive for developing countries to adopt. This can have the effect of isolating people and excluding them from the benefits of technological advancement.

COMPUTERS AND INFORMATION

If you are looking for a device that has brought radical changes in speed and convenience, look no further than the computer. Computers have revolutionized the way we accomplish many tasks, including writing, calculations, and communication. Computers convert all information—even audio and video signals—into numbers and then perform calculations with the numbers. Computers use **binary numbers**, that is, numbers with just ones and zeroes. These numbers correspond to the on and off states of the millions of tiny transistors in the microcircuits. Because the data is converted to strings of digits, this method of storing and transmitting information is often referred to as a digital technology.

*info***BIT**

Programming Pioneer

By 1952, Grace Hopper (1906-1992) had developed a working compiler, a program that translates English words into the special codes needed to run computers. Such compilers are the key to all the high-level computer languages we use today. Hopper also co-authored COBOL, a widely used programming language for businesses. The term "computer bug" originated in 1951 when Hopper found a moth jamming a relay in one of the first large-scale computers.

Electricity and Computers

Different techniques can be used to store and transmit information, but all of them take advantage of electrical current in one way or another. For example, a compact disc (CD) player scans a CD with a laser. Tiny pits stamped into the surface of the shiny disc cause the laser light to be reflected in pulses. A photodetector converts the light pulses into electrical pulses. This produces a digital signal with exactly the same sequence of ones and zeroes as the master recording used to make the CD.

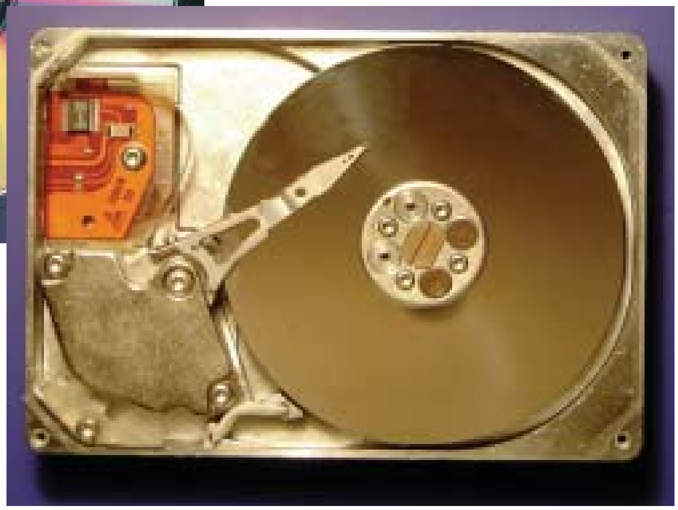


Figure 4.12 Compact discs (CDs) and computer hard drives both store digital information, although in different ways.

A hard drive in a computer also uses pulses of electricity to record and transmit information. In a hard drive, a highly polished aluminum or glass disk coated with a thin layer of magnetic material rotates at speeds of up to 300 km/h. Electrical pulses are sent to an arm with read/write heads. These tiny electromagnetic coils magnetize spots on the spinning disk. When a head reads the disk, the magnetized spots induce pulses of current in the electromagnetic coil. This reproduces the ones and zeroes in the original signal. When the heads are writing, they respond to electrical signals from the computer's processor. When the heads read the disk, the hard drive sends an electrical signal to the processor. Electrical signals control all the functions of a computer, including the images on the screen and the sounds from the speakers. If these electrical signals can control your computer, could signals also be sent to control a remote computer? Such signals are the key to networking and the Internet.

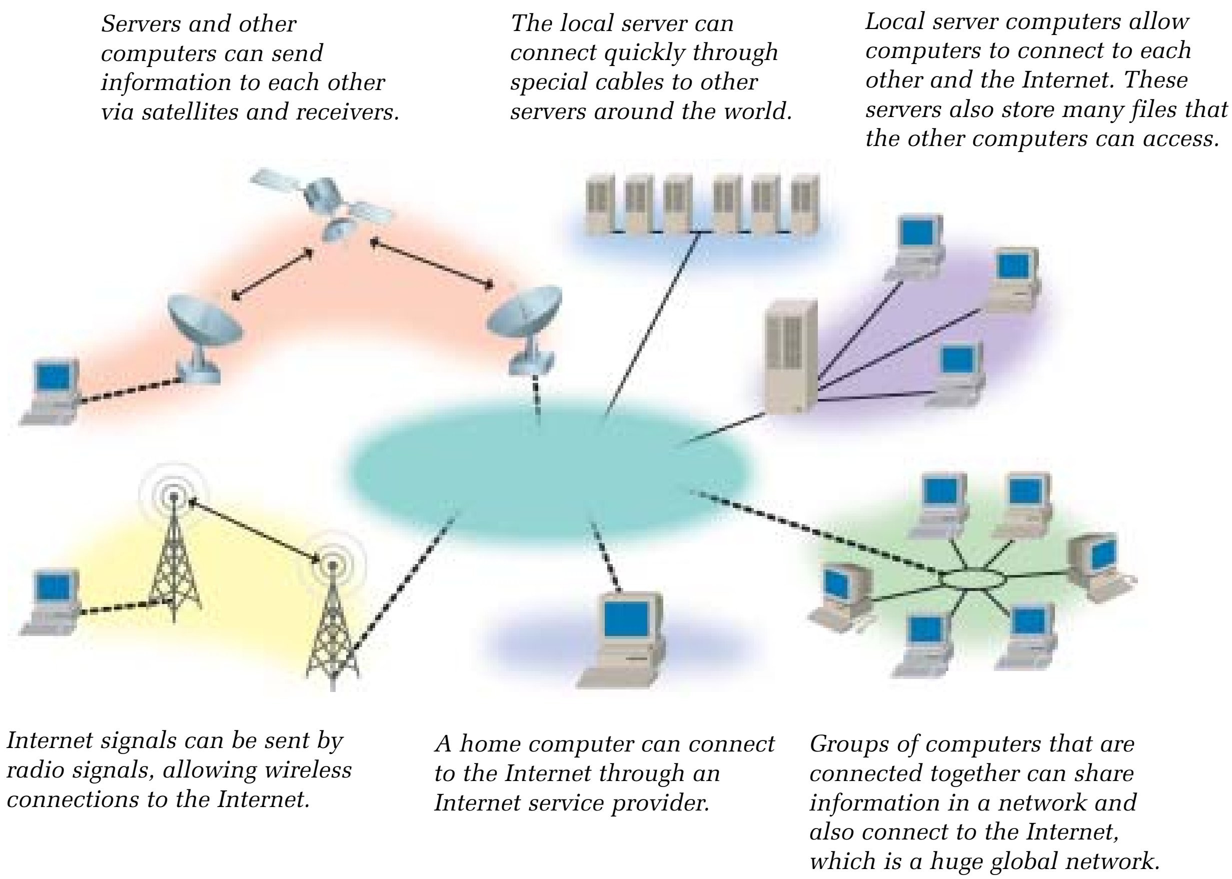


Figure 4.13 Electrical signals sent between computers around the world make internetworking possible.

Electrical Transmission of Information

There is little doubt that electronic storage of information is a huge benefit to society. Information is cheaper to store, easier to find, and much more compact. For example, a single digital video disc (DVD) can store more information than a whole set of encyclopedias. Electronic media can store audio and video, as well as text, which often makes information easier to understand and more entertaining. Hard drives in personal computers make storage and retrieval of large amounts of information fast and convenient. Thousands of hard drives in servers connected to the Internet all around the world put huge amounts of information at your fingertips.

But there are some concerns about the explosion of information and electronic technology. One issue is access to technology. Some countries are too poor to establish the infrastructure necessary to connect computers and transmit information.

Another issue is privacy. Data transmission is not always secure. Files, such as financial and personal information, sometimes fall into the wrong hands. “Hackers” attempt to break into networks either to steal information or to cause damage for the sake of challenge, or for no reason at all.

*re*SEARCH

Encryption

Ever since the transfer of information became possible, people have been developing ways to protect it. Such protection is especially important for the transfer of financial information such as credit-card numbers over the Internet. Find out more about encryption. Use an example to show how encryption is done and how it is used. Start your information search at www.pearsoned.ca/scienceinaction.

Can you trust all the information that you find over the Internet? With huge volumes of information stored worldwide, some of it will be wrong or misleading. Most people have good intentions, but some will post "facts" that they have not checked properly. Others may deliberately send out wrong information.

Another concern is "information overload." With greater and greater capacity to store information, it becomes increasingly more difficult to find the particular piece of information that you need.

Search engines were developed to help sort through the vast amount of unorganized information on the Internet. A search engine is an application that searches the Internet for keywords or phrases that you enter in a query field. Internet sites that match your keywords are then reported back to you.

However, search engines work in different ways and may not be as helpful as you might expect. For example, some search engines report only results from sites on the Internet that have been manually entered in a database. Useful sites that have not been entered in the database are not reported. Other search engines report only the most-visited sites on the Internet; that is, the most popular sites. Because of this, a more useful, less popular site may be overlooked. This explains why using different search engines may provide different results for the same keywords or phrases that you are searching for.

Check and Reflect

Key Concept Review

1. Name two benefits of electrical technologies.
2. What is special about a "binary" number?
3. Explain some of the drawbacks of information technology.
4. a) In what form is computer information stored?
   b) In what form is it transmitted?

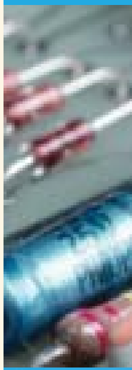
Connect Your Understanding

5. Why could more technology make sustainability more difficult?
6. Explain how it is possible for your home computer to connect to and retrieve information from a computer in another country.
7. How is an Internet server computer different from a home computer? How is it the same?

Extend Your Understanding

8. What does electricity have to do with the storage of information on a computer?
9. A classmate explains to you that his mother is treating her own medical condition with health advice she found while using the Internet. What, if any, concerns might you have about this?

SECTION REVIEW



Assess Your Learning

Key Concept Review

1. What is sustainability? Give one example.
2. Describe the advantages and disadvantages of using coal as an energy source.
3. Briefly describe geothermal and tidal methods of generating electricity.
4. Describe some of the ways that computers can connect with each other.
5. Why are coal, natural gas, and oil referred to as "fossil" fuels?

Connect Your Understanding

6. Use a Venn diagram to compare the generation of electricity using coal with hydro-electricity generation. How are they similar? How are they different?
7. A group of Alberta farmers forms a co-operative group and builds a factory that turns grain into alcohol as a fuel for generators and cars. Would this energy source be renewable or nonrenewable? Explain.
8. Do advances in computer technology benefit everyone in the world equally? Explain your answer.

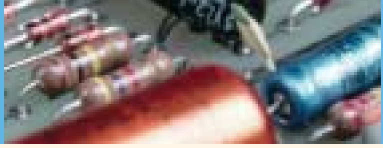
Extend Your Understanding

9. *A nuclear power plant provides energy using a radioactive source, so a turbine is not needed.* Explain why you agree or disagree with this statement.
10. You notice your neighbour replacing her exterior house lights with lower watt bulbs. Would you describe this as "conservation" or "sustainability"?
11. Cars today include electronic systems that control much of their operation. Identify one benefit and one drawback to the use of these electronic systems.

Focus On SCIENCE AND TECHNOLOGY

Technological problems can often be resolved with more than one solution. The different solutions may involve a variety of designs, processes, and materials. Think about what you learned in this section.

1. Give one example that you encountered of a problem that had more than one solution.
2. Was one solution better than the others? Why or why not?
3. If you did Activity D-12 Problem Solving: Harness the Wind, how did you know when you had a solution that would work?



Unit Summary: Electrical Principles and Technologies

Key Concepts / Section Summaries

1.0

Key Concepts

- electric charge and current
- circuits
- electrical energy storage
- energy transmission
- measures and units of electrical energy

1.0 Electrical energy can be transferred and stored.

- There are two types of electricity: static and current. Static is electrically charged particles at rest. Current is flowing electrically charged particles.
- Voltage is a measure of how much electrical energy each charged particle carries. Current is the rate at which charged particles flow.
- Electricity can be dangerous, so safety should always be a concern.
- Electricity can be produced through chemical reactions and stored in different types of cells. Cells can be combined to form batteries.

2.0

Key Concepts

- electric current
- circuits
- energy transmission
- measures and units of electrical energy
- electrical resistance and Ohm's law

2.0 Technologies can be used to transfer and control electrical energy.

- Different substances provide various levels of resistance to electric current. Electricity flows more easily in conductors than in insulators.
- The amount of electrical resistance is measured in ohms. Voltage is measured in volts. Current is measured in amperes.
- Ohm's law states that the current flowing through a conductor is proportional to the voltage applied to it.
- Meters are used to measure electricity. Voltmeters measure voltage. Ammeters measure current. Ohmmeters measure resistance. Multimeters measure all three.
- Series circuits provide a single pathway for current. Parallel circuits provide multiple pathways for current.

3.0

Key Concepts

- forms of energy
- energy transformation
- generation of electrical energy
- energy transmission
- measures and units of electrical energy

3.0 Devices and systems convert energy with varying efficiencies.

- Energy exists in different forms, such as chemical, thermal, mechanical, and electrical energy.
- Energy can be transformed from one form into another. For example, a thermocouple can change thermal energy into electrical energy.
- Electric motors transform electrical energy to mechanical energy.
- Power is the rate at which a device converts energy. It is calculated by multiplying current by voltage. Energy is calculated by multiplying power by time.
- Input energy and usable output energy can be compared to determine the efficiency of an energy-converting device.
- Reducing the amount of energy wasted by devices that convert energy increases their efficiency.

4.0

Key Concepts

- energy transformation
- energy transmission
- generation of electrical energy
- energy storage
- renewable and nonrenewable energy

4.0 The use of electrical energy affects society and the environment.

- A variety of alternative energy sources can be used to generate electrical energy. These include fossil fuels, nuclear energy, geothermal energy, biomass, hydro-electricity, tides, wind power, and solar energy.
- Energy sources are either renewable or nonrenewable.
- Electrical generation can produce by-products and effects that harm the environment.
- Energy and nonrenewable resources can be conserved through choices that reduce consumption.
- Sustainability means using resources at a rate that can be maintained indefinitely.

Three Gorges Dam

The Issue

In 1994, the Chinese government began a massive project on the Yangtze River called the Three Gorges Dam. The project is designed to provide electricity to large areas of rural China, where many people live in poverty without electricity. It will also control flooding. The Yangtze often overflows and floods large areas of northern and central China. In the 20th century, such flooding killed over 300 000 people. When it is completed in 2009, this dam will be one of the largest in the world.

- When complete, the dam will be 2.3 km across and 185 m tall. It will create a lake about 600 km long and 200 m deep.
- The dam will require 27 million cubic metres of concrete. That's enough concrete to cover 4000 football fields to a depth of one metre!
- The dam will produce over 18 GW (gigawatts) of power.

Many people in other countries and in China do not think the dam should be built. The chart below gives two different viewpoints about the project.

Go Further

Now it's your turn. Use the following resources to help you learn more.

- Look on the Web: Use the Internet to find out about the Three Gorges Dam. Begin your search at www.pearsoned.ca/scienceinaction.
- Ask the Experts: Many engineers and archeologists are available through question-and-answer sites on the Internet. A local energy council or government agency may also be able to give you information.
- Look It Up in Newspapers and Magazines: Check for articles about this issue in newspapers and magazines.

Analyze and Address the Issue

Use the information you have gathered to analyze the costs and benefits of the Three Gorges Dam project. Write a brief report stating your conclusion about whether the project should be completed. Support your conclusion with your research data.

Should China Complete the Three Gorges Dam?

Yes	No
The dam may be able to stop devastating flooding. The dam's control mechanisms may be able to save lives by managing water levels.	**The dam presents an even worse flooding danger if it fails**. Millions of people live downstream of the dam. A failure of the dam would be catastrophic.
The dam would produce much needed electricity. The poor of rural China do not even have refrigerators. Electricity would provide the possibility of modern conveniences.	**The dam requires almost 2 million people to be uprooted and relocated.** The reservoir will flood thousands of farms and villages.
Electricity would provide the means for modernization. Rural China has few of the advantages of even the smallest Western communities. With electrical power, rural Chinese can begin to modernize their economy.	**The dam's reservoir will submerge many priceless artifacts and natural treasures.** Over a thousand archeological sites will be ruined.

PROJECT

BUILDING AN ELECTRICAL DEVICE

Getting Started

Designing an electrical device offers many opportunities to discover answers for yourself. In this activity, you will plan how to build an electrical device that performs a particular function. Then you will build and modify a prototype. Using your choice of materials and what you have learned about electrical circuits, you will design a device or model of your own choice.

Your Goal

Demonstrate your understanding of electrical circuitry and energy conversions by using your imagination to pick a device or model to build. It can be any device that *uses electricity to perform a task.* Your goal will be to build the device that can successfully performs the task(s) of your choice. For example, consider building one of the following:

- a reversible escalator with an emergency switch
- a model electrically wired home, with special features such a pressure-sensitive welcome mat light
- a model animal kennel with doors that open electrically
- a rescue truck that moves and has a ladder that can be raised or lowered
- a switch-operated animal feeder that allows you to release food remotely

What You Need to Know

This project involves designing electrical circuits. Review what you have learned about electrical circuits and converting electrical energy into different forms. Recall how to supply current to a circuit and then control the current so that the circuit performs the task you desire. For your design to work, you will have to combine these concepts successfully. Before you begin, you may want to review Toolbox 3 to help you with problem solving as you develop your device. You may also want to consult Toolbox 13 to review the electrical symbols you need to use in your circuit diagrams.

Steps to Success

1. With your group, brainstorm ideas for solutions to the problem. Sketch ideas as you come up with them.
2. Decide what equipment you will need. Are there materials you can collect from home? Ask your teacher for help with any of the materials that you cannot collect yourself.
3. Carefully consider safety before you begin to construct your prototype. Show your teacher your final plan for approval, and then begin building your device.
4. When you have built your device, test to see if it meets your goals. After your test, you may need to make some changes and repeat the tests.
5. Look at your classmates' devices. Make a quick sketch of one of their designs and of a modification to improve it. Discuss this modification with your classmates.

How Did It Go?

6. Now that you have planned and constructed your device, write an evaluation of your approach to solving this problem. Did it work well? What would you do differently and why?

Unit Review: Electrical Principles and Technologies

Unit Vocabulary

1. Create a concept map that shows how each of the following terms are connected. Use the word *electricity* as your starting word.

energy	resistance
batteries	series
motor	efficiency
current	cells
insulator	mechanical energy
power	voltage
electrolyte	conductor
generator	parallel

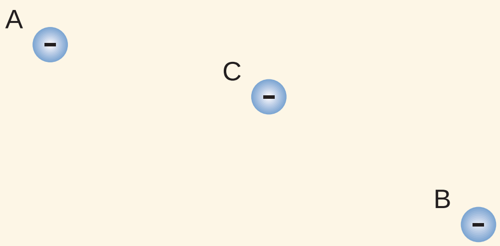
Key Concept Review

1.0

2. How can a Van de Graaff generator help in the study of electrical charge?

3. Describe an electric power grid. What is its purpose?

4. Consider two negative charges that are fixed in position (A and B below). What would happen if a movable negative charge were placed at point C? Explain.



5. What is a short circuit? Is it dangerous? Explain.

6. Explain how an electrical wet cell functions.

2.0

7. A friend replaces a cord on a kettle with a new one much thinner than the original. When the kettle is plugged in, the new cord gets much hotter than the old one did. Explain why.

8. Dimmer switches are convenient ways of controlling the amount of light in a room. Describe how a dimmer switch works.

9. Use Ohm's law to solve the following problems:

a) What voltage is applied to a 5.0-Ω resistor if the current is 1.5 A?

b) A voltage of 80 V is applied across a 20-Ω resistor. What is the current through the resistor?

c) The current running through a starter motor in a car is 240 A. If this motor is connected to a 12-V battery, what is the resistance of the motor?

10. Use electrical symbols to draw a series circuit with a four-cell battery, a motor, and two bulbs. Draw a parallel circuit using the same components. Describe the difference in current flowing through the two circuits.

3.0

11. What do the terms "work" and "energy" mean?

12. What is the role of the commutator in an electric motor?

13. Would it make more sense for an electric company to charge by the joule or by the watt? Explain.

UNIT REVIEW: ELECTRICAL PRINCIPLES AND TECHNOLOGIES

14. Solve the following power problems:
   a) The current running through a coffee maker connected to a 120-V source is 8.0 A. What is the power rating of this device?
   b) A 120-W motor draws 1.2 A of current. What is the voltage across the motor?
   c) A 5000-W dryer is connected to a 240-V source. What is the current flowing through the dryer?

15. How much energy does a 100-W light bulb use in an hour?

16. A 500-W hot plate adds 250 kJ of energy to a container of water while heating for 10 min. How efficient is this heating process?

17. Use the example of a gasoline-powered car to explain the concepts of input energy, output energy, and efficiency.

18. Describe three methods for reducing the amount of energy wasted in the home.

4.0

19. Could a thermal generating plant be effective without a turbine? Explain.

20. What is meant by a "non-thermal" method of generating electricity? Describe an example of such a method.

21. Discuss the positive and negative aspects of generating electricity with coal, nuclear power, and wind power.

22. Describe the difference between renewable and nonrenewable energy sources. Give two examples of each.

23. If current world oil reserves will last longer than your lifetime, why should you bother to conserve energy?

24. Describe the advantages and disadvantages of transmitting information electronically.

Connect Your Understanding

25. Explain why a cow that touches an electric fence gets a mild shock, but a bird sitting on the same wire doesn't feel any electricity at all.

26. A classmate would like to connect multiple motors together in a circuit. But every time a motor is added, an undesirable side effect occurs—all of them spin a little slower. Discuss possible solutions and explain how they would correct the problem.

27. You receive a nasty shock from a kettle with a frayed cord, and your arm temporarily feels numb. Is this numb feeling caused by current or voltage? Explain.

Extend Your Understanding

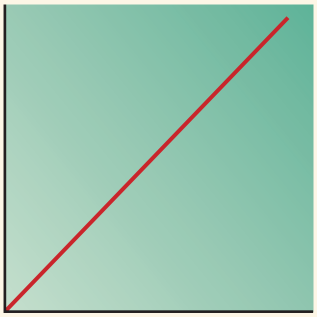
28. Does a decision to conserve a resource mean that the resource now becomes sustainable? Explain.

29. Does it make any sense to spend more money for a more efficient appliance? Explain.

30. Thinking that a loose electrical cable has been turned off, a construction worker tries to move it. The voltage contracts the worker's muscles, so they cannot let go of the wire. A wooden pole and a copper pipe are nearby. Could you use either of them to nudge the victim away from the live wire? Explain.

Practise Your Skills

31. This graph shows the relationship between voltage and current that emerged in tests for a particular resistor. Does this resistor work according to Ohm's law? Explain.



32. Construct a graph similar to the one above. Draw two lines that would represent the relationship between current and voltage for two resistors of different values. Write a short summary statement explaining the lines you have drawn.

Self Assessment

33. List two questions about elecctricity-related issues that you'd like to explore further.

34. How could you improve the results of your work in the problem solving and inquiry activities you did in this unit?

35. How could you improve your work in group situations?

Focus On SCIENCE AND TECHNOLOGY

In this unit, you have investigated science and technology related to electrical principles and technologies. Consider the following questions.

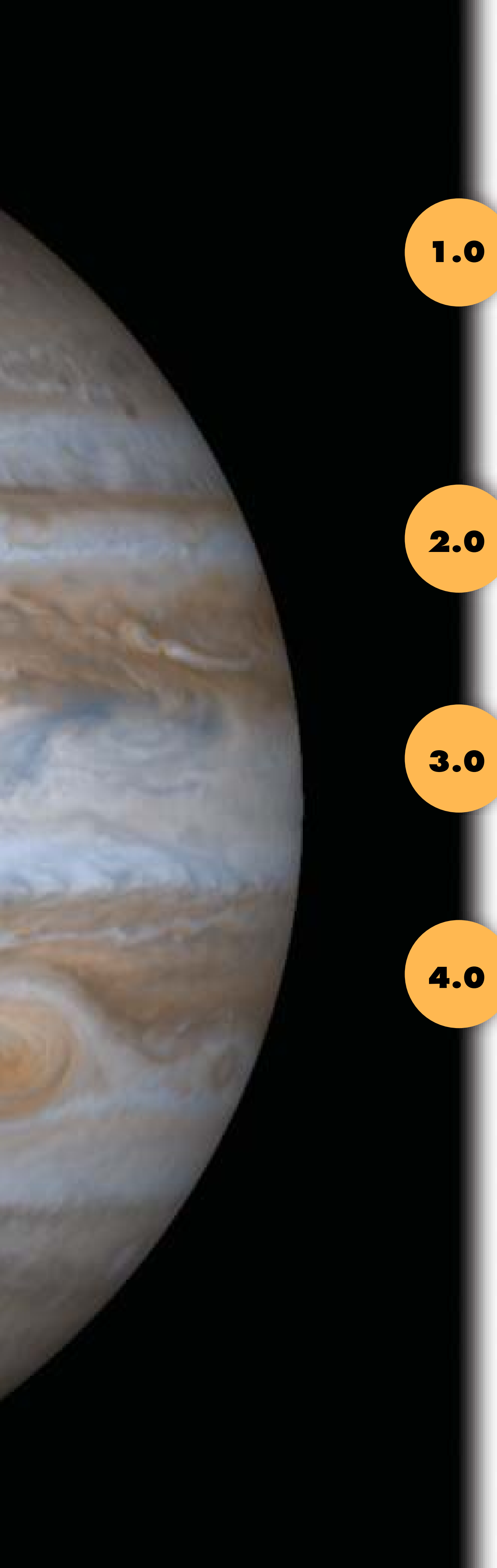
36. Reread the three questions on page 273 about science and technology related to electrical principles and technologies. Use a creative way to show your understanding of one of these questions.

37. Describe an example of how an advance in science led to the development of a useful new technology.

38. Describe how the development of electrical technologies affects and is affected by the environment.

UNIT E

Space Exploration



In this unit, you will cover the following sections:

1.0 Human understanding of both Earth and space has changed over time.

1.1 Early Views About the Cosmos
1.2 Discovery Through Technology
1.3 The Distribution of Matter in Space
1.4 Our Solar Neighbourhood
1.5 Describing the Position of Objects in Space

2.0 Technological developments are making space exploration possible and offer benefits on Earth.

2.1 Getting There: Technologies for Space Transport
2.2 Surviving There: Technologies for Living in Space
2.3 Using Space Technology to Meet Human Needs on Earth

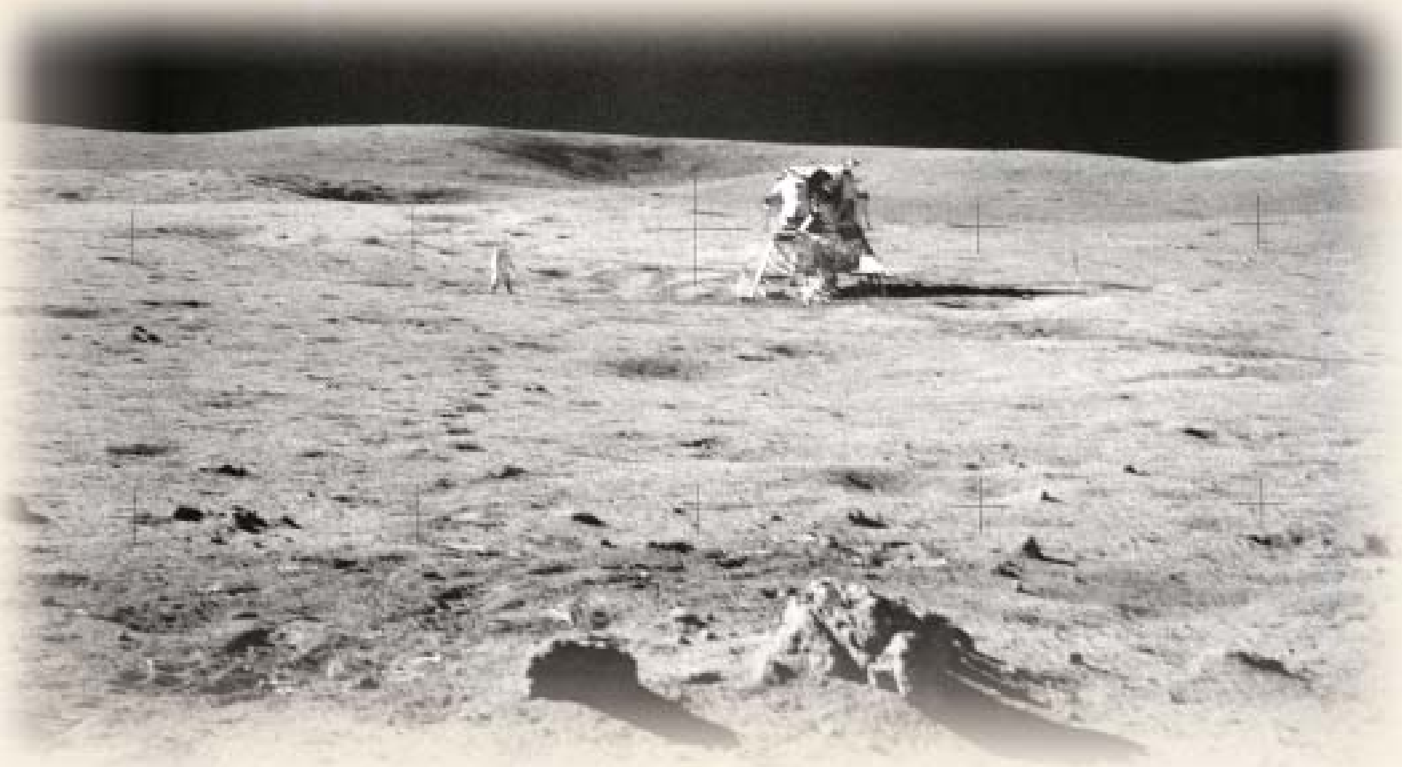
3.0 Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

3.1 Using Technology to See the Visible
3.2 Using Technology to See Beyond the Visible
3.3 Using Technology to Interpret Space

4.0 Society and the environment are affected by space exploration and the development of space technologies.

4.1 The Risks and Dangers of Space Exploration
4.2 Canadian Contributions to Space Exploration and Observation
4.3 Issues Related to Space Exploration

Exploring



When humans walked on the Moon for the first time, the world watched.

The first major step in the human journey to explore space occurred on July 20, 1969. That was the date when two U.S. astronauts, Neil Armstrong and Edwin "Buzz" Aldrin, walked on the Moon, becoming the first people to visit a body in the solar system other than Earth. It also marked the first time that people on Earth could look up at the Moon and know that there were people on its surface looking back at them!

Short Excursion to the Moon

It took four days for the lunar module *Eagle* to make the trip from our planet to the Moon's surface. When it touched down, only a few seconds' worth of the budgeted fuel for landing remained. If the process of landing had taken longer, the *Eagle* would have started using up the fuel rationed for getting the spacecraft and its crew home.

The most sophisticated technology of the time was used to carry the astronauts safely to the Moon and back to Earth, a journey that, in total, took a little over eight days. Future journeys into space may take months, even years in travel time, but such is the nature of exploration. Leaving the safety of Earth's atmospheric bubble will always pose one of the ultimate challenges to our ingenuity. That is the reason that humans continue to search, stretching the limits of their imaginations to create the technology that will take us ever farther into space.

GIVE IT A TRY

CRATER PATTERNS ON THE MOON

The surface of the Moon is covered with "impact craters" of every size. These are depressions made when meteoroids (small pieces of rock in space) and asteroids (much larger rocky bodies) strike the ground with a tremendous force. Most meteoroids and asteroids encountering Earth burn up in Earth's atmosphere and never reach the ground. The Moon does not have an atmosphere and, therefore, any meteroid or asteroid caught in the Moon's gravity ends up hitting the surface. This activity gives you an idea of how crater patterns are caused by these impacts.

1. Place the trays on a newspaper-covered table or floor area.
2. Pour the flour into the trays to a depth of about 5 cm.
3. Gently sprinkle the cocoa powder over the flour so that a mostly brown layer is visible on the surface.
4. Drop the rocks and marbles from a variety of heights onto the flour-and-cocoa surface. Sketch the different impact patterns left by the dropped "meteors."
5. Experiment with letting the rocks and marbles hit the surface at an angle. How does this change the impact pattern?

Materials & Equipment

- two large plastic or aluminum trays
- newspaper
- flour (one 3.5-kg bag)
- cocoa powder (about 250 mL)
- rocks or marbles of different sizes

Focus On SCIENCE AND TECHNOLOGY

As you learn in this unit about the advances humans have made in exploring and understanding the nature of space, you will be given many opportunities to solve problems using your knowledge of both science and technology.

Science provides an orderly way of studying and explaining the nature of things. Technology tries to find solutions to practical problems that arise from human needs. As you will discover in working through this unit, there are often many possible solutions to the same technological problem. To guide your reading as you study how science and technology interact and support each other, keep the following questions in mind:

1. **How much do humans know about space?**
2. **What technologies have been developed so that space can be studied?**
3. **How have space technologies contributed to the exploration and use of space, and how have they benefited our life on Earth?**

1.0 Human understanding of both Earth and space has changed over time.

Key Concepts

In this section, you will learn about the following key concepts:

- technologies for space exploration and observation
- reference frames for describing the position and motion of bodies in space
- distribution of matter through space
- composition and characteristics of bodies in space

Learning Outcomes

When you have completed this section, you will be able to:

- identify different perspectives on the nature of Earth and space
- investigate and illustrate the contributions of technological advances to a scientific understanding of space
- describe the distribution of matter in space
- identify evidence for, and describe characteristics of, bodies that make up the solar system and compare their characteristics with Earth's
- describe and apply techniques for determining the position and motion of objects in space
- investigate predictions about the motion, alignment, and collision of bodies in space

Imagine that your teacher brings to class a meteorite that is about the size of a grapefruit. Meteorites are pieces of rocky space debris that hit Earth. Your teacher asks you to study and describe the meteorite's surface. With your unaided eye, you would be able to see many of the object's characteristics, such as its colour, lustre, and texture. With a magnifying glass, you would see even more detail, perhaps the colour and shape of the surface particles.

Now, think how your description would change if you could use a high-powered microscope that greatly magnifies a chip from the meteorite. Details you could never have noticed before would become visible. As a result, your understanding of the meteorite's composition would improve.

In this section, you will learn how human understanding of Earth and the universe has changed over thousands of years, boosted each step of the way by advances in technology. You will also learn that the role of observation in guiding scientific understanding of space remains as important today as it was to early astronomers. Only the capacity to see more is constantly expanding.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Early Views About the Cosmos

Objects in the sky have fascinated humans throughout history. Many of these objects you have certainly seen yourself, such as the Sun, the Moon, stars and constellations, and planets, such as Venus, Mars, and Jupiter. Maybe you have also been fortunate to see an eclipse, a comet, a meteor shower, or the aurora borealis. All of these celestial bodies and events have been watched in wonder for thousands of years. They fuelled the human imagination, marked the passage of time, and foretold the changes in seasons. Early knowledge of them was passed from generation to generation and from culture to culture, often as legends and folklore.

Figure 1.1 The First Nations peoples of the Pacific Northwest thought the night sky was a pattern on a great blanket overhead. The blanket, they believed, was held up by a spinning "world pole," the bottom of which rested on the chest of a woman underground named Stone Ribs.

*info***BIT**

One-Mitt Measure
Inuit in the high arctic traditionally used the width of a mitt held at arm's length to gauge the height of the Sun above the horizon. When the Sun rose to a height of one-mitt width, it meant that seal pups would be born in two lunar cycles.

GIVE IT A TRY

EVOLVING IDEAS ABOUT PLANETARY MOTION

In this subsection, you will be learning how our early understanding of space and Earth's place in it have developed through history.

1. Make a time line that shows when key ideas about space were proposed and who proposed them. Start your time line at 3000 B.C. and add to it as you read through this subsection. End at the heliocentric model of the solar system. For each idea, be sure to include the observations the person made that led to the idea.
2. Compare your time line with that of other students in the class. Add to your time line any ideas you might have missed.
3. Discuss with the class the main technologies that were used by people in developing each key idea on your time line.

Figure 1.2 The origins of England's Stonehenge remain an archeological puzzle.

TRACKING COSMOLOGICAL EVENTS

Two very special annual events for our ancestors were the summer and winter **solstice**. The word "solstice" comes from the Latin *sol* meaning sun, and *stice* meaning stop. In the northern hemisphere, the summer solstice occurs near June 21. It marks the longest period of daylight in the year and represents the start of summer. The winter solstice occurs near December 21. It marks the shortest day of the year and the start of winter. (The conditions are the reverse in the southern hemisphere.)

Prediction of the approach of summer and winter was important to early peoples, and many ancient civilizations built huge monuments to honour their beliefs about the change. While they may have had only the power of the unaided eye, their observations of the position and path of the Sun throughout the year were highly accurate. More than 3500 years ago, for example, a people (possibly the ancient Celts) erected the megaliths of Stonehenge, still standing in southern England. Arranged in concentric circles, the enormous stones mark the summer and winter solstices. Ancient African cultures also set large rock pillars into patterns that could be used to predict the timing of the solstices.

Another phenomenon honoured by early cultures was the **equinox**, one in the spring (about March 21) and one in the fall (about September 22). The word "equinox" comes from the Latin *equi* meaning equal, and *nox* meaning night. At the equinox, day and night are of equal length. The Mayans of Central America built an enormous cylinder-shaped tower at Chichén Itzá in about A.D. 1000 to celebrate the occurrence of the two equinoxes.

The ancient Egyptians built many pyramids and other monuments to align with the seasonal position of certain stars. The entrance passage of Khufu, the Great Pyramid at Giza, once lined up with Thuban (a star in the constellation of Draco). At the time the pyramid was built, starting about 2700 B.C., Thuban was the closest star showing true north. Two thousand years ago, aboriginal peoples of southwestern Alberta used large rocks to build medicine circles in which key rocks aligned with the bright stars that rose in the dawn, such as Aldebaran, Rigel, and Sirius.

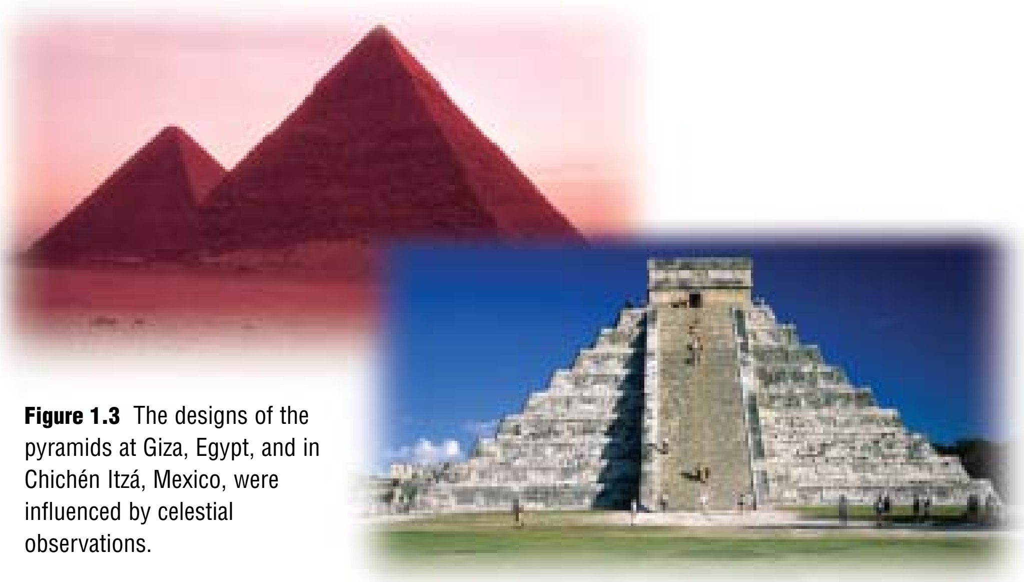


Figure 1.3 The designs of the pyramids at Giza, Egypt, and in Chichén Itzá, Mexico, were influenced by celestial observations.

Models of Planetary Motion

For as long as people have been watching the nightly promenade of stars and planets, they have sought ways of explaining the motions they observed. The religions, traditions, myths, and rituals of ancient cultures all reveal different interpretations of how the universe works. Seen from Earth, everything in the sky appears to be in motion. The Sun rises and sets. The Moon, in its ever-changing phases, travels across the sky. Planets shift against a background of stars. Even constellations (groupings of stars) appear to change position in the sky throughout the year. Our ancestors had to make sense of this constant pattern of change by using the science and technology of the day.

Geocentric Model

About 2000 years ago, the Greek philosopher Aristotle proposed a **geocentric**, or Earth-centred, model to explain planetary motion. In the model, he showed Earth at the centre, surrounded by a series of concentric spheres that represented the paths of the Sun, Moon, and five planets known at the time (see Figure 1.4). To explain why the distant stars did not move, Aristotle hypothesized that they were attached firmly to the outermost sphere (what he called the "celestial sphere") where they stayed put as though glued to an immovable ceiling.

Little optical technology is believed to have existed in Greece during the time Aristotle was making his observations about the cosmos. However, he was aided by the mathematics and geometry of Pythagoras and Euclid, which he used to calculate the size and shape of the spheres.

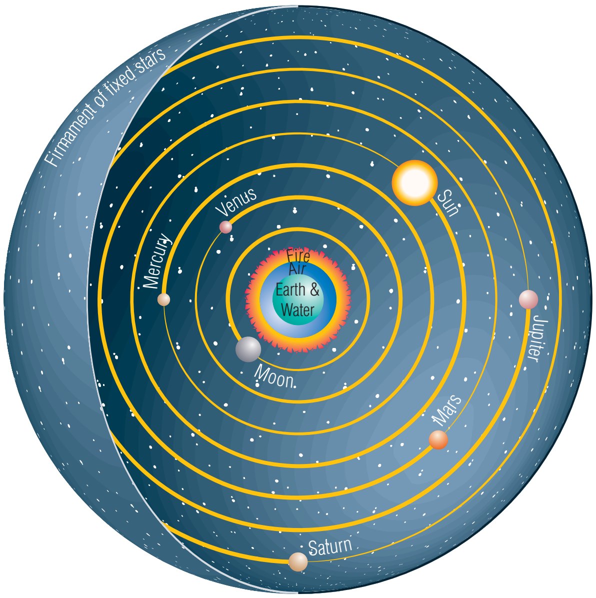


Figure 1.4 Aristotle's geocentric model of our solar system explained much—but not all—about planetary motion. In this model, Earth was the centre of the universe.

The geocentric model allowed early astronomers to forecast such events as the phases of the Moon, but it still could not explain many other observations. For example, why did Mars, Jupiter, and Saturn sometimes seem to loop back opposite to their usual movement across the sky?

reSEARCH

Legends of the Sun

The Sun played a prominent role in the mythology of many ancient cultures. Research the beliefs, ceremonies, and legends that three of the following groups held about the Sun: North American First Nations, Australian Aborigines, Aztecs, Chinese, Egyptians, Greeks, Inuit, Japanese, and Norse. Compare your findings with those of others in the class. Begin your search at www.pearsoned.ca/scienceinaction.

Heliocentric Model

The Earth-centred model of our solar system lasted for almost two thousand years. Then, in 1530, Polish astronomer Nicholas Copernicus proposed a dramatically different model, one that explained planetary motion much more simply than did the complicated geocentric model. Copernicus suggested that the Sun was at the centre and Earth and the other planets revolved in orbits around it. This is called the **heliocentric** model (Figure 1.5).

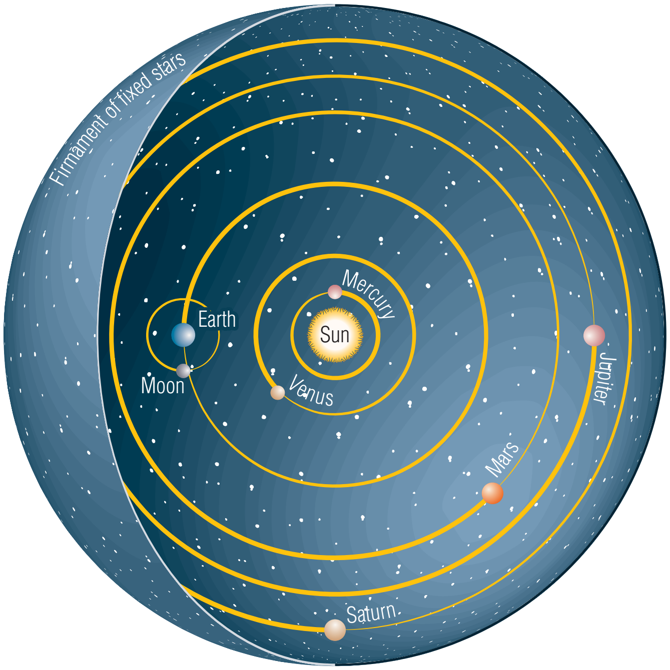


Figure 1.5 The heliocentric model of our solar system put the Sun at the centre of the universe. It was considered, at the time, to be a revolutionary idea.

A little less than 100 years later, a new generation of scientists—with the help of a major technological invention, the telescope—provided solid evidence for Copernicus's theory. Notable among these scientists was the renowned Galileo Galilei of Italy. In the 1600s, using a telescope not much stronger than the standard binoculars you might use today, he was the first person to view mountains on the Moon, a "bump" on either side of Saturn (later found to be the outer edges of the planet's rings), spots on the Sun, moons orbiting Jupiter, and the distinct phases of Venus.

Even though Galileo's discoveries added credibility to the Copernican ideas, the model could still not predict planetary motion very accurately. A German mathematician, Johannes Kepler, came up with the next solution to the puzzle. Using detailed observations of the movement of the planets (observations carefully recorded by the great Danish astronomer, Tycho Brahe), Kepler discovered what was missing from the Copernican ideas. The orbits of the planets, he realized, were **ellipses** and not circles. Today, the Sun-centred model of our solar system is used as a guide when we study other solar systems.

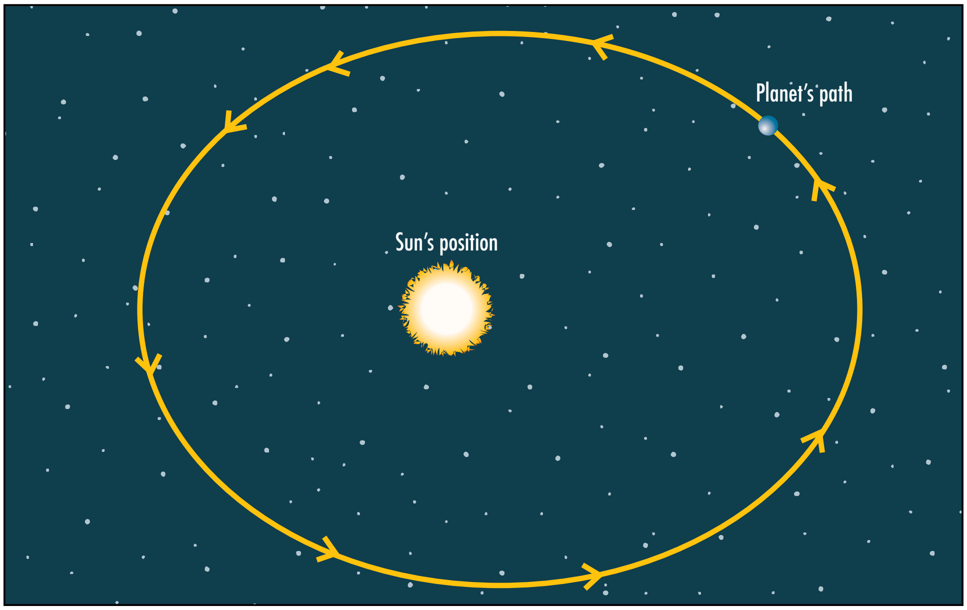


Figure 1.6 Once astronomers realized that planets orbited the Sun in elliptical paths, not circular paths, they were better able to predict planetary motion.

QUICKLAB

Elliptical Loops

Purpose

To draw a series of ellipses and investigate their properties

Procedure

1. Draw a straight line, about 20 cm long, down the middle of the paper. Position the paper on top of the cardboard and set the cardboard on a firm, flat surface such as your desk top.
2. Position the pins 5 cm apart along the drawn line and push the pins through the paper and into the cardboard so they are standing upright.
3. Place the loop of thread around both pins. Then, with the pencil point resting inside the loop, pull gently until the thread is taut and the pencil point is touching the paper (see Figure 1.7).
4. While keeping a slight outward pressure with the pencil against the thread, start drawing a line in a circular motion around the pins. You will see an ellipse (an oval shape) start to form. A circle is formed around one focal point. An ellipse is formed around two focal points.
5. Repeat steps 3 to 5 two more times, once setting the pins closer together and once setting them farther apart. Observe how the ellipse changes.

Questions

6. Describe what happens when the pins are moved different distances apart. How does the position of these focal points change the shape of the ellipse?
7. Imagine that one of the pins is the Sun and the pencil point is a planet. What controls the shape of the elliptical path?
8. What shape would you expect if both pins were at exactly the same point?

Materials & Equipment

- sewing thread (30 cm long), with ends tied to make a loop
- paper (letter-size)
- ruler
- pencil
- cardboard (30 cm by 30 cm)
- 2 straight pins or tacks

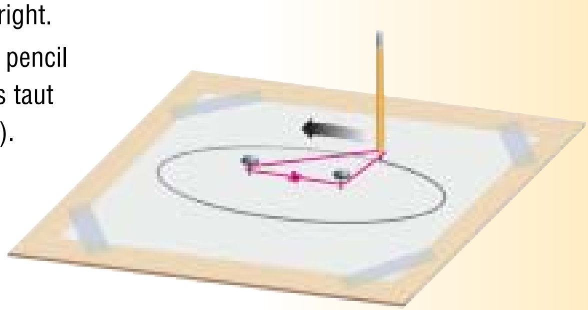


Figure 1.7 Step 3

Check and Reflect

Key Concept Review

1. Define solstice. What are the significant dates associated with the solstices in the northern hemisphere?
2. What was the ancient monument of Stonehenge believed to be used for?
3. What word is used to describe the times when the length of day equals the length of night? When do these occur?
4. List and describe three monuments built by ancient people to honour celestial bodies.

Connect Your Understanding

5. What did the summer and winter solstices indicate to ancient people?
6. Explain the main difference between the heliocentric model of the solar system and the geocentric model.
7. Why was the change from a geocentric model to a heliocentric model considered such a revolutionary idea?

Extend Your Understanding

8. Johannes Kepler used hundreds of years' worth of historical data collected by many astronomers (notably Tycho Brahe) and his own precise measurements to modify the Copernican model. How did the change proposed by Kepler make the model more realistic?
9. The velocity at which a planet travels does not remain constant throughout its orbit. As it gets closer to the Sun in its orbit, a planet tends to speed up a little. Why do you think this occurs? Use Figure 1.6 to assist you with answering this question.

Figure 1.8 The Caracol, a 3000-year-old Mayan observatory located at Chichén Itzá on the Yucatán Peninsula in Mexico

1.2 Discovery Through Technology

Step by step, our understanding of space and Earth's place in it has progressed, thanks in large part to the improvement of the tools available to observe, record, measure, and analyze what we see. This process of discovery boosted by technological advance is going on all the time.

Figure 1.9 State-of-the-art technology today will be thought of as old-fashioned to the next generation of science students.

*info*BIT

Fasten Your Seat Belts

The Sun lies about 149 599 000 km from Earth. Compared to other distances in the universe, that is not very far. However, if you could fly in a 747 airliner from Earth to the Sun (travelling at about 965 km/h), the flight would last close to 17 years.

*QUICK*LAB

Telling Sundial Time

Purpose

To make a model sundial and plot shadow patterns

Materials & Equipment

- a sheet of polar graph paper (circular graph paper)
- a golf tee
- adhesive tape
- a pencil

Procedure

1. Go to an area of your classroom or another room in the school where the Sun is shining in. (If you must leave the classroom to do this activity, be sure to ask your teacher's permission first.)
2. Tape the paper on a flat surface in the sunlight. Stand the golf tee upside down in the centre of the graph paper.
3. With your pencil, plot the shadow cast by the golf tee on the graph paper and make a note of the time. Repeat this step at regular intervals during the day.

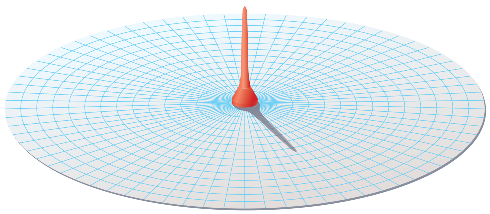


Figure 1.10 Step 2

Questions

4. Describe the pattern you see in the shadow plots you have drawn during the day. Sketch the pattern in your notebook.
5. If you were to repeat this activity every day for a year, would the same pattern result each time? Explain your answer.

The Astronomer's Tools

Humans are very inventive, and have worked hard over the centuries to develop tools to help them better understand the sky and its mysteries. Sundials, for example, have been used for more than 7000 years to measure the passage of time. Ancient Egyptians invented a device called a merkhet to chart astronomical positions and predict the movement of stars. About the 2nd century A.D., the Egyptian astronomers also designed a tool called a quadrant to measure a star's height above the horizon. Arabian astronomers used the astrolabe for centuries to make accurate charts of star positions. In the 14th century, astronomer Levi ben Gurson invented the cross-staff to measure the angle between the Moon and any given star. With each of these technological innovations, astronomers made new discoveries and gained more knowledge about what they were seeing.

quadrant *astrolabe* *cross-staff* *early telescope*

Figure 1.11 Many early tools were invented to study and predict celestial motion. Sailors and other explorers tested these instruments in their travels to uncharted places of the globe.

Then came the telescope. Invented in the late 16th century, it revolutionized astronomy. Suddenly, astronomers such as Galileo could see more in the night sky than had ever been possible. Telescopes revealed exciting details about Earth's closest planetary neighbours, and showed the existence of other neighbours in our solar system. We learned that the size of what lay beyond Earth was greater than anything we could have imagined.

With each new improvement, the optical telescope pushed astronomy ahead. As our viewing ability got better, the vast distance between objects in space became obvious.

Today, almost 500 years after the telescope's invention, super-powerful optical and radio telescopes operating from Earth, satellites orbiting around Earth, and sophisticated space-based telescopes have shown us the immensity of objects in space and of distances across the universe. (You will learn more about space technologies in Section 3.0.) We have discovered that our Sun is only an average star, lying in a small corner of an average galaxy that is one among billions of other galaxies.

The Immensity of Distance and Time in Space

If you were asked to measure the size of your school, you probably would not do so using millimetres. Neither would you use centimetres to describe the distance from your school to home. Finding the appropriate unit of measurement is important when describing distances.

In the case of measuring distances in space, not even kilometres are practical to use. To have a practical means of describing such enormous distances, astronomers devised two new units of measure.

Astronomical Units

The **astronomical unit** (AU) is used for measuring "local" distances, those inside our solar system. One AU is equal to the average distance from the centre of Earth to the centre of the Sun (149 599 000 km). Astronomers use this when describing positions of the planets relative to the Sun.

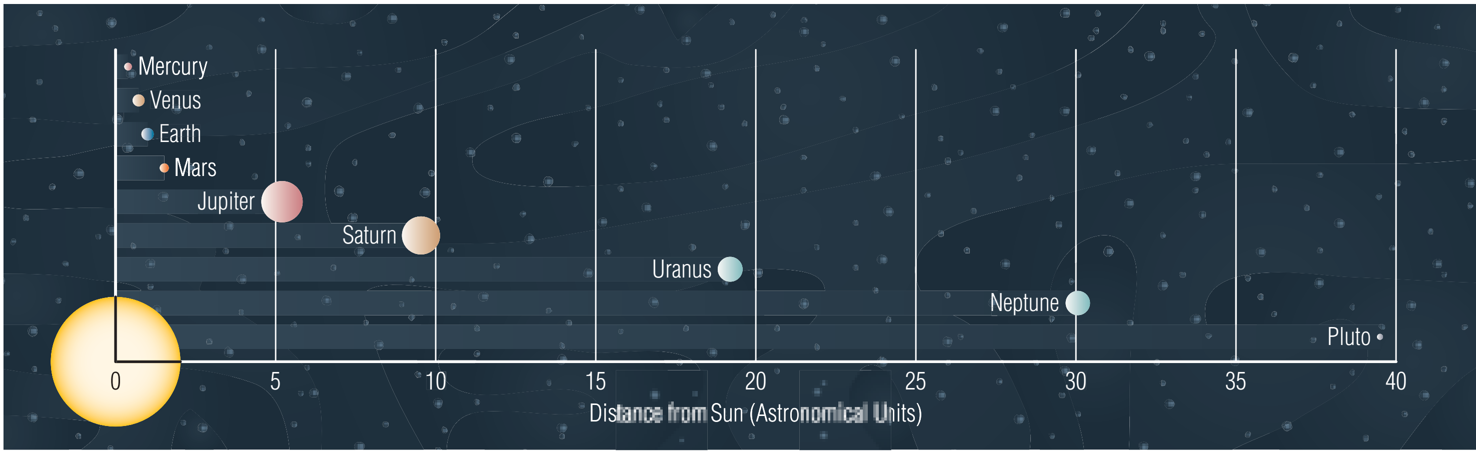


Figure 1.12 The relative distances of the nine planets from the Sun. Note that the bodies are not to accurate scale in this figure. If they were, the Sun would have to be shown with a diameter of about 57 mm.

Light-years

The vast distances beyond the solar system, out to stars and galaxies, are so great that even astronomical units are too tiny as measures. Instead, the **light-year** is used. It equals the distance that light travels in one year.

Light travels at a speed of 300 000 km/s. In a year, that adds up to about 9.5 trillion km. If you wanted to wind a string 1 light-year long around Earth's equator, you would have enough string to wrap it around *236 million times*! The distance to Proxima Centauri, the next nearest star to Earth after the Sun, is a little over 4 light-years.

*info*BIT

Big, Bigger, Biggest

Earth is about 1/1000 the volume of Jupiter, our solar system's largest planet. Jupiter is about 1/1000 the volume of the Sun. The Sun is about 1/300-millionth the volume of the star Betelgeuse (located in the constellation of Orion).

ACTIVITY E-1

Inquiry

How Big Is the Sun?

The Question

Can we accurately measure the diameter of the Sun by using an indirect method?

Materials & Equipment

- metre-stick
- 2 pieces of cardboard, approximately 15 cm by 15 cm each (one piece of cardboard will have a 5 cm by 5 cm opening cut into its centre)
- 1 piece of aluminum foil, approximately 8 cm by 8 cm
- 1 piece of white paper, 10 cm by 10 cm
- masking tape
- drawing compass
- ring stand (optional)
- ruler
- calculator

Procedure

1. Working with a partner, tape a piece of cardboard to each end of the metre-stick. Then tape the piece of aluminum foil over the square opening in one piece of cardboard, and tape the white paper in the middle of the other piece of cardboard.

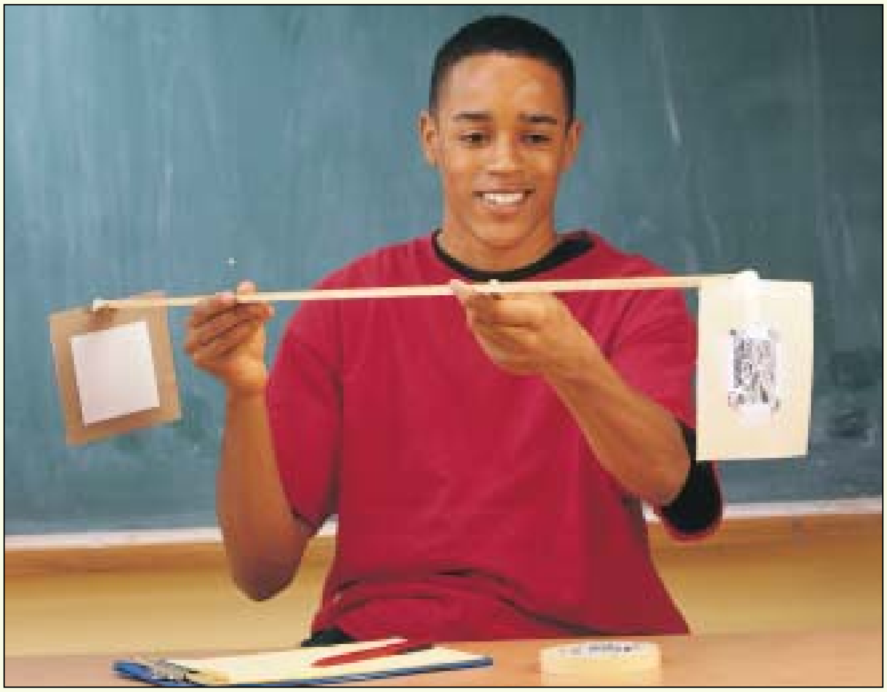


Figure 1.13 Step 1

2. Using the compass point, poke a small hole (about 1 mm in diameter) in the aluminum foil. Be careful not to make the hole any larger than that.
3. Take your apparatus and a pencil outside. (This procedure can be carried out even on a slightly cloudy day, as long as the Sun can still cast a shadow.)
4. One partner holds the metre-stick horizontally with the aluminum piece pointing toward the Sun. He or she should move the end of the metre-stick around until the Sun shines through the pinhole and forms a circular image on the piece of white paper. (Note: The person holding the apparatus should try to steady it by resting it against his or her chest. Another option is to steady the metre-stick by resting it on a ring stand.)

Caution!
Never look at the Sun directly.

5. The other partner marks the diameter of the circle with two pencil lines on the paper (see Figure 1.14).
6. Carry out steps 4 to 5 again, obtaining a pinhole image of the Sun and marking its diameter on the paper. Repeat a third time.

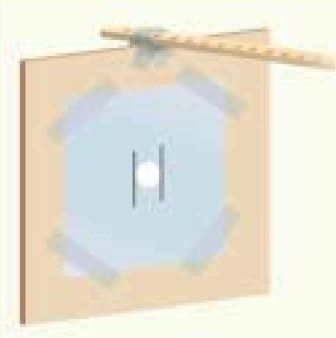


Figure 1.14 Step 5

Analyzing and Interpreting

7 Calculate the average diameter of the Sun's image. Measure the marks you made on the white paper and find the average diameter (*d*) for your three measurements (in centimetres).

8 Use the following ratio to determine the diameter of the real Sun:

$$\frac{d}{100\text{ cm}} = \frac{D}{150\ 000\ 000\text{ km}}$$

Where: *d* is in centimetres
D is in kilometres
100 cm is the distance between the cards
150 000 000 km is the distance between the Sun and Earth

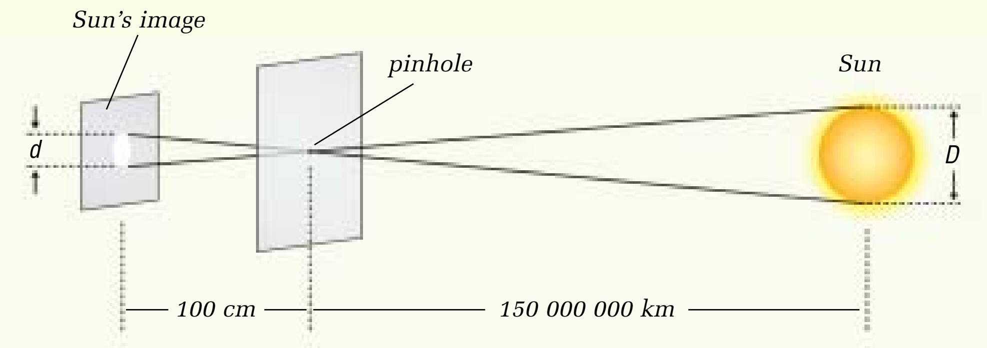


Figure 1.15 Step 8

9 In a reference book or on the Internet, look up the actual diameter of the Sun. Use that figure in the equation below to calculate the accuracy of your measured value. The "percent error" shows how far from (or close to) the real value your measured value is.

$$\text{percent error} = \frac{(\text{actual value} - \text{measured value})}{\text{actual value}} \times 100$$

10 What did you find? How accurate was your measured value of the Sun's diameter?

Forming Conclusions

11 Describe the possible sources of error that might make your measurement inaccurate.

12 Do you agree or disagree that the diameter of the Sun can be accurately measured by using an indirect means? Explain.

Applying and Connecting

13 Could you use this method of measurement to obtain the diameter of another distant body such as Jupiter? Could you use it to measure the diameters of bodies outside our solar system?

14 Why must all measurements of size and distance in space be made indirectly?

GIVE IT A TRY

Take a Walk Through the Solar System

How has our knowledge of the solar system improved as technology has advanced? One way is that we have a better understanding of the vast distances between the planets.

Planet	Number of steps from the Sun
Mercury	less than 0.4
Venus	0.75
Earth	1
Mars	1.5
Jupiter	5
Saturn	9.5
Uranus	19
Neptune	30
Pluto	39.5

Purpose

To create a scale model of the solar system

Procedure

1. Organize into groups of 10. Each member in the group chooses to represent the Sun or one of the nine planets. Go outside to a large playing field.
2. The "Sun student" stands in place at one side of the field. He or she calls out each planet name in turn, plus the number of steps that the "planet student" must take from where the Sun is standing. (Refer to the table on the right, which shows the planet distances from the Sun at a footstep scale representing the actual distance.) Each step should be about 1 m long.

Questions

3. In a class discussion, share what you learned about distances in the solar system. What did you notice about the positions of the planets relative to the Sun?
4. How do the distances between the inner planets compare with the distances between the outer planets?

Looking into the Past

When you look at an object in space, you are seeing it as it was at an earlier time. That's because it takes time for the light from the object to travel to Earth across the great distance in space. Gaze at the Moon and you see it as it was about a second before. Light from the Sun takes about 8 min to reach Earth. Light from the planet Pluto, visible with the aid of a telescope, takes an average of about 5 h to reach Earth. Images of stars in the centre of our galaxy take 25 000 years to reach us.

The farther out into the universe we are able to look, the deeper into the past we see. Today's modern telescopes, for instance, are capable of collecting light that has travelled from distant galaxies. Even more astonishing are the images that the Hubble Space Telescope, launched in 1990, has captured. (You will learn more about this space-based telescope in subsection 3.1.) Astronomers believe that what the Hubble Space Telescope is viewing reaches back some 12 billion years.

Figure 1.16 Some of these stars may no longer exist, but we are only receiving their light now.

Check and Reflect

Key Concept Review

1. Name three instruments used throughout history to observe the motion of the planets and stars.
2. Explain how a sundial works.
3. What term is used to describe the distance between Earth and the Sun?
4. How far does light travel in one second?

Connect Your Understanding

5. Before the development of any technology for observing the sky, how did people map the motion of objects in the night sky?
6. Why were dependable navigation instruments important to the explorers who were crossing oceans to find new lands?
7. How did the telescope change human understanding of space?

Extend Your Understanding

8. What is the general relationship between the size of a planet and its distance from the Sun?

1.3 The Distribution of Matter in Space

When you look at the night sky from a city or town, you can see many of the brighter stars. Journey into the countryside, away from the light pollution of the city, and the night sky will appear to be completely full of stars. All of those bright points of light in space are separated by unimaginably large distances.

Figure 1.17 Using modern telescopes, astronomers have been able to study starlight from faint, remote stars, such as those in the Milky Way galaxy shown here.

What Is a Star?

A star is a hot, glowing ball of gas (mainly hydrogen) that gives off tremendous light energy. The number of stars in the universe is in the billions of billions.

Stars vary greatly in their characteristics. Our Sun has a mass 300 000 times greater than Earth, with an average density of 1.4 times that of water. In diameter, Betelgeuse is 670 times larger than our Sun, but only 1/10-millionth as dense. Stars vary greatly in their colours as well. The colour of a star depends on its surface temperature. Very hot stars look blue. Cooler stars look red.

In the 1920s, two scientists, Ejnar Hertzsprung and Henry Norris Russell, began comparing the surface temperature of stars with the stars' brightness (luminosity). When they plotted their data, Hertzsprung and Russell discovered that the distribution of star temperature and brightness is not random. Instead, as the "Hertzsprung-Russell diagram" shows (see Figure 1.18), the stars fall into several distinct groupings. Part of this pattern has since been accounted for by the current theory of how stars evolve and change over very long periods of time.

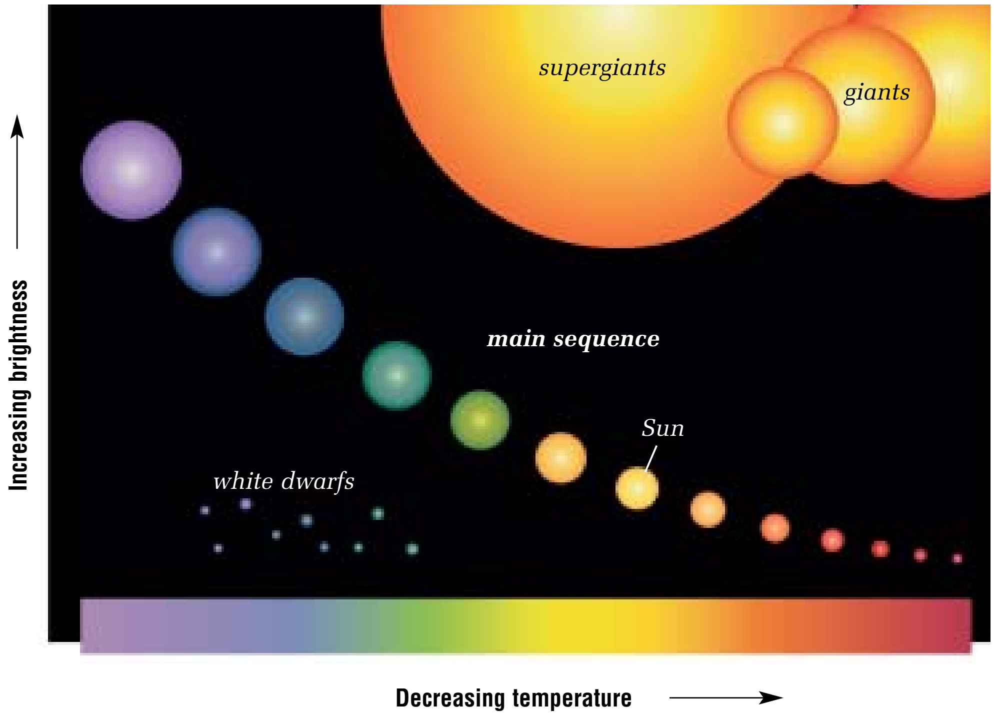


Figure 1.18 The results of graphing data from thousands of stars was the Hertzsprung-Russell (H-R) diagram. Our Sun belongs in the middle of the diagram in a grouping of stars called the *main sequence*. Ninety percent of all stars fit into this grouping.

*QUICK***LAB**

What Colour and Temperature Tell Us About Elements

(Teacher Demonstration)

Purpose

To observe the colour and temperature associated with different elements

Procedure

1. Light the Bunsen burner.
2. Place 10 drops of the $LiCl_{(aq)}$ in a test tube.
3. Dip a wooden splint into the test tube containing the $LiCl_{(aq)}$, moistening the splint tip.
4. Remove the splint from the test tube and hold the moistened end in the hottest part of the burner flame. Students should observe the colour and record what they see. Often the colour disappears quickly, so repeat the procedure if necessary.
5. Repeat steps 2 to 4 for each of the other solutions. In each case, students should record what they observe.

Questions

6. What was responsible for the different colours you saw?
7. What can the colour of the flame reveal?
8. How would this information be useful for astronomers studying the spectrum of a star?

Materials & Equipment

- 8 test tubes (75 mm by 100 mm)
- test-tube rack
- wood splints
- Bunsen burner
- closed fume hood
- solutions of $LiCl_{(aq)}$, $KCl_{(aq)}$, $NaCl_{(aq)}$), $CuCl_{2(aq)}$, $BaCl_{2(aq)}$, $SrCl_{2(aq)}$, $CaCl_{2(aq)}$

Caution!
The materials in this demonstration can be hazardous if inhaled. Observe the reactions from a safe distance.

*info***BIT**

Meet a Really Big Star

Our Sun is a very average star in the middle part of its life. How average is it? Stand 1 m away from the wall. This distance represents the Sun's diameter. At this scale, the diameter of the largest star now known would be 2300 m (2.3 km).

The Birth of a Star

Just as every living thing on our planet is born, lives, and dies, a star has a life cycle, too. Stars form in regions of space where there are huge accumulations of gas and dust called **nebulae**. Each nebula is composed of about 75% hydrogen and 23% helium. The other 2% is oxygen, nitrogen, carbon, and silicate dust. Some of this **interstellar matter** came from exploding stars.

The attraction of gravity acting between the atoms of gas and grains of dust can cause a small area of the nebula to start collapsing into a smaller, rotating cloud of gas and dust. As more material is drawn into the spinning ball, the mass at its core increases and the temperature climbs. If the core gets hot enough, it will start to glow. This is a **protostar**, the first stage in a star's formation. As the process of "star-building" continues, the interior of the protostar gets hotter and hotter. When the core reaches 10 000 000°C, hydrogen starts to change to helium. This process, known as fusion, releases great quantities of energy and radiation. A star is born.

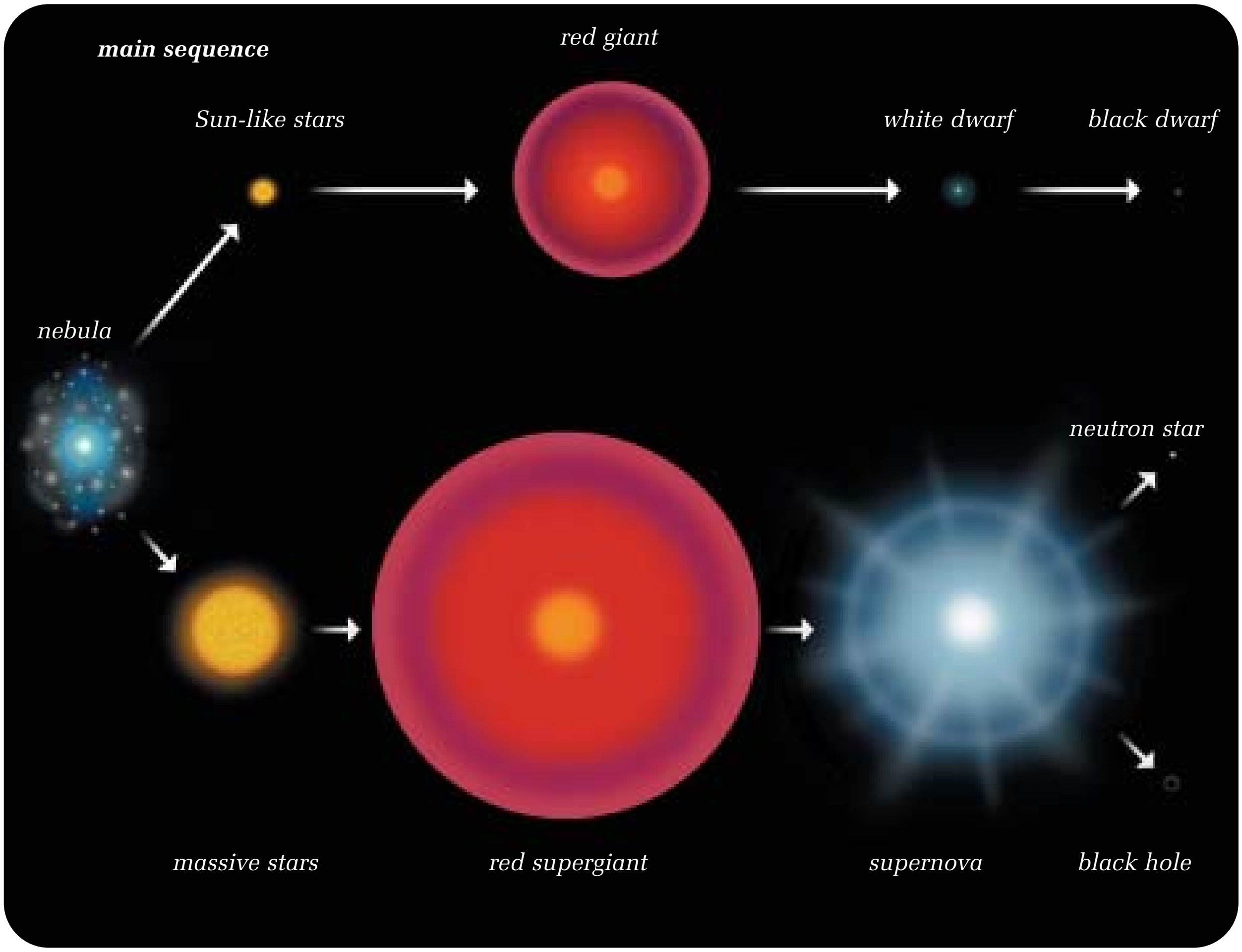


Figure 1.19 From nebular material, stars form with a variety of masses. The life cycles of massive stars differ from those of Sun-like stars.

The Life and Death of Stars

Depending on the mass of the star formed from a particular nebula, the star will be **Sun-like** (in terms of mass) or **massive**. Both types of stars spend most of their lives in this **main sequence**, converting hydrogen to helium in their cores. The outward pressure of radiation on the stellar material is counteracted by gravity, so the stars are in a stable state. All stars remain in this state for millions to even billions of years.

Just as fuel in the gas tank of a car eventually runs out, so does the fuel in a star. When the hydrogen in the core has been used up, the stable-state star shrinks in size, heating the helium core so that it first starts fusing to carbon, then to other elements. As gravity causes the star to contract, further nuclear reactions occur, leading to expansion of the outer layers. In this way, the star becomes larger, turning into a **red giant** if it is a Sun-like star, or a **red supergiant** if it is a massive star. Our Sun will become a red giant in about 5 billion years. At that time, the Sun's diameter may extend out past the present orbit of Mars.

The final stage in a star's life occurs when the fusion reaction stops. For a Sun-like star, fusion ends when the core temperature in the star is no longer hot enough to keep the reaction going. With no heat input from fusion, the decreasing pressure is unable to prevent gravity from causing the star to collapse slowly on itself. The Sun-like star continues to shrink, gradually becoming a **white dwarf**, no larger than Earth. Eventually, the star will fade completely until it evolves into a cold, dark **black dwarf.** According to physicists, it takes so long for a white dwarf to cool that no black dwarf may yet have had time to form in the universe.

In a massive star, the fusion reaction stops when the star runs out of fuel. The lack of heat input into the core from fusion enables gravity to get the upper hand. In this case, gravity causes the star's core to collapse rapidly on itself. The collapse ends suddenly with an outgoing shock wave. This in turn causes the outer part of the star to explode in a catastrophic event known as a **supernova**. If the star is not destroyed entirely by the explosion, the core is left as a **neutron star** or a black hole. A neutron star is a rapidly spinning object only about 30 km in diameter. A **black hole** is a highly dense remnant of a star in which gravity is so strong that not even light from the radiation going on inside the remnant can escape.

*info***BIT**

Too Much to Swallow

Some stars become neutron stars when they collapse. A teaspoon of material from a neutron star is so dense it would have a mass of 100 000 t.

Figure 1.20 The giant galactic nebula NGC 3603. At the upper left of the image is the blue supergiant star, Sher 25. Near the centre is a star cluster dominated by young hot stars. The enormous pillar of gas is sculpted by the stellar outflow winds created as the new stars form.

*re*SEARCH

Black Holes

Astronomers are discovering that black holes are more common than was first expected. Research how black holes form and where they can be found. Begin your search at www.pearsoned.ca/ scienceinaction.

Black holes are themselves invisible to telescopes. Astronomers only know about their existence indirectly because of how material near a black hole becomes very hot and bright.

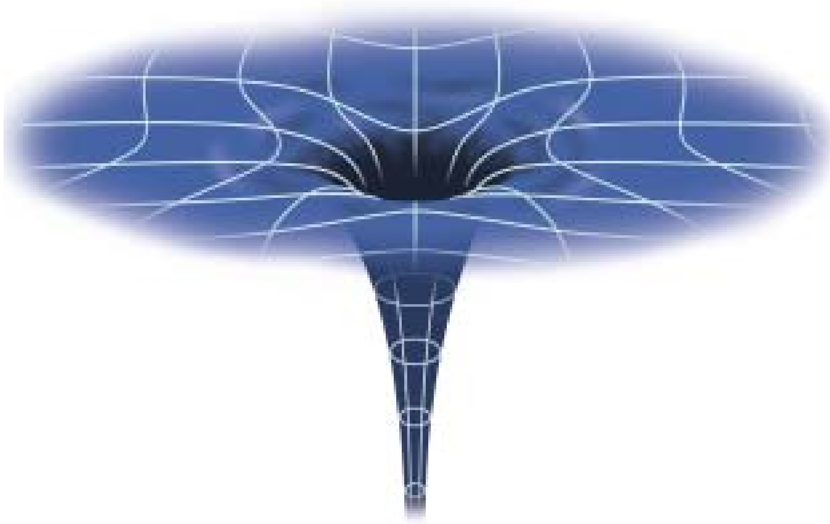


Figure 1.21 Occasionally, massive stars collapse on themselves with such violence that they become super-dense. The gravity around these bodies is so intense that even light cannot escape being pulled inward. These bodies are called black holes.

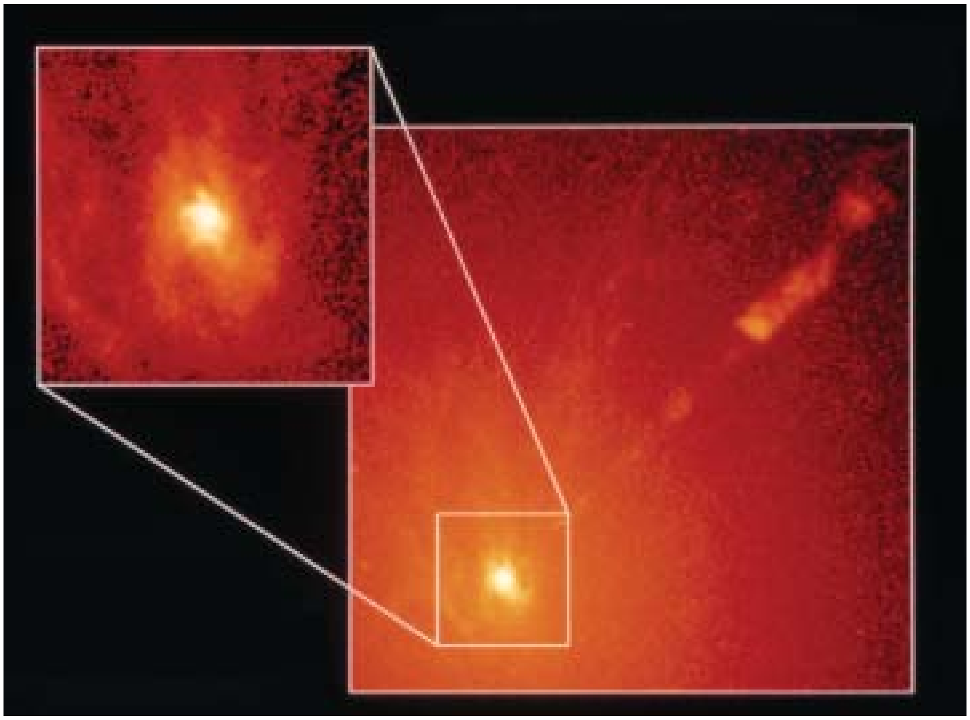
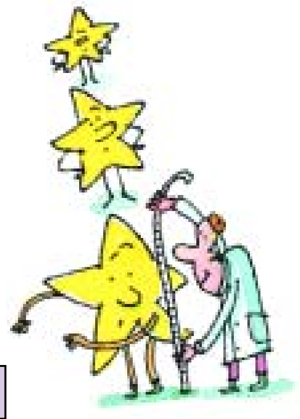


Figure 1.22 A supermassive black hole in the galaxy M87. The inset image shows stars and gas orbiting the galaxy's bright nucleus. By calculating the speed of the orbiting material, astronomers have concluded that the nucleus contains a black hole about 3 billion times the mass of our Sun. The large image shows a bright band of material that may be super-heated gas ejected from the black hole.

GIVE IT A TRY

CLASSIFYING STARS BY SIZE



The great variety of stars in the sky can be grouped in any number of ways, including by colour, temperature, and age. Another way to classify stars is by their size.

1 The list below contains information about a number of imaginary stars. In your notebook, make four columns with the headings: Red Supergiants, Giants, Main Sequence Stars, and White Dwarfs. Categorize each of the stars under the appropriate heading.

Star	Radius (Sun=1)	Density (Sun=1)	Mass (Sun=1)
Beta Brittanee	40.0	0.00014	6.0
Krueller's Star	0.7	6.3	0.5
34 Pygmi A	2.3	1.8	2.0
Von Wendle's Star	0.018	71 000	0.41
Shecky	776.0	0.000003	20.0
15 Ashlee Pi	35.0	0.00018	7.0
Scorpo-3	0.022	90,000	0.73
Prilcyon	1.5	0.9	1.8
R Schminky-5	999.0	0.0000005	18.0
Iaetapi	87.0	0.00006	5.0

2 When you have completed your classification, answer the following questions.

a) What did you base your classifications on?

b) What did you notice about the very small stars?

c) What did you notice about the densities of the giants and supergiants?

d) Black holes form when certain types of stars collapse on themselves. There are two stars on your list that have the potential to become black holes. Using the data in the table, explain which two stars you think could become black holes.

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Human Star Power

"We are stardust" is a line in the chorus of a popular song from the 1970s. It sounds like a far-fetched idea, but in fact it's true. Humans are carbon-based life forms. The carbon making up our bodies was created inside ancient stars that exploded, distributing their elements in our region of the galaxy.

Star Groups

Constellations are the groupings of stars we see as patterns in the night sky. Officially, there are 88 constellations recognized by the International Astronomical Union. As well, there are many unofficially recognized star groupings. These are **asterisms**. One of the most famous asterisms visible from the northern hemisphere is the Big Dipper, which is part of the constellation Ursa Major. The ancient Greeks saw the stars that make up Ursa Major as a bear. The early Black Foot nation of North America also saw a bear. Ancient Europeans saw a variety of different patterns including a chariot, a wagon, and a plough. Figure 1.23 shows two common star patterns and their associated constellations as we know them today.

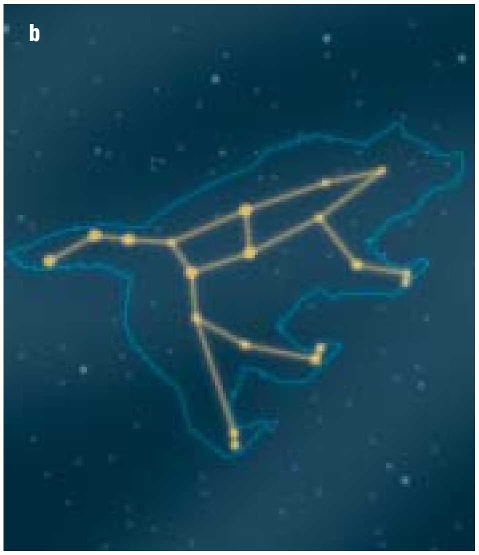


Figure 1.23 (a) The constellation of Orion, a figure in Greek mythology who was thought of as a great hunter. Note the three bright stars making "Orion's Belt." Betelgeuse is the star at Orion's right shoulder.

Figure 1.23 (b) The Big Dipper forms part of the constellation of Ursa Major, or the Great Bear.

Galaxies

A **galaxy** is a grouping of millions or billions of stars, gas, and dust. It is held together by gravity.

The galaxy we live in is a spiral galaxy called the Milky Way. It is shaped like a flattened pinwheel, with arms spiralling out from the centre. Viewed from the side, a spiral galaxy looks a little like a compact disc with a marble in the middle sticking out evenly on either side. Our galaxy is believed to contain from 100 billion to 200 billion stars. There are two other main types of galaxies: elliptical and irregular. Astronomers have estimated there may be a billion billion galaxies in the universe.

Figure 1.24 Viewed from above or below the plane, a spiral galaxy appears to have long curved arms radiating out from a bright central core. Young stars provide most of the light in the arms. Older stars provide most of the light in the central region.

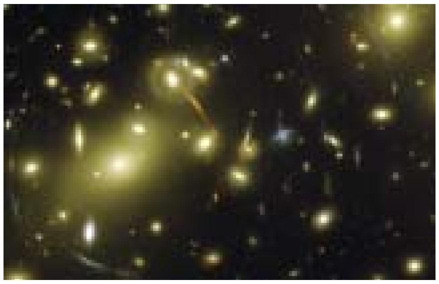


Figure 1.25 An elliptical galaxy has a shape similar to that of a football or egg and is made up mostly of old stars. This picture shows many elliptical galaxies.

Figure 1.26 An irregular galaxy has no notable shape and tends to be smaller than the other two galaxy types. A mixture of old and young stars is found in irregular galaxies.

Check and Reflect

Key Concept Review

1. What is the main chemical element in a star?
2. What is the connection between a supernova and a black hole?
3. What is the term used to refer to a group of millions of stars?
4. Explain the Hertzsprung-Russell diagram in your own words.

Connect Your Understanding

5. True or false: "Stars exist with every combination of brightness (luminosity) and temperature. No specific patterns exist when star data with these characteristics are plotted." Explain your answer with reference to the Hertzsprung-Russell diagram.
6. Why are nebulae sometimes referred to as "stellar nurseries"?
7. Create a word sequence that correctly summarizes the life cycle of massive stars. Use the words: red supergiant, nebula, supernova, massive star, neutron star. Connect each word with an arrow (⟶).
8. Considering the number of stars in space, why don't astronomers see greater numbers of dwarf stars?

Extend Your Understanding

9. Imagine two stars in a galaxy. Both are at the end of their life spans. One star ends up as a white dwarf, the other ends up as a black hole. Describe the conditions that led to these stars having different outcomes.
10. The light we see from the planets in our solar system is just the light reflected from the Sun. Why do planets appear brighter than the vast majority of stars we see?

math Link

The Power of the Sun

A watt (W) is a measure of power. A megawatt (MW) is a million watts. Most household items do not require that much power. For example, a typical light bulb requires 100 W to work. The Sun releases 380 billion billion megawatts every second. How many 100-W light bulbs could the Sun power?

1.4 Our Solar Neighbourhood

In Section 1.3, you learned that stars are born in stellar nurseries called nebulae. The formation of our solar system, including the Sun and nine planets, occurred in much the same way.

The "protoplanet hypothesis" is a model for explaining the birth of solar systems. The process can be described in three steps:

1. A cloud of gas and dust in space begins swirling.
2. Most of the material (more than 90%) accumulates in the centre, forming the Sun.
3. The remaining material accumulates in smaller clumps circling the centre. These form the planets.

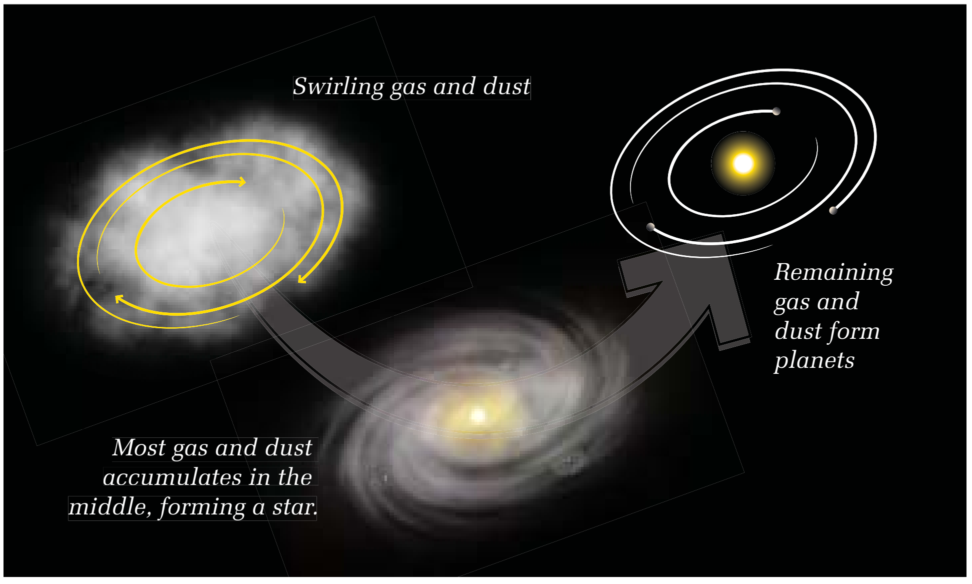


Figure 1.27 The three stages in the formation of a solar system, according to the protoplanet hypothesis (sometimes known as the "nebular theory")

The Sun

At the centre of our solar neighbourhood sits the Sun. For thousands of years, we learned all we knew about the Sun from looking at it, and that wasn't easy to do. After telescopes were invented it wasn't long before filters were designed to allow observers to gaze directly at the Sun. Satellites have offered an even closer look. The Sun is almost 110 times wider than Earth. If the Sun were a hollow ball, almost a million Earths would be required to fill it.

The temperature at the surface of the Sun, which is constantly bubbling and boiling, is about 5500°C, while the core is close to 15 000 000°C. The Sun releases charged particles that flow out in every direction. This **solar wind** passes Earth at an average speed of 400 km/s. Earth is protected from the solar wind by its magnetic field.

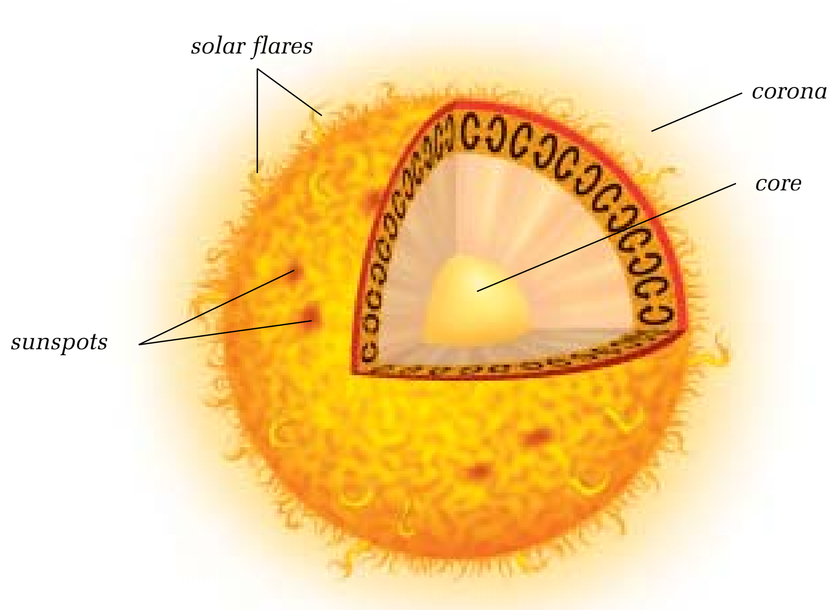


Figure 1.28 The Sun, like most stars, is made up of two main gases, hydrogen and helium. They are packed very densely at the core, held together by gravity.

The Planets

The planets that make up our solar system are as different as the people that make up a family. Every planet has its own unique features and characteristics. The solar system can be divided into two distinct planetary groups: the inner planets, also called terrestrial, or Earth-like, planets; and the outer, or Jovian (in reference to Jupiter), planets. The terrestrial planets tend to be smaller, rockier in composition, and closer to the Sun than the Jovian planets. The Jovian planets are large and gaseous and are located great distances from the Sun.

Technology has enabled us to learn a lot about our nearest neighbours in space. All the planets except Pluto have been visited by orbiting space probes. Mars and Venus have had robots land on their surface.

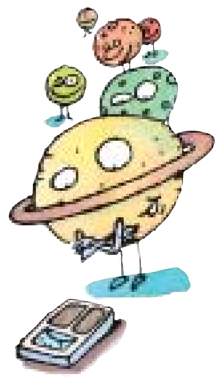
SKILL PRACTICE

Building a Planetary Spreadsheet

In this subsection, you will learn about many of the characteristics of the bodies that make up our solar system.

As you work through this section, prepare a single spreadsheet to compare and contrast all the information provided on pages 394–396 about the planets. You may choose to organize your spreadsheet with the planets down the left-hand column and characteristics across the top, or planets across the top and characteristics down the left-hand column. A sample characteristic could be "Atmosphere" and the data could be a simple yes or no answer.

With a small group, think up eight questions that could be used to test a person's knowledge of how the planets compare to one another. For example: Which planet has the smallest mass? Does Jupiter complete its orbital revolution faster or slower than Saturn? As a class, exchange your questions.



Mercury

Most of what we know about Mercury has been determined by telescopes and satellite data.
Mercury is the closest planet to the Sun. Its surface is very similar to that of the Moon. Like the Moon, Mercury has no atmosphere and therefore no protection from the bombardment of meteroids, asteroids, and comets. The scars of millions of years of impacts can be seen. Other parts of Mercury's surface are smooth, probably due to lava flowing through cracks in the rocky crust. The temperatures on Mercury vary greatly, from over 400°C on the sunny side to –180°C on the dark side.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density Earth=1	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
0.39	0.38	0.06	1	0	180	59 days	0.017	88 days

Venus

Venus is similar to Earth in diameter, mass, and gravity, and is often called Earth's twin. A closer look at conditions on Venus's surface shows where the similarities end. Venus would be horrific for humans to visit. Surface temperatures are kept hot due to a greenhouse effect caused by thick clouds. Temperatures can be over 450°C—hot enough to melt lead. The atmospheric pressure is about 90 times that on Earth. The surface of Venus cannot be seen by telescope because of its thick cloud cover. The permanent clouds are made of carbon dioxide, and it often rains sulfuric acid (the same acid found in a car battery). Russians landed a probe on Venus in 1982, but it only lasted there for 57 min. In 1991, the spacecraft *Magellan* mapped Venus using radio waves (radar). It found huge canyons, extinct volcanoes, and ancient lava flows. Venus is one of the only planets in the solar system to rotate from east to west—opposite to the other six.

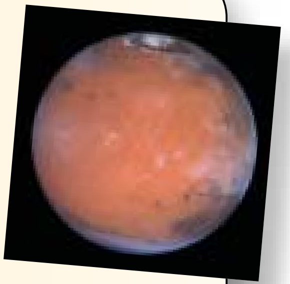
Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
0.72	0.95	0.86	0.96	0	480	243 days	0.004	225 days

Earth

Earth is unique in the solar system for several reasons. It is the only planet where water exists in all three phases: solid, liquid, and gas. It is also the only planet that is at the appropriate distance from the Sun to support life as we know it. As well, Earth's atmosphere provides protection from cosmic rays and ultraviolet radiation that would otherwise harm life. Seventy percent of the planet's surface is covered in water. Earth is one of the few places in our solar system that has active volcanism.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
1	1	1	1	1	15	23.93 h	1	365.25 days

Mars



Mars has been studied by telescope for centuries. Two missions have successfully landed robotic probes on the surface of the planet: *Viking* in 1976 and *Mars Pathfinder* in 1997. Mars is often referred to as the "red planet," though it is actually more orangey. This is caused by the iron oxides on the planet's surface. Mars has two polar ice caps, one made up of frozen carbon dioxide and water, the other of just carbon dioxide. The atmosphere is very thin and composed mainly of carbon dioxide. Although the average surface temperature is extremely cold, temperatures at Mars's equator can reach 16°C in the summer. Like Venus and Earth, Mars has canyons, valleys, and extinct volcanoes. Mars also has two small moons, Phobos and Deimos.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
1.52	0.53	0.11	0.71	2	–53	24.6 h	0.98	607 days

Jupiter

Jupiter has been observed through telescopes since the 1600s. The *Voyager* probes visited Jupiter and many of its 16 moons in 1979, followed by the *Galileo* probe in the mid-1990s. Jupiter is the largest of all the planets in the solar system, and contains more than twice the mass of all the other planets combined. It is a gas giant composed mainly of hydrogen and helium, and scientists speculate that if Jupiter were only 10 times larger than it is, it may have formed into a star. The Great Red Spot on Jupiter is a huge storm in its atmosphere. Jupiter has three very thin rings.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
5.27	11.25	318	0.24	28	–108	9.85 h	2.4	11.9 years

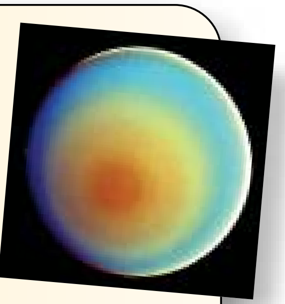
Saturn

Galileo saw Saturn's rings with his primitive telescope in 1610, though he initially thought they were a group of planets. *Voyager 1* and *2* flew by Saturn in 1980 and 1981, respectively. In late 2004, the *Cassini* spacecraft will reach Saturn and drop a probe onto Titan, the largest of the planet's 19 moons. Saturn is the second largest planet in our solar system and has the most distinctive ring system of all the nine planets. Over a thousand rings exist, composed of pieces of ice and dust that range in size from grains of sand to house-sized blocks. Saturn's composition is similar to Jupiter's—mostly hydrogen and helium. Because of the planet's quick rotation, wind speeds at Saturn's equator have been estimated at over 1800 km/h.

Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
9.54	9.45	95	0.13	19	–180	10.38 h	2.3	29.5 years

Uranus

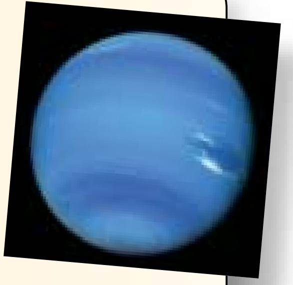
Voyager 2 has given us most of our close-up information about Uranus, last sending data back to Earth in 1986 before it left the solar system. Satellite and telescope analyses have provided other interesting details. Uranus has one of the most unusual rotations in the solar system: its axis of rotation is tilted toward the plane of its orbit, making it appear to roll during its orbit. Another gas giant, Uranus is composed mainly of hydrogen and helium. Methane in its atmosphere gives the planet a distinctive blue colour. Uranus has a large ring system, and 17 moons.



Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
19.19	4.01	15	0.21	17	–214	17.4 h	2.2	84 years

Neptune

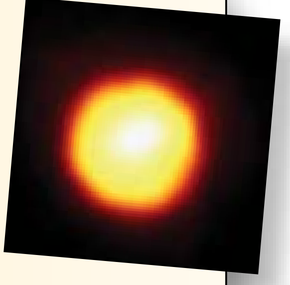
When scientists observed the orbit of Uranus to be different from what they had calculated, they searched for an eighth planet. In 1846, they found Neptune. About a century and a half later, *Voyager 2* flew to Neptune to collect more information. The composition and size of Neptune make it very similar in appearance to Uranus. Another gas giant composed of hydrogen, helium, and methane, Neptune (like Uranus) is bluish in colour. Very little of the Sun's energy reaches the eighth planet. Neptune gives off about 3 times more energy than it receives. It boasts the fastest wind speeds in the solar system, at 2500 km/h. Like all the other gas giants, Neptune has its own ring system, as well as eight moons.



Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
30.06	3.96	0.17	0.27	8	–220	16.2 h	1.6	165 years

Pluto

Pluto was discovered by telescope in 1930. Since then, the most useful information about it has come from the Hubble Space Telescope. One of the greatest debates among planetary astronomers currently is whether Pluto is a planet or not. It is a frozen ball of methane smaller than our moon. It doesn't fit the pattern of the outer planets, which tend to be large and gaseous, and it isn't rocky like the terrestrial planets. Pluto's orbit is raised 17.2° from the plane of the other planets and is more elliptical than that of other planets. Like Venus and Uranus, Pluto rotates from east to west. Between 1979 and 1999, Pluto was closer to the Sun than Neptune. Some astronomers believe that Pluto and its moon, Charon, are comets captured by the Sun's gravity from the area of debris on the outer edge of the solar system called the Kuiper Belt.



Distance from the Sun (AU)	Radius (Earth=1)	Mass (Earth=1)	Density (Earth=1)	Number of Moons	Average Surface Temp. (°C)	Period of Rotation	Number of Rotations per Earth Day	Period of Orbital Revolution
39.5	0.19	0.002	0.36	1	–230	6.39 days	0.17	248 years

Other Bodies in the Solar System

Asteroids

Between the orbits of Mars and Jupiter lies a narrow belt of small, rocky or metallic bodies travelling in space. These are called **asteroids**. They can range in size from a few metres to several hundred kilometres across. The largest asteroid, called Ceres, is over 1000 km wide. Scientists aren't certain where the asteroids came from.

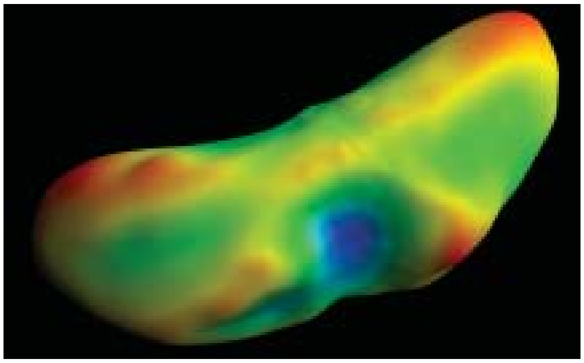


Figure 1.29 The asteroid Eros is only 33 km long and 13 km wide. This image was taken in March 2000 by *NEAR Shoemaker*, the first spacecraft to orbit an asteroid. In February 2001, the spacecraft landed on Eros.

GIVE IT A TRY

How Can Collisions Occur in All That Space?

The motion of the planets in our solar system is generally regular and predictable. Even the motion of many smaller bodies in the solar system, such as asteroids and comets, has been charted and calculated. Every once in a while, however, the gravitational force of a planet or a moon can affect the path of a smaller object and send it on a course toward the Sun. Even though Earth's orbit may be in the way of that new path, chance plays an important role in determining whether a collision between Earth and the object will occur or not.

1 Out on the school grounds, your teacher will stand in place and swing a tetherball, volleyball, or similar type of ball in a slow circle overhead. The ball will be attached to a 3-m piece of cord. The ball represents Earth in its orbit around the Sun (your teacher).

2 Your teacher will provide you with one or two small soft projectiles, such as beanbags or marshmallows.

3 Stand at least 1 m outside the arc made by the swinging ball. Using a gentle underhand lob, throw your projectile toward the moving target—orbiting "Earth." If you succeed in hitting Earth, you will hear the impact or see the projectile deflect off the ball.

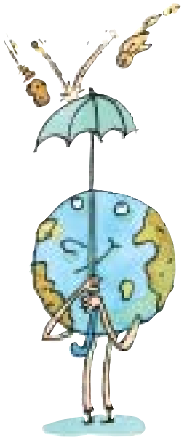
4 After everyone in the class has had a throw or two, add up the number of hits that occurred. Are you surprised by the number? Why? What made this challenge difficult? What would increase the chances of making contact with the ball?

5 Back in your classroom, write a paragraph describing how your observations in this activity might be related to the occurrence of collisions between Earth and other small objects in the solar system.

Materials & Equipment

- ball (such as tetherball or volleyball) with ring attachment
- 3-m piece of cord
- small, soft projectiles (such as beanbags or marshmallows), 2–3 per student

Caution!
When throwing any object, do so gently and aim only at the intended target.



Comets

Comets, often described as "dirty snowballs," are objects made up of dust and ice that travel through space. Their long tails and bright glow only appear when they get close to the Sun. When that happens, the Sun heats the materials on the comet and gases are released. These gases then get pushed away from the comet by the solar wind. The tails of some comets can be millions of kilometres long.

Comets spend most of their time slowly orbiting in the outer reaches of the solar system. Only when an event, such as the close passing of another body, occurs might a comet's path be pushed toward the inner solar system. Then a comet can end up in a regular orbit around the Sun. Comets that orbit the Sun will make a predictable appearance because their paths are large ellipses. One of these is Halley's comet, which is visible from Earth every 76 years. The last time it was seen was in 1986.

Meteoroids, Meteors, and Meteorites

Small pieces of rocks flying through space with no particular path are called **meteoroids**. Meteoroids can be as small as a grain of sand or as large as a car. Practically invisible to most telescopes, we are usually only aware of meteoroids as they hurtle through our atmosphere. When one gets pulled into the atmosphere by Earth's gravity, the heat of atmospheric friction causes it to give off light and it is known as a **meteor**. These are the so-called "shooting stars" that can often be seen streaking across the night sky. If a meteor lasts long enough to hit Earth's surface, it is called a **meteorite**. Some meteor showers are predictable, such as the Leonids.

Figure 1.30 Meteorites are rocky or metallic in composition. The largest known meteorite weighs more than 60 t. It lies where it fell at Hoba West in Namibia.

Figure 1.31 Two impact craters left by a meteorite in northern Quebec

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Halley's Comet's Elliptical Path

The path of a comet around the Sun is elliptical. Knowing its shape allows astronomers to predict when the comet will return to pass by Earth again. Halley's comet has an average 76-year orbit. Shortly after its last visit in 1986, observers saw it brighten unexpectedly. That might mean it collided with something. We will have to see what happened when it makes its scheduled return visit in 2062.

Figure 1.32 Halley's comet

Tracking Objects in the Solar System

As you have learned in previous sections, the paths of the major bodies in the solar system are ellipses. Because astronomers understand the nature and geometry of elliptical orbits, as well as of celestial motion, they now understand the paths of planets and their moons. This means that a variety of events can be accurately predicted, including both solar and lunar eclipses. Recall from earlier studies that a solar eclipse occurs when the Moon, passing between the Sun and Earth, casts a shadow on Earth. A lunar eclipse occurs when Earth passes between the Sun and the Moon, casting its shadow over the Moon.

Knowing so much about orbital paths and speeds, astronomers can predict eclipses well into the future. Some enthusiasts make it a hobby to plan trips wherever they can around the world to witness eclipses.

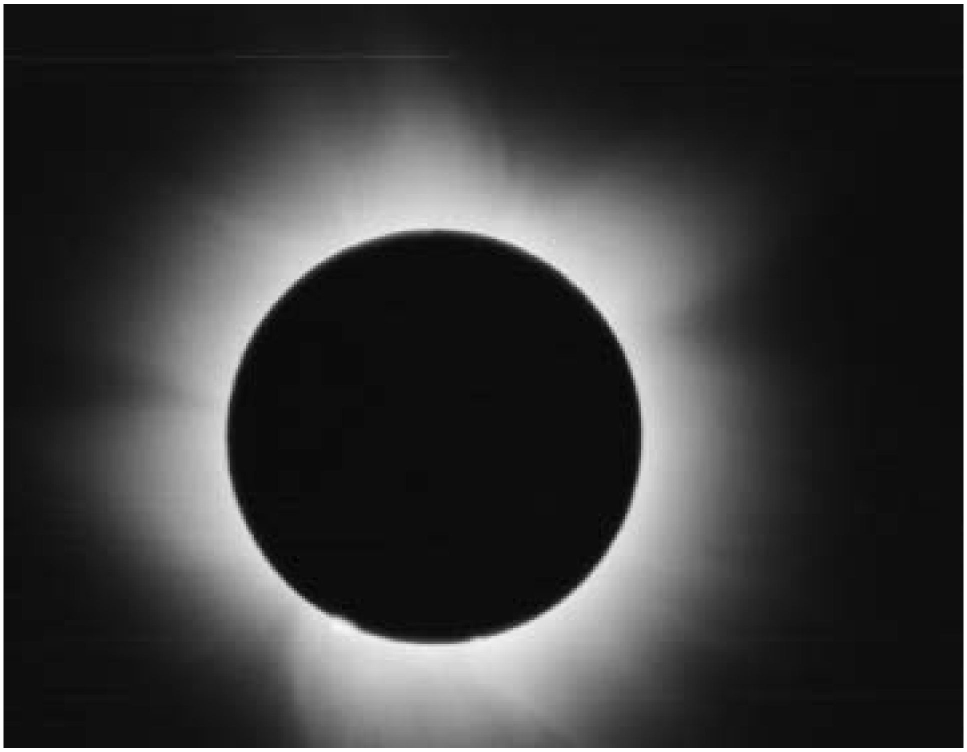


Figure 1.33 During a total solar eclipse, the Sun's corona is visible.

Understanding of orbits has also led to the discovery of many different comets. The paths of comets are elliptical, too, but larger and longer than planetary paths. Through careful observation and the use of some basic mathematics, astronomers are able to calculate the paths of some known comets and predict when they will next be close enough to Earth to be seen. Halley's comet is one example.

Tracking and discovering comets is a job shared by sky-watchers at all levels, from astronomers who work for the National Aeronautics and Space Administration (NASA) to backyard enthusiasts. NASA also has a system for tracking meteors.

reSEARCH

Other Solar Systems

Several dozen planets have been discovered orbiting other stars in our galaxy. With each discovery, astronomers are learning that our solar system is not the same as every other one. Investigate the latest research on new planets and find out how different they are from the ones in our solar neighbourhood. Begin your search at www.pearsoned.ca/scienceinaction.

Figure 1.34 The predictable path of Comet Shoemaker–Levy allowed astronomers to anticipate and monitor the comet's collision with Jupiter in 1994.

Check and Reflect

Key Concept Review

1. List the names of the inner, or terrestrial, planets.
2. Name three ways in which the outer, or Jovian, planets are alike.
3. Explain the main ways in which the inner planets differ from the outer planets in our solar system.
4. Describe what an asteroid is.
5. Why are comets sometimes referred to as "dirty snowballs"? Why are their tails visible?
6. What is the name for a meteoroid that survives its journey through our atmosphere and hits Earth?

Connect Your Understanding

7. Describe in your own words how the solar system formed.
8. On the upper surface of Jupiter's atmosphere, the attractive force of gravity is 2.5 times that on Earth. What would a bathroom scale show if a 50-kg person were weighed on Jupiter?
9. For about 20 years, from 1979 to 1999, Pluto was closer to the Sun than Neptune was. Explain why this was possible.

Extend Your Understanding

10. Why would it be unreasonable to expect Saturn-like rings around any of the inner planets?
11. Explain how it is possible for an asteroid or a comet to cut directly across Earth's orbital path but not strike Earth.
12. Suppose a gaseous planet half the size of Saturn were discovered. Where in the solar system do you think it would be located? Give a reason for your answer.

1.5 Describing the Position of Objects in Space

Suppose you were talking on the phone to your friend who lives in the house beside you. From your windows you are looking at the night sky. Your friend finds an interesting stellar object and wants you to look at it. How can you be sure you are both looking at the same thing?

To locate the position of an object in space, two questions must be answered: "How high in the sky is it"? and "In which direction"? This problem can be solved with only two measurements. The first is the compass direction, called the **azimuth**. With due north as 0° and going clockwise, the azimuth will tell you which direction to point. For example, 180° from 0° would have you pointing due south; 270° would have you pointing west. The second measurement shows how high the object is in the sky. This is called **altitude**. The altitude ranges from 0 at the horizon to 90° straight up. With these two measurements, stargazers can pinpoint objects in space. **Zenith** refers to the highest point directly overhead.

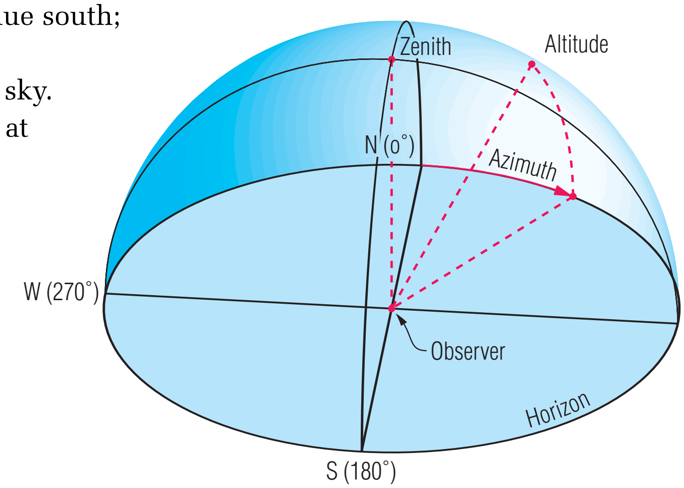


Figure 1.35 The imaginary dome that allows us to describe the position of a celestial object

GIVE IT A TRY

Estimating Positions in Space

In this activity, you will investigate how accurately you can estimate the position of an object above you by using a simple tool, your fist.

1. From your desk, select a small object that is high up on a classroom wall. Choose the wall that is farthest from your desk. The object can be a clock, a tack, or even just the upper corner of the room.
2. Extend one arm out in front of your body and make a fist. Close one eye and look down your arm, as though you were taking aim at something. The height of your fist as you see it this way represents about 10° of altitude.
3. From a standing position beside your desk, and using your fist as described in step 2, estimate the height (in degrees) of the object you have chosen. Start with one arm held out horizontal to the floor. Then, using both arms, count the number of times you have to place one fist on top of the other until you "climbed" to the object's position. *For example: 6 fists × 10° = 60°.* Record your "altitude" estimate in your notebook.
4. Next, estimate the compass direction of the object. Your teacher will tell you where due north is. Imagine that point to be 12 o'clock in a clock face. Describe the direction in which your object lies from north (12 o'clock) by reference to its position on the imaginary clock face (e.g., 2 o'clock). Combine this with the first measure of elevation.
5. Compare the accuracy of your results with that of some of your classmates. What similarities or differences do you notice in your results? Explain why these might have occurred.

Activity E-2

Problem Solving

Where Do We Look?

Recognize a Need

To find a particular star in the night sky is not as simple as pointing and saying, "There it is!" To find the specific location, a set of rules must be followed and accurate directions given. A star's position is like an address to a house: no two are exactly alike. How is the position determined, and how can another person find the exact same star?

Materials & Equipment

- cardboard
- circle protractor
- pen
- scissors
- string
- small weight (such as a washer or rubber stopper)
- straight drinking straw
- adhesive tape
- thin straight object (such as a souvlaki stick or a straight piece of wire)

The Problem

Searching the night sky, you have discovered a bright star that wasn't visible before—a supernova perhaps. To claim your fame as the star's discoverer, you have to confirm its position with the Astronomical Society. The Society requests that you send the star's bearing (azimuth) and altitude. You have a telescope, but no way of knowing the exact position of the star in the sky. The challenge is to build a device, find the star, and correctly identify the coordinates. The only way to solve the problem is to construct an astrolabe.

Criteria for Success

- Build a functioning astrolabe with materials provided.
- Locate the star with the astrolabe.
- Use the correct technique to identify the coordinates with the astrolabe.

Build a Prototype

1 Draw a semicircle about 20 cm in diameter on the cardboard. Using a protractor, mark the 10° increments on the cardboard and label them (see Figure 1.36). Cut out the cardboard protractor.

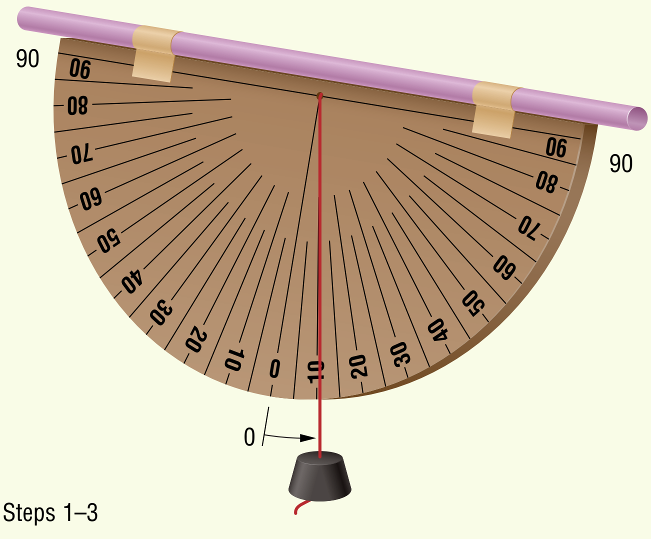


Figure 1.36 Steps 1–3

2 Tie one end of the string to the weight and attach the other end to the centre of the cardboard. The weight should be able to swing freely, as shown in Figure 1.36.

3 Tape the straw to the cardboard as shown in Figure 1.36. The angle you read from the string on your new astrolabe indicates the angle your target is above the horizontal.

Test and Evaluate

Note: For this part of the activity, your teacher will have hung a sphere (representing your star) from the ceiling.

4 Sitting at your desk, locate the "star" in the sky using the straw as a telescope. The weight should be hanging straight down (Figure 1.37).

5 Once you have found the star, hold the astrolabe as steady as possible and read the altitude off the cardboard scale (or have another student read it for you). Write this number down as "altitude" (for example: 45°).

6 Your teacher will tell you where due north is. Lay the circle protractor on your desk and align the 0° with due north. Tape the protractor on your desk to hold it in place.

7 Place the thin straight object on the circle protractor with one end at the centre of the protractor and the other end pointing in the direction of the star. The azimuth is always measured clockwise from the north in degrees. Read the angle measured clockwise from due north. This is the azimuth of the star.

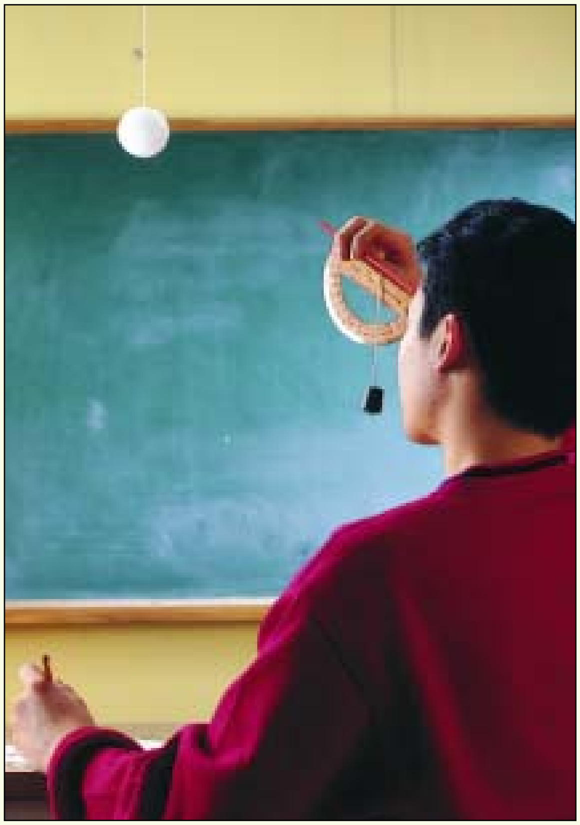


Figure 1.37 Step 4

Communicate

8 Imagine that, after locating the position of the star, you send the coordinates to the Astronomical Society. A week later they call to say they followed your directions exactly, but could not find the star. You are certain you were careful. What might have happened that would make your coordinates incorrect?

9 Do your coordinates match those of any of your classmates? Explain why they might not.

10 If it were a real star you were looking at and you took coordinates every night for one full year from the same location, would the coordinates change or remain the same? Explain your answer.

Extension

You can record the altitude of the Sun with an astrolabe. Point the straw at the Sun with one hand, and hold your other hand, palm up, to the other end of the straw. Move the straw around until you see a small circle of light on the palm of your hand. Read the angle on your cardboard scale. This shows you the altitude of the Sun. Make three measurements and calculate an average. Try this at the same time for five days in a row. Does the Sun's altitude change or does it stay the same? Explain..

Caution! Do not look directly at the Sun through the straw.

*re***SEARCH**

Star-studded Flags

Stars are part of the design of the national flags of Australia, Brazil, and New Zealand and the state flag of Alaska. Find out which stars the flags depict and explain why you think that is. Begin your research at www.pearsoned.ca/scienceinaction.

Determining the Motion of Objects in Space

Because they are at such enormous distances from Earth, the stars appear to stay in one place in the sky. Only when viewed over extremely long periods of time can some stars be seen to move very slightly.

When observing planetary motion, however, a person needs to wait only a few days or weeks to see a planet change its position against the background of stars. "Planet" comes from the ancient Greek word for "wanderer." The movement of these wandering celestial planets mystified early people. Sometimes the planets seemed to speed up over time in their movements across the sky. Other times they appeared to stand still. The path in the sky along which the Sun appears to move is called the **ecliptic**.

In section 1.1, you read about how astronomers such as Aristotle and Copernicus tried to explain the motions of the planets which, when viewed from Earth, seemed very complex. Different interpretations of the available information eventually led to new theories being proposed. An example of this was Kepler's suggestion that the planets' paths were ellipses and not circles.

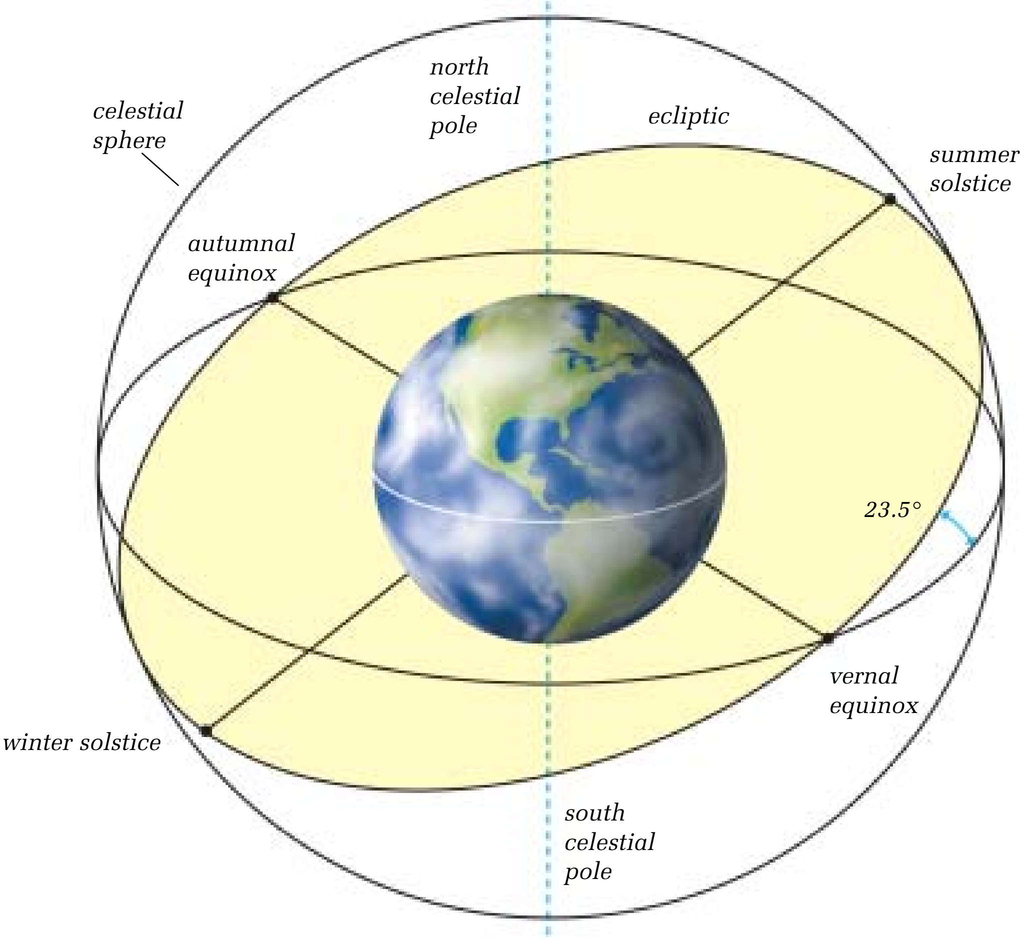


Figure 1.38 The *celestial sphere* is the name given to the very large imaginary "sphere of sky" surrounding Earth. (Think of Earth lying within a large hollow ball.) The *celestial equator* is the imaginary line around that sphere of sky directly above Earth's equator. The ecliptic—the apparent path of the Sun through the sky during the year—crosses the celestial equator at the vernal (spring) and autumnal (fall) equinoxes. The Sun's most northerly position on the ecliptic marks the summer solstice. Its most southerly position marks the winter solstice.

Check and Reflect

Key Concept Review

1. What name is given to the compass direction when we are trying to locate an object in the night sky?
2. Define altitude.
3. What is the point directly overhead called?
4. Explain what the ecliptic is.

Connect Your Understanding

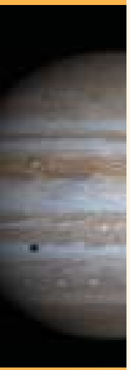
5. Why did the Greeks call the planets "wanderers"?
6. Why must two coordinates, azimuth and altitude, be given to specify the location of an object in the night sky?
7. The table below has two incorrect entries.
   a) Identify each error and correct it.
   b) Explain why each of the two entries is incorrect.

Reading	Azimuth	Altitude
1	30°	93°
2	364°	45°

Extend Your Understanding

8. Is it ever possible to specify the location of an object in the sky knowing only the altitude? Explain your answer.
9. Imagine two friends, one in Calgary and the other in Edmonton, observing the same body in space. Describe how their coordinates would be different for the same object.
10. a) Does the rotation of Earth affect azimuth and altitude measurements of stars? Explain why or why not.
    b) What can be done to ensure someone using your measurements would be able to find the object you located?

Figure 1.39 If you know the altitude and azimuth coordinates of an object in the sky, you can accurately describe its position to someone else.



Assess Your Learning

Key Concept Review

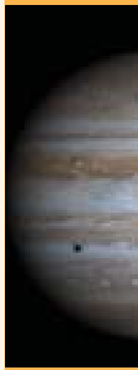
1. Why was it necessary for ancient people to develop technology to better understand the motions of bodies in space?
2. Define a) astronomical unit and b) light-year.
3. What two characteristics of stars are plotted on the Hertzsprung-Russell diagram?
4. What name do we give the nuclear reaction that produces helium from hydrogen?
5. Explain the difference between a constellation and an asterism.
6. Is the Sun likely to become a neutron star? Explain your answer.
7. Imagine that you observe two stars in the night sky. One is an old star and one is a young star. What differences between the two might you observe?
8. What prevents a neutron star from collapsing under its own gravity?
9. What type of galaxy is the Milky Way? Sketch what this type of galaxy looks like.
10. a) In what way are Mars and Earth similar?
    b) In what ways are they different?

Connect Your Understanding

11. Compare the general characteristics of the inner planets with those of the outer planets. Copy the table below into your notebook and fill it in.

Feature	Inner Planets	Outer Planets
Composition		
Number of moons		
Ring systems		
Size		
Surface temperature		

12. Which planet has surface features that most closely resemble Earth's? Briefly describe those features.
13. The speed of light is 300 000 km/s. The Sun is about 150 000 000 km from Earth.
    a) How long does it take light to get from the Sun to Earth?
    b) The distance around Earth at the equator is about 40 000 km. How long would it take light to go around the world once?
14. Explain why distances to stars are not measured in kilometres or astronomical units.
15. Describe the protoplanet hypothesis of how a solar system forms. Use sketches to support your answer.



Extend Your Understanding

16. Explain why it is necessary on Earth to have a leap year (one extra day, February 29) every four years.

17. Figure 1.40 shows the orbital paths of Neptune and Pluto. As you know from this section, Pluto's path cuts across the path of Neptune. Give two reasons why it is unlikely their orbital paths will ever collide.

Figure 1.40 Question 17

18. The greater the mass of an object, the greater its gravitational attraction. The object with the largest mass in our solar system is the Sun. Because of its large mass, it not only holds the planets in their orbits, but it also attracts great amounts of space debris from the far reaches of the solar system. On occasion, large chunks of debris have even hit Earth, but not as many as astronomers have predicted could hit Earth. What might be some explanations for Earth's apparent "luck" in not being hit by more space debris?

Focus On SCIENCE AND TECHNOLOGY

Our understanding of space and the universe around us is directly connected to the technology we use to make observations. As the technology has improved, so has our ability to find answers to our questions. Consider the following questions and use examples from your work in this section to support your answers.

1. How has technology affected the way humans look into the universe?
2. How have technological advances over time improved our understanding of space?
3. Why has distance in space proven to be such a challenging factor to overcome?

2.0 Technological developments are making space exploration possible and offer benefits on Earth.

Key Concepts

In this section you will learn about the following key concepts:

- technologies for space exploration
- life support technologies
- communication technologies

Learning Outcomes

When you have completed this section, you will be able to:

- analyze space environments, and identify challenges that must be met in developing life-supporting systems
- describe technologies for life-support systems, and interpret the scientific principles on which they are based
- describe technologies for space transport, and interpret the scientific principles involved
- identify materials and processes developed to meet needs in space, and identify related applications
- describe the development of artificial satellites, and explain the major purposes for which they are used

"From space, if you look back just a few degrees away from Earth, you see the black void of the universe—the cold vacuum of space. But when you look back at the Earth, bathed in sunlight, you see where we all live. We are all voyagers in space together."

—*Roberta Bondar, Canadian astronaut, quoted in the Canadian Space Agency's "Canada in Space: Destination Earth" (1993)*

The lure of leaving Earth to explore other planets and beyond is the same lure that has always drawn humans to explore what lies over the horizon. The urge to venture into uncharted seas, distant countries, and extreme environments, such as the Arctic and Antarctica, is no different than the urge to venture into space.

From the earliest unmanned rockets to the re-useable space shuttles of today, the biggest challenges of exploring space have been finding ways: 1) to go fast enough to achieve orbit around Earth or break free of Earth's gravity and travel to other planets; 2) to keep equipment operating in the extreme environment of space; and 3) to transport people out and back safely. In searching for solutions to these problems, scientists have used technology and technologists have used science.

In this section, you will learn about technologies developed to send objects into space and to make life support and transport in space possible. You will also learn about the spin-offs from such innovations that are being used here on Earth.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 Getting There: Technologies for Space Transport

Humans have come a long way since their early experiments with rocketry to propel objects high into the sky. Today, hundreds of satellites circle Earth. They transmit non-stop information for use in communications, navigation, research, and weather forecasting. Robotic space probes have investigated all the planets of our solar system except Pluto. As well, manned spacecraft—notably the Russian *Mir* space station, the American space shuttle, and the International space station—have conducted studies while in Earth's orbit.

Getting an object into "space" (outside Earth's atmosphere) first required figuring out what speed an object needed to overcome the force of gravity pulling the object back toward Earth. That speed, it was found, had to be at least 28 000 km/h.

infoBIT

The First Rocketeer

A legend from 16th century China suggests that the first rocket-assisted flight was attempted by Wan-Hu, a Chinese official. Forty-seven rockets were attached to a chair that was connected to two kites. After all the rockets were ignited, there was a massive explosion. No traces of Wan-Hu, the chair, or the kites were ever found.

QUICKLAB

The Power of Steam

Note: This may be done as a teacher demonstration.

Caution! Be careful around the heating tray to avoid getting a burn.

Purpose

To observe the power of steam propulsion

Procedure

1. Set up the apparatus as shown in Figure 2.1.
2. Fill the beaker until it is about half full of water.
3. Turn on the heating tray to boil the water.
4. When the water starts boiling, record your observations.
5. After you have completed the activity, turn off the power to the heating tray. DO NOT touch the apparatus until it has had sufficient time to cool down.

Questions

6. What made the pinwheel turn?
7. Why was the funnel put over the beaker upside down?
8. Would the pinwheel have turned if no funnel were used? Explain your answer.
9. How could you improve this set-up to make the pinwheel spin faster?

Materials & Equipment

- plastic pinwheel
- test-tube clamp
- thermometer clamp
- plastic funnel to fit beaker
- one 250-mL beaker
- water
- heating tray
- pencil and notepaper

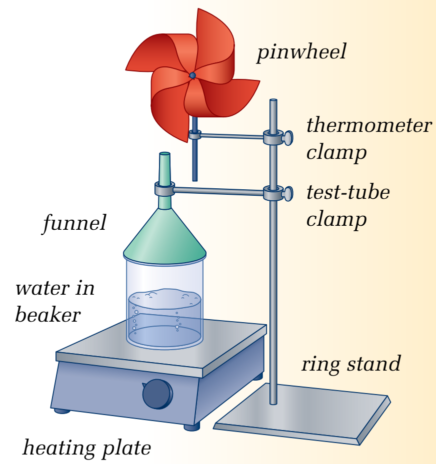


Figure 2.1 Step 1

The Achievements of Rocket Science

Figure 2.2 Space exploration really started once large rocket boosters were developed. Cape Canaveral in Florida is the major launch facility of the National Aeronautics and Space Administration (NASA).

Figure 2.3 Archytas's "pigeon" is said to be the first rocket ever recorded.

The first step in space exploration has been figuring out a way to get off the planet. The sophisticated rockets used today to transport unmanned and manned craft into space are tributes to human technological ingenuity and achievement. These complex rockets have far simpler origins than you might imagine. Around 400 B.C., the Greek mathematician Archytas used escaping steam to propel a model pigeon along wires. In the 1st century A.D., the Chinese were using gunpowder to make rocket-propelled arrows for battle.

On October 4, 1957, the Soviet Union became the first country in the world to launch an artificial satellite. It was called *Sputnik*, the Russian word for satellite. A month after *Sputnik* was put into orbit around Earth, the Soviet Union launched a second space capsule. This one carried an occupant, a small dog named Laika, who survived for seven days as the capsule orbited Earth. The event marked the first time any living creature had been sent into space. The valuable information gained from that mission set the path for human space travel.

Figure 2.4 *Sputnik I* was only about as large as a basketball, but its launch marked the beginning of the satellite age.

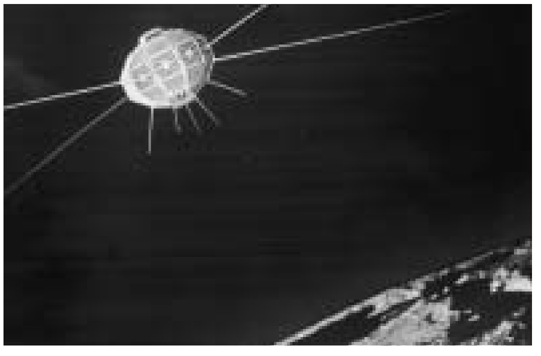


Figure 2.5 On September 29, 1962, Canada became the third nation in the world (after the Soviet Union and the United States) to launch its own satellite, *Alouette I*.

QUICKLAB

Stabilizing Rocket Flight

Have you ever wondered why rockets have fins?

Purpose

To test the effects of fins in stabilizing a rocket for flight

Procedure

1. Cut a strip about 13 cm long and 3 cm wide from the paper. Roll the strip snugly around the pencil and tape it closed to create a long tube (your "rocket"). Twist the end of the paper around the pencil point to make the nose cone.
2. Slip the pencil out the other end of the tube. Gently blow into the open end of the tube and feel for leaks along its length. If air is escaping, seal the leaks with more tape.
3. Test Flight 1: Insert one end of the straw into your rocket. With the other end of the straw in your mouth, tilt your head back slightly and blow a quick puff of air into the rocket. Observe how the rocket flies.
4. Retrieve the rocket. From the left-over paper, cut out two sets of fins. Tape these to the tube as shown below. (Hint: Adding tabs to the fins makes them easier to tape to the tube.)
5. Test Flight 2: Again, launch your rocket with the straw and observe the rocket's flight.

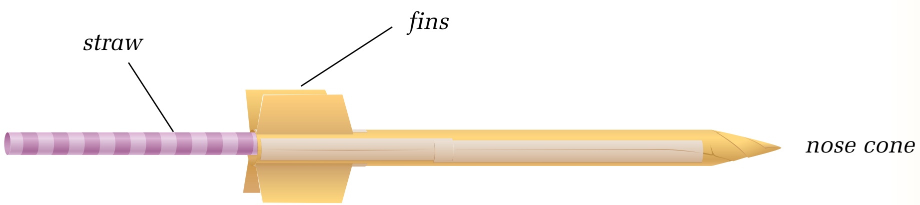


Figure 2.6 Model rocket

Questions

6. How does the rocket's performance in the first test compare to that in the second test? Write a brief conclusion about how fins affect a rocket in flight.
7. Do you think that fins would have much effect on a rocket's performance outside Earth's atmosphere?

Materials & Equipment

- a sheet of paper
- scissors
- a pencil (at least 14 cm long)
- tape
- a drinking straw (a little narrower than the pencil)

Caution!
Point your rocket in a safe direction only, away from other people.

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Space Travel Tip: Pack Lightly

When preparing a manned spacecraft for a long trip, engineers try to organize the mass of the load as follows: 3% as machinery (tanks, engines, and fins); 6% as payload (including air, water, food, satellites, crew quarters, and the astronauts), and 91% as fuel.

The Science of Rocketry

Rocketry relies on a fundamental law of physics: for every action, there is an equal and opposite reaction. An inflated balloon is similar to a simple rocket. A balloon filled with air is confining gas under pressure. Release the mouth of the balloon and it will be propelled in a direction opposite to the path of the escaping gas. Rockets also use gas under pressure confined in a chamber or tank. An opening in the chamber allows the gas to be released, producing thrust (push) and causing the rocket to be propelled in the opposite direction.

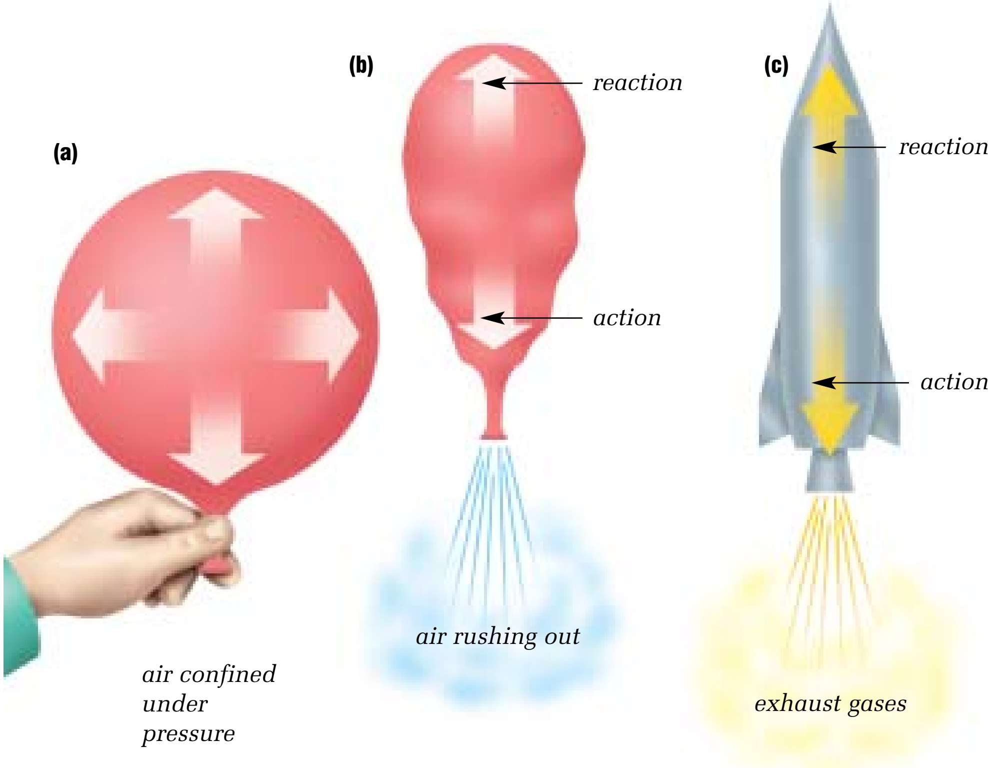

Figure 2.7 In an inflated balloon (a), the air pressure pushes equally in all directions. When the air is allowed to escape, the action causes a thrust reaction (b). Rockets are propelled in a similar way (c).

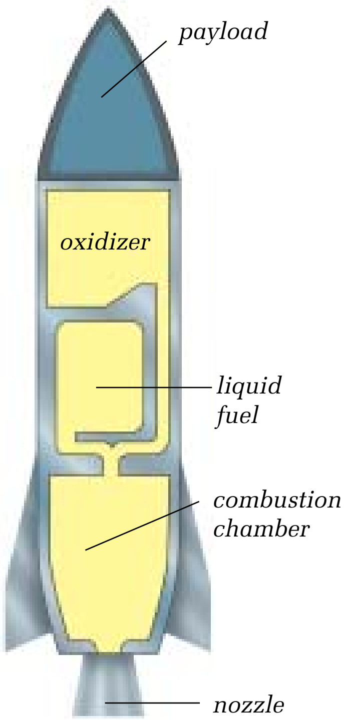

Figure 2.8 A modern rocket in cross-section

There are three basic parts to a rocket: the structural and mechanical elements, the fuel, and the payload.

- The structural and mechanical elements are everything from the rocket itself to engines, storage tanks, and the fins on the outside.
- The fuel can be any number of materials, including liquid oxygen, gasoline, and liquid hydrogen. The mixture is ignited in a combustion chamber, causing the gases to expand and leave as exhaust.
- The payload refers to the materials needed for the flight, including crew cabins, food, water, air, and people.

The Future of Space Transport Technology

If humans are to visit other bodies in our solar system, technology still has a long way to advance. Ion drives and solar sails are two new devices being considered for propelling spacecraft between the planets.

Ion Drives

Ion drives are engines that use xenon gas instead of chemical fuels. In the spacecraft engine, the xenon is electrically charged, accelerated, and then emitted as exhaust. This action pushes the spacecraft in the direction opposite to the emission.

The thrust generated by an ion drive is 10 000 times weaker than the thrust achieved by today's chemically fuelled rocket engines. Can you feel the force created by the page of this textbook resting on your hand? That force is roughly equal to the force an ion drive would exert against your hand. However, the thrust from an ion drive lasts an extremely long time. In space, that little bit of force applied over a long period of time results in a very fast vehicle. For great distances, the amount of fuel required is about 1/10 of what would be used by a typical spacecraft.

reSEARCH

It's Always Sunny— Above the Clouds

In August 2001, NASA launched *Helios*, the first remotely piloted, solar-powered "flying wing" that can fly more than 30 000 m above Earth. Find out more about the design of the craft, the science behind the design, and how NASA hopes to apply the technology to explore space. Begin your search at www.pearsoned.ca/scienceinaction.

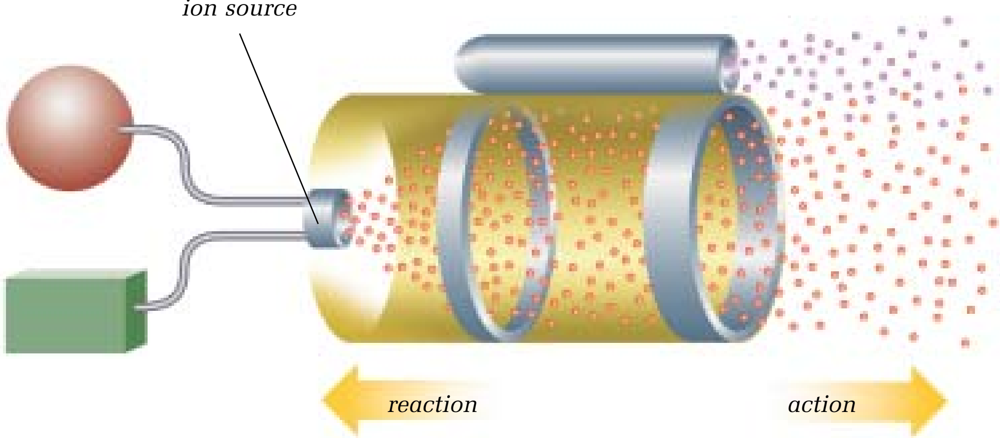

Figure 2.9 Ion drives may be an option for powering spacecraft that could take the first astronauts to Mars. Imagine a car getting about 19 000 km/L of fuel. That is the potential benefit of an ion drive.

Solar Sails

The idea of propelling spacecraft using solar sails is similar to the idea of propelling boats using wind sails. Instead of harnessing air currents for energy, solar sails would use the Sun's light. The Sun emits electromagnetic energy in the form of photons. The solar sails being tested are made of carbon fibre. When the photons hit the sail, the energy transmitted causes the spacecraft to move. Proposals for solar sails suggest that they might be made from material that could be spread as thin as plastic wrap and extend over 400 m^2. Use of solar sails is expected by 2015.

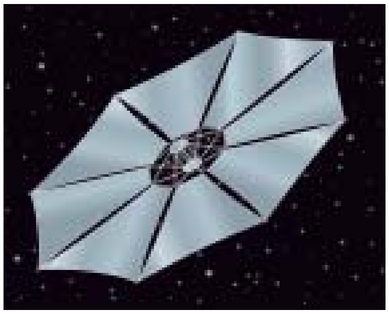

Figure 2.10 Some scientists estimate that a spacecraft powered by solar sails could travel about 5 times as fast as a current spacecraft.

ACTIVITY E-3

Problem Solving

DESIGNING A SOLAR SAIL-POWERED SPACECRAFT

Materials & Equipment

- for the sail: a variety of materials (such as thin cloth, paper, plastic wrap, wax paper, aluminum foil)
- for the wheels: a variety of pieces of cardboard of varying thickness
- scissors
- for the spacecraft body: small piece of wood (about 10 cm long, 3 cm wide, 1.5 cm thick)
- thumbtacks
- small gauge, rigid wire
- masking tape
- washer (about the diameter of a quarter)
- electric fan
- stopwatch

Recognize a Need

The solar sail holds great promise for interplanetary flight. With the Sun as an energy source, the potential for economical power seems limitless. Yet, what is the best design for such a sail? Logically, one might think that the larger the sail, the faster and farther a craft could go. In this activity, you will learn that many details must be considered in designing any spacecraft.

Note that in this activity you will be simulating solar power and its effects on the design of solar sails. Instead of using the Sun's light to power your craft, you will be using wind currents.

The Problem

With the materials provided, you are to design a sunlight-powered spacecraft that will take a specified payload (the washer) to a set destination. The craft must be able to travel straight to hit its destination, make the trip in the shortest time possible, and arrive at the destination with the payload intact.

Criteria for Success

- Produce a set of scale drawings of your craft and label them. Briefly describe the scientific principles met by your design, and justify the choices you made.
- Use simple materials to build a functioning model spacecraft powered by a sail. The craft must be able to travel the minimum design distance to the destination, without dropping its payload.

Brainstorm Ideas

1 Working in a small group (your "design team"), discuss which of the materials you have available would be most suitable for a solar sail.

2 Consider the options for the overall design of the craft, including: size of the body; size, thickness, and position of the wheels; size and shape of the sail; and position of the payload.

3 Make a labelled sketch of your proposed model before you build it; modify the design if necessary.

Build a Prototype

4 Cut the wheels from the cardboard provided.

5 Use the thumbtacks to fasten the wheels to the piece of wood.

6 Cut the sail from the material of your choice.

7 Use the wire to form a support, or mast, for the sail. Tape the end of the wire to the wood.

8 Tape the washer to the wood as your payload.

Test and Evaluate

9 Perform a preliminary test on your spacecraft by blowing on the sail. (No testing is to be done with the fan yet.) Adjust your design as necessary.

10 Predict how far your spacecraft will travel in your official test.

11 After all modifications have been made, run the official test on a smooth, hard surface.

12 Place your model at the designated starting position, with the target destination (about 1 m wide) 2 m away. Set the fan on the floor, about 30 cm behind the craft. *Note: Be careful when using an electric fan.*

13 As soon as you release the craft, start the stopwatch to time the journey to the target. Repeat your test three or four times and calculate the average speed.

14 Now, without a fixed destination, test the maximum distance your craft will travel.

Communicate

15 Write a brief summary describing the relationship between the speed of your spacecraft and: (i) the size of the sail; (ii) the size of the wheels; and (iii) the material of the sail. Also explain how the position of the payload affected the balance and speed of your craft.

16 What problems did you experience with your prototype? Explain how you might correct these, and invite suggestions from other design teams.

17 Was the maximum distance you predicted your craft could travel close to the actual distance you found in your test? Explain how you arrived at your prediction and why your model performed or did not perform as predicted.

18 In which ways does your model operate like a solar sail? In which ways does it not?

Figure 2.11 Brainstorm ideas and build a prototype.

Shuttles, Space Probes, and Space Stations

In the decades since the first simple satellites, the science of rocketry has sent humans on round-trips to the Moon and sent robots to investigate our neighbouring planets. It has also launched the Hubble Space Telescope to let us look far out into the universe and back in time to the birth of the universe—generally thought now to be some 12 to 15 billion years ago.

There are three main types of spacecraft in use. Shuttles transport personnel and equipment to orbiting spacecraft. Space probes contain instrumentation for carrying out robotic exploration of space. (These are described in more detail in section 3.2.) Space stations are orbiting spacecraft that have living quarters, work areas, and all the support systems needed to allow people to live and work in space for extended periods.

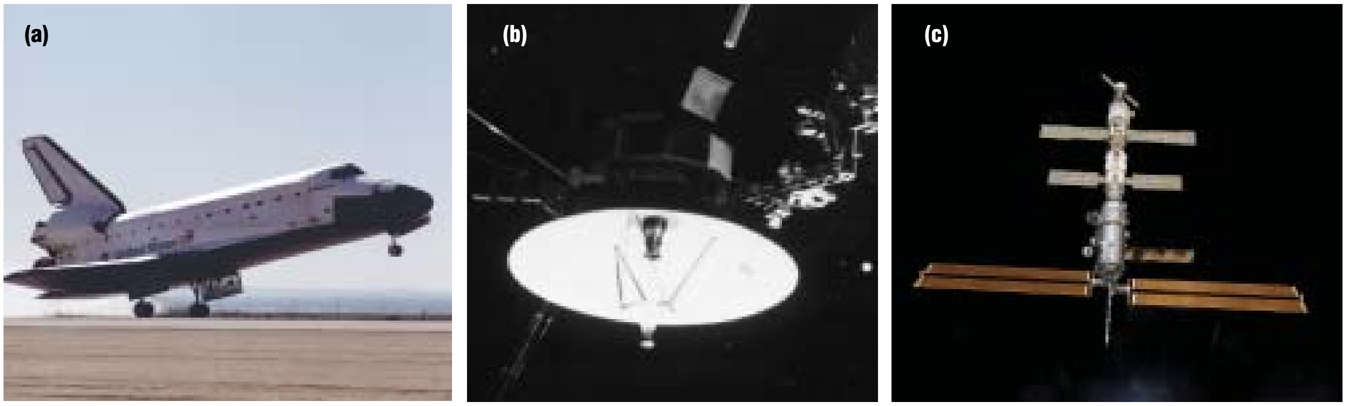

Figure 2.12(a) American space shuttle, **(b)** *Voyager* space probe, and **(c)** International space station

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Ticket to the Moon

A Japanese company is already taking reservations for trips to the Moon in 2010. In a recent North American survey, more than 60% of the people who responded said they would like to take a vacation in space. Of those people, most said they would not hesitate to spend three months' pay for a two-week vacation off the planet.

The Next Step

A manned interplanetary space journey would be much easier if the spacecraft did not not have to begin by fighting Earth's gravity or travelling through its atmosphere. Scientists believe that the best place to start an interplanetary flight is from an orbiting space station or even from the Moon.

The International Space Station, orbiting Earth at an altitude of 350 km, provides such a place. It is a joint project of 16 nations, including the United States, Canada, Japan, Russia, Brazil, and 11 nations of the European Space Agency. The station will serve as a permanent laboratory in space, as well as a command post for building and launching interplanetary rockets. Construction of the International Space Station is well under way, with modules (subsections of the craft) being made and sent up from Earth. When it is completed, it will have a living and working space equal to the size of three average-sized Canadian houses.

Almost certainly, more space stations will be established in the future. As well, several private companies are planning to develop hotels and amusement parks in space or on the Moon.

Figure 2.13 Humans are ready for the next step in leaving Earth and living for extended times in space.

Check and Reflect

Key Concept Review

1. Archytas's model pigeon is the first rocket ever recorded. What method did he use to propel his pigeon?

2. Who were the first people to use gunpowder to propel arrows with the aid of rockets, and when?

3. Which was the first country to launch an artificial satellite?

4. Describe the three basic parts of a rocket, and draw and label a sketch showing the parts.

5. Name two alternatives to rocket engines that scientists are studying as a means of propelling spacecraft on long journeys.

Connect Your Understanding

6. Explain what would happen if a rocket's payload were greater than the allowed percentage.

7. What is the main attraction for using an ion drive for powering spacecraft?

8. Besides savings in fuel costs, what is the other main advantage to using a solar sail?

Extend Your Understanding

9. The force of gravity on the moon is 1/6th of that on Earth. Imagine you had a summer job as a chef's assistant at a hotel on the Moon. Describe the challenges you would face doing each of the following activities inside the hotel, and how you would overcome those challenges.

a) washing dishes
b) cooking pancakes
c) climbing stairs
d) having a swim in a pool

10. Imagine a luxury hotel located on the bright side of the Moon. Describe three hazards that might face a structure located there.

11. Every planet in our solar system except Pluto has been explored either remotely (by probe) or on its surface (with a microwave oven-sized robotic "lander"). Research the technology that has been used to study each planet, and investigate why a space probe has not yet been sent to Pluto.

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All-Occasion Pen

NASA spent close to $2 million designing a pen that would work in space. It had to be able to write in a vacuum, upside down in microgravity conditions, and in temperatures that range from +200°C in full sun to -200°C in the shade.

2.2 Surviving There: Technologies for Living in Space

Only a thin atmosphere encircling our planet holds all we need for life on Earth. Outside that bubble is the "cold vacuum of space" that Canadian astronaut Roberta Bondar referred to in the introduction to this section. It is an environment that is hostile to human life in numerous ways.

Figure 2.14 Canadian astronaut Julie Payette played an active role in assembling the International Space Station.

GIVE IT A TRY

SHARING A SMALL PLACE IN SPACE

Using a piece of cord 16 m long, lay out a square on the floor that measures 4 m × 4 m. Imagine that this outlines the size of the spacecraft that will be your home for 12 months during a trip to Mars.

Stand in the square with five other classmates. For about 1 min, move around with your fellow astronauts as best you can in the space provided.

Return to your desks and, with your group, think about all the problems that could arise during a long trip in this type of confinement. Some of the aspects to consider include work space, room for exercise, and issues of privacy. In your notebook, list all the potential problems you identify. Beside each problem, write a solution that you and your group can suggest. When you are finished, compare the problems and solutions you identified with those that other groups noted.

Hazards of Living in Space

People travelling and working in space do not need an Earth-like environment simply for comfort. It is a matter of survival. Humans have orbited Earth, flown far into space, landed on the Moon, and returned safely to our planet. We are now aiming to put a human—not just a robotic machine—on another planet for the first time. Scientists believe we now have the technology to send a group of astronauts to Mars and back. This will not be a typical week-long mission for space shuttle astronauts, nor will it be a few months as experienced by astronauts in the International Space Station. Astronauts going to Mars will be gone for two to three years.

Environmental Hazards

Space is a vacuum, with no air or water. It also contains many hazards for the spacecraft and its occupants, including the damaging effects of cosmic rays and solar radiation and the risk of being hit by meteoroids. There is no atmosphere so temperatures can range from unimaginably cold in shadows to extremely hot in the full sun. The gases in the atmosphere that keep us alive on Earth do not exist in space. Neither does the pressure of the atmosphere, which helps regulate our heartbeats.

Psychological Challenges to Confined Living

Long trips in a confined living space may also lead to psychological problems. Imagine spending every minute of every day with one person for two years. Now imagine spending that two years in an enclosure not much bigger than your classroom. Stepping outside for a breath of fresh air is strictly prohibited!

Figure 2.15 The space in which astronauts live and work is extremely cramped.

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Record-Holder for Space Living

In 1995, Valery Polyakov, a Russian cosmonaut (the Russian term for astronaut) returned to Earth after living for a record 437 days in space. He suffered loss of bone mass, but by exercising strenuously for two hours every day, he stayed physically fit and was able to walk away from his spacecraft unassisted after he arrived back on Earth.

The Body and Microgravity

Before astronauts can travel to distant planets in our solar system, there is much to be learned about how the human body adapts physically to living in space. A particular problem is living in **microgravity**. Recall from earlier studies that **gravity** is the force of attraction between masses. On Earth, gravity gives us our feeling of weight. Microgravity is the condition in which the gravitational forces that act on mass are greatly reduced. For example, a person would weigh only one-third on Mars of what he or she would weigh on Earth. That's because on Mars the force of gravity is weaker (only one-third) than on Earth. In space, that person is almost completely weightless, as are the spacecraft and all of its contents.

In conditions of weightlessness, the body undergoes many changes. Bones have much less pressure on them than normal and so they expand. The heart does not have to pump as hard to circulate blood. Muscles used for walking and lifting do not get used as much, and therefore weaken. Even a person's visual depth perception is affected. These and other concerns will be extensively studied on the International Space Station in preparation for interplanetary travel.

Figure 2.16 There are several problems for the human body when it has been in space for long periods of time. Bones lose their calcium and become more brittle. Muscle mass starts shrinking. Exercising in space helps keep the muscles fit.

The Space Suit

When walking or working outdoors on Earth, we usually try to dress appropriately for the conditions, wearing a warm jacket if it is cold and rain gear if it is wet. When taking a walk in space, however, we would be faced with a more difficult environment. Once astronauts leave their spacecraft, everything they need to survive must be brought with them: air, water, a heating system, a cooling system—even a portable toilet.

In addition, the suit must be flexible enough to allow the astronaut to grasp a wrench or twist a bolt. Each space suit is custom-designed for the man or woman who will wear it, from the size of the shoes to the size of the gloves.

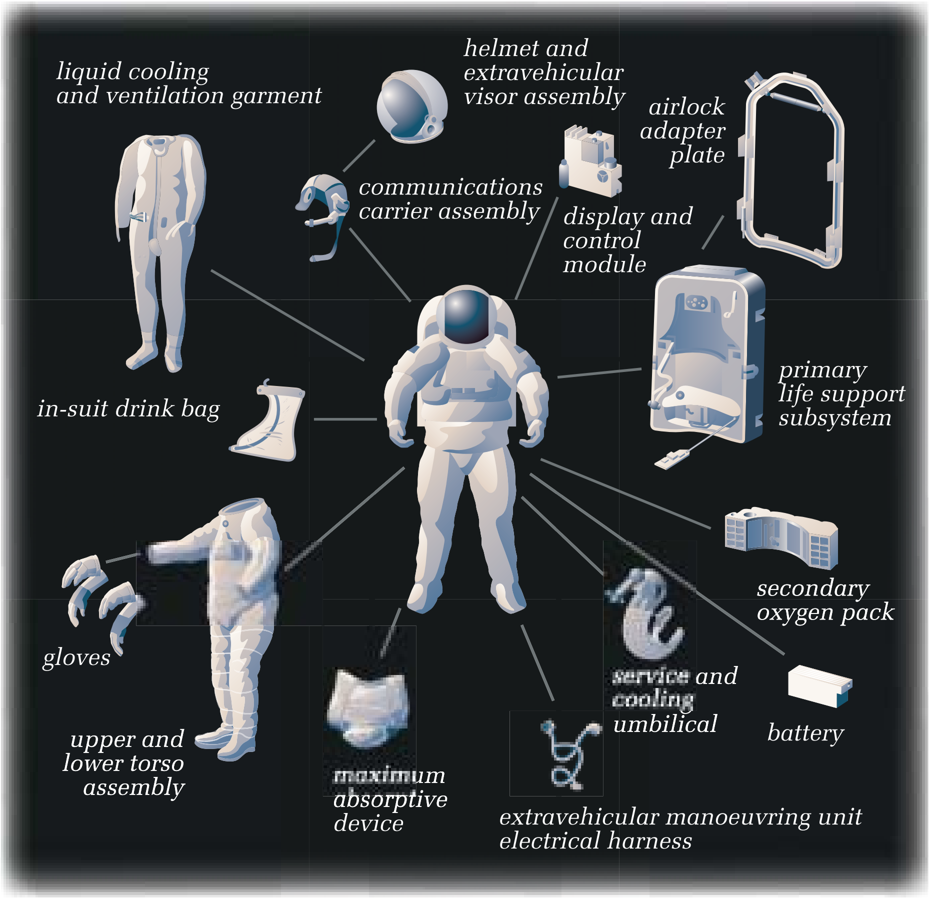


Figure 2.18 The first astronauts to walk in space were connected to their spacecraft with a hose that supplied oxygen and a means of communication. Modern astronauts use a suit that is completely self-contained, enabling them to work outside their crafts for up to 9 h at a time.

Figure 2.17 A space suit is a mini-Earth system that allows the wearer to work freely outside the spacecraft. The *Apollo* suits cost about $400 000 (U.S.) each. Today's space suits cost about $20 000 (U.S.).

A Home in Space

Outside Earth's atmosphere, none of the life-support systems that humans must have for survival exist. If people are planning to move out to space colonies in the coming years, their space station homes will have to come with several important features. First, clean water, breathable air, and comfortable temperatures and air pressure must be provided. As well, the station must carry its own source of power to provide the energy necessary to run the life-support systems and other equipment at all times.

Recycling Water

The International Space Station will be using devices that can recycle almost 100% of the water in the station. This includes waste water, water used for hygiene, and moisture in the air. Careful recycling of water on the space station will keep a crew of seven comfortable for several months.

reSEARCH

Technology for Life

Choose one of the technologies necessary for providing life support to humans during space travel and research the history of its development. Begin your search at www.pearsoned.ca/scienceinaction.

Recycling is also essential in the day-to-day life in a space station. Because there is so little room for storage, as much of the materials carried as possible must be recyclable or reuseable. Consider, for example, the challenge of how best to use the limited supply of water carried in a spacecraft. Researchers have developed the technology to filter, purify, and recycle the same water again and again on long space flights. This technology is now also being used on Earth to provide environmentally safe sewage treatment for houses.

On the International Space Station, the Environmental Control and Life Support Systems are designed to ensure life support. The functions of the life-support system include:

- recycling wastewater (including urine) to produce drinking water;
- using recycled water to produce oxygen;
- removing carbon dioxide from the air;
- filtering micro-organisms and dust from the air; and
- keeping the air pressure, temperature, and humidity (air moisture) stable.

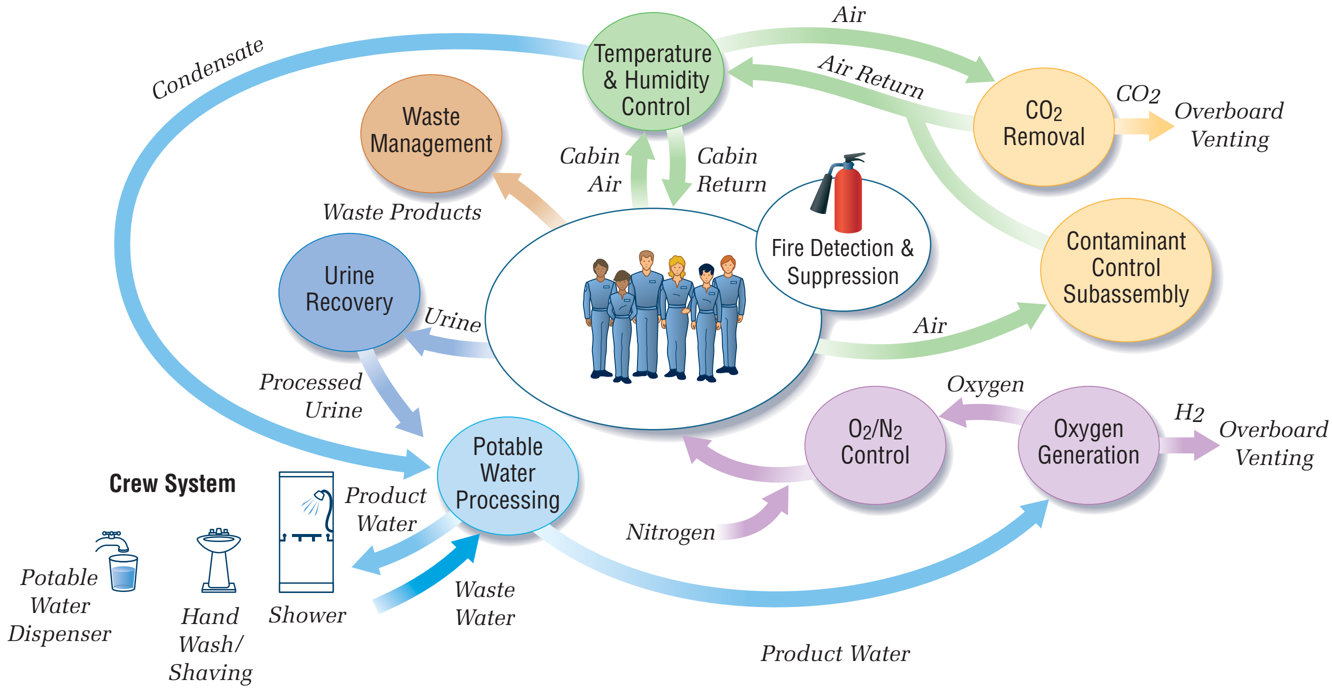


Figure 2.19 The water recycling system aboard the International Space Station

Producing Oxygen

Scientists have also come up with a simple but effective way of producing oxygen in space. As you may recall from past studies, the process of electrolysis uses electricity to split water molecules into their component elements: hydrogen and oxygen. Applied in a spacecraft, this process can supply most of the oxygen a crew needs. The hydrogen is vented into space.

Activity E-4

Experiment **on your own**

Designing and Building a Water Filter

Before You Start

There are many challenges to living in space. One is how to maintain a good supply of useable water for drinking, washing, and other activities. As humans plan ever-longer space voyages, the need for safe recycling of the precious water carried on a spacecraft or space station becomes of the utmost importance.

In this activity, you will investigate how well different materials filter water. You may wish to use Toolbox 2: The Inquiry Process of Science to help you plan your experiment.

The Question

How effective are various materials for filtering water and improving its clarity?

Design and Conduct Your Experiment

1 Write a hypothesis about which common substances (such as pea gravel, sand, cotton balls, and charcoal chips) would make suitable materials for a water filter.

2 Decide which materials and equipment you will need to test your hypothesis. For example:
   a) What types of filtering materials will you use?
   b) What will you use as the main part of the filter to contain the filtering materials?
   c) What type of material are you attempting to filter out of the water?

3 Plan your procedure. For example:
   a) What evidence would you get from your experiment that would prove your hypothesis? How will you know your filter worked?
   b) What are the manipulated, responding, and control variables?
   c) What steps will you take to produce the data you need?
   d) How will you collect and organize the materials and observation data you collect for each trial?
   e) How will you assess the effectiveness of the different filtrates?

Figure 2.20 Planning your procedure

4 Write up your procedure and include a design. You may wish to use Toolbox 8: Diagrams to Help with the Design. Ask your teacher to approve the procedure before you begin.

5 Conduct your experiment.

6 Compare your results with your hypothesis. How accurate was your hypothesis? If your findings did not support your hypothesis, suggest reasons why.

7 Share and compare your procedure, set-up, and results with those of your classmates. How do the results compare? Is there anything you could do to improve on the design of your experiment?

8 What type of controls did you use to ensure that your data was valid?

Caution!
Do not drink or taste any of the water samples.

Activity E-5

Problem Solving

Space Station Design: The Value of Teamwork

Recognize a Need

To design an orbiting space station requires millions of dollars. To transport the materials into space and construct such a station requires billions of dollars. No country can afford to build a space station on its own. A better idea is a cooperative team effort, one that uses a great variety of expertise and shares the costs.

The Problem

You and two or three other classmates represent a country that has been assigned the task of designing a module for the new *Pangea* space station. First, you will work with all the other teams (as a class) to design a space station for a crew of 20 men and women. Then, your team will design and build a model of one of the modules of *Pangea*.

Criteria for Success

To be successful, the final assembled space station must (1) show close fit and (2) match the original plan agreed to by all teams.

Brainstorm Ideas

1 As a class, brainstorm ideas for how many and what type of modules the new space station needs. Agree on an overall plan and make a general sketch of it.

2 Organize into small groups, each representing the design team for a country. (The number of groups depends on the number of modules chosen in Step 1.) Your teacher will randomly assign a module to each group. With your team, brainstorm ideas for your module, keeping in mind the criteria for success.

Build a Prototype

3 Using your choice of box, cardboard, and small household items, construct your scale model. Label the parts clearly.

Test and Evaluate

4 Present your module on the due date set by your teacher. This should be the first time that teams see the other models.

5 Connect the modules on a large table or on the floor, using the original sketch for the space station as a guide.

6 Evaluate the results. How well does the final space station match the original plan? Are the modules to the same scale? Do they fit together well?

Communicate

7 As a class, discuss problems that arose during module construction. In a brief written summary, make recommendations about how the design and construction process for the space station model could be improved.

8 Think about how cooperating countries must overcome problems in building a space station together. Brainstorm a list of ways that communication is achieved.

Materials & Equipment

- box (shoe box or similar)
- pieces of cardboard
- a variety of small household items (film canisters, match boxes, wire, toothpicks, etc.)
- scissors
- tape
- glue

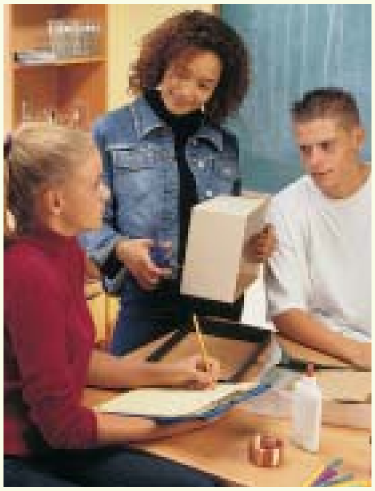


Figure 2.21 Step 2

Check and Reflect

Key Concept Review

1. Briefly describe how working on the International Space Station might affect a person psychologically.
2. How does living in a microgravity environment for a long period of time affect the human body?
3. Why must a space suit be flexible?
4. How many people are there in a typical crew on the International Space Station?

Connect Your Understanding

5. Name four necessities of an astronaut, in order to work outside a spacecraft.
6. Explain why a regular ballpoint pen will not work in space.
7. What problems do astronauts encounter when trying to eat and swallow their food?

Extend Your Understanding

8. The following table shows the problems that the human body encounters when it is in space for a long time. Copy the table into your notebook and write a recommended solution to each problem. This may require some out of class research.

Problems of Living in Space	Recommendations
1. Loss of body mass	
2. Decrease in the production of red blood cells	
3. Loss of bone mass and density	
4. Loss of calcium, electrolytes, and plasma with excretion of body fluids	
5. Loneliness, isolation, depression	

9. Imagine you were going to spend 3 months in the International Space Station. Make a list of all the items you would like to bring for recreation during that period. Remember the storage and mass limitations.
10. Adjust your list in question 9 so that the total mass of the items equals 1 kg (your allowed limit). Explain which item is the most important item to you and why.

Careers and Profiles

ASTRONAUT

Few people have ever looked out a window and had a view of the entire country of Canada, from coast to coast to coast. One of those who has, however, is Dr. Roberta Bondar. In January 1992, Dr. Bondar became Canada's first female astronaut when she was assigned to be a payload specialist on NASA's shuttle flight STS-42. Dr. Bondar grew up in Sault Ste. Marie, Ontario. From the time she was eight years old, she was fascinated with building model rockets, space stations, and satellites, and inspired by the idea of exploring space. As she grew up, her interest in space research increased. Pursuing her dream of a career in the area meant choosing a field of study that she thought would be valuable in space research. She turned to medicine, specializing in neurology, the study of the nervous system.

Also important in helping her succeed in her chosen career have been Dr. Bondar's many non-academic interests. She has a pilot's license and is an accomplished photographer. She also enjoys exploring the outdoors. Anyone thinking of pursuing a career in space research and exploration, she says, should develop a wide variety of interests related to his or her goals.

Dr. Bondar identifies three main characteristics of a good astronaut. First is self-discipline. The second is the ability to be team player. Third is the ability to work alone. Good astronauts must have confidence in their own abilities and be able to contribute to the entire team.

What does Dr. Bondar see for the future of Canadians in the space exploration field? For one, she predicts more technological breakthroughs such as RADARSAT, which will provide us with increasing information about how our world is changing. She also points to expected advancements in communications and global positioning hardware. Canadian astronomers, she adds, continue to be at the forefront of new discoveries. While astronauts tend to get a great deal of media attention, Dr. Bondar emphasizes that it is the technical staff, researchers, development engineers, and astronomers who are "pushing the envelope" in space discoveries.

Figure 2.22 Dr. Roberta Bondar

Dr. Bondar offers the following advice for students interested in becoming involved in the space field. Keep your focus, develop a wide range of interests, and never lose your sense of wonder and curiosity. Start by being explorers of your own planet. Learn as much as possible about the great diversity Earth has to offer. In this way, even if you never go into space yourself, you will start to see and appreciate our planet in a new light.

1. Why should a person who is interested in becoming an astronaut have a wide variety of interests related to that goal?
2. Why do you think it is important for astronauts to be good team players, as well as being able to work on their own?
3. What do you think would be the most interesting part of being an astronaut?

2.3 Using Space Technology to Meet Human Needs on Earth

Although we may not realize it, our daily lives are full of products and systems that were first developed for exploring space. From instant powdered juice drinks and top-of-the-line sports equipment, to satellites that allow us to talk to friends who live far away, we rely on "space age" technology in many ways.

SATELLITES

Satellites—sometimes referred to as "artificial satellites"—are objects that are built and sent into Earth's orbit by humans. (A "natural" satellite refers to any small body that orbits a larger body, such as a moon orbiting a planet.) Looking like small spherical containers or snap-together toy structures, these relatively small objects are loaded with electronic equipment, digital imaging apparatus, and other instrumentation. They transmit the information they receive to ground stations by radio waves, a topic you will learn more about in Section 3.0.

Satellites play a major role in our lives, performing a variety of functions from space. They can help us communicate, observe and forecast weather, predict magnetic storms, and even find our location on the planet. We send satellites into space to allow us to watch television and make long-distance phone calls. Some newer cars even come equipped with satellite tracking devices. Computers in these cars receive satellite signals. This information is then relayed to the driver as directions to the nearest gas station or a particular address.

infoBIT

High Spy
Some military and national defense satellites conduct surveillance from hundreds of kilometres above Earth. The cameras on these satellites are so sensitive that they can see you play tennis, and even tell what brand of tennis ball you are using!

Figure 2.23 Satellite technology can help drivers in unfamiliar cities find their way around.

Putting satellites into orbit outside Earth's atmosphere was an important step in the history of space exploration. Their use continues to lead to advances in both our scientific understanding of space and the development of further space-related technology.

QUICKLAB

Data Relay from Space to Earth

Most data received from research satellites are relayed to stations on Earth through a network of satellites and ground-based receivers. The information, received as signals, must be decoded and then transmitted to the user through communication networks. In this activity, an imaginary NASA satellite named SNIFF (SuperNova Infrared Fact Finder) collects data about a supernova and transmits the data—through a series of relay points—to a scientist working at the University of Alberta.

Purpose

To simulate how data are transmitted from space to someone on Earth, and to show some problems that must be overcome to make such transmissions successful

Procedure

1. Your teacher will assign roles to eight students, as listed on the right.
2. In a large space, the eight students should arrange themselves according to the pattern shown in the diagram. The rest of the class will be observers.
3. Students in roles 4, 6, 7, and 8 stand in a small circle, facing out. They represent the four relay positions on Earth. In unison, they will revolve counterclockwise very slowly to represent the spinning Earth.
4. Students in roles 3 and 5 are satellites in geosynchronous orbit, which means they must move in time with Earth's rotation.
5. The SNIFF satellite (role 2) lies at low altitude and orbits Earth about 15 times a day. The student in this role should walk at a quick pace around Earth, about 2 m away. The student should complete several orbits for every one rotation of Earth. The supernova (role 1) should be a fair distance away and not moving.
6. The ball represents the data (in this case, light) being picked up from the star by SNIFF. When students are in position and moving, data transmission can start. The supernova tosses the ball to SNIFF. SNIFF sends the ball to the DRS. The DRS sends the ball to ground station #1. Ground station #1 sends the ball to the communication satellite, who then sends it to ground station #2 in Calgary. Ground station #2 hands the ball to the University of Alberta in Edmonton (simulating a land-line telephone/Internet connection). Finally, the University hands the ball to the scientist (simulating a computer network connection).
7. Repeat the relay two or three times. Observe what happens.

Questions

8 What conditions are necessary for SNIFF to be able to communicate with the relay satellite?

9 What would make this type of satellite communication easier and more dependable?

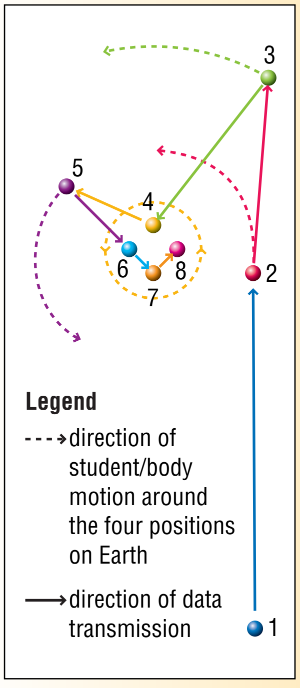
10 With reference to the simulation, describe what problems must be overcome in transmitting data from space to a specific location on Earth.

Materials & Equipment

- a small rubber ball (about 15 cm diameter)

Student Roles

1. a supernova
2. the SNIFF satellite
3. the Data Relay satellite (DRS)
4. ground station #1
5. a communication satellite
6. ground station #2
7. the University of Alberta
8. a scientist



(Adapted from EUVE Dataflow Demo, UC Berkeley and NASA)

Communication Satellites

In the early part of the 20th century, telegraph and telephone communication across the North American continent travelled through wires. Cable connections needed to be physically in place in order for one person to talk with another. This was a difficult and expensive process even on land. Setting up telephone communication with someone across an ocean was a much greater challenge that required the laying of submarine cables. Communication satellites have eliminated the need for costly cable laying.

Today, satellites use digital systems that result in clearer transmissions and allow for a great number of users at any one time. Every nation in the world now employs "wireless" technologies for a wide range of communications.

Figure 2.24 Launched in 1972, Telesat Canada's *Anik 1* provided Canada with communication across the entire continent. Canada was also the first country in the world to use satellites to transmit television broadcasts.

Satellites for Observation and Research

Satellites are invaluable tools for monitoring and forecasting weather. Weather satellites are designed to stay in one position above Earth. This is called a *geosynchronous orbit*, which means that the satellite moves at the same rate as Earth spins. In this way the satellite can observe the same area at all times. The result is 24-hour-a-day monitoring of weather conditions.

Observation satellites can do more than just take photographs and monitor weather. Two Canadian satellites, LANDSAT and RADARSAT, have been used to follow ships at sea, monitor soil quality, track forest fires, report on environmental change, and search for natural resources. RADARSAT sees more than 1 000 000 km^2 of Earth in each of its orbits. These satellites are not in geosynchronous orbit.

Figure 2.25 A weather satellite being launched into orbit from the space shuttle

Remote Sensing

The main purpose of satellites in low Earth orbit (at 200 to 1000 km altitude) is to carry out remote sensing. Remote sensing is a process in which imaging devices in a satellite make observations of Earth's surface and send this information back to Earth. Images can be photographs taken by cameras or data collected from the sensing of heat and other invisible energy waves. Remote sensing can provide information on the condition of the environment on Earth, natural resources, and effects of urbanization. This information is used for planning.

Figure 2.26 Satellite picture of weather over southern Manitoba

Satellites as Personal Tracking Devices

Imagine always knowing your position on the planet, accurate to within a few metres. The Global Positioning System (GPS) lets you do just that. This technology was designed to give people, wherever they are, their location on the ground at any time. Twenty-four GPS satellites are in orbit around Earth, which means that at least three are above any given location in the world at any given moment. Radio signals from the satellites are picked up by a hand-held receiver (which is about the size of a small hand-held video game). The signals are translated by a computer in the receiver, which then shows on a digital display the operator's position in relation to the satellites.

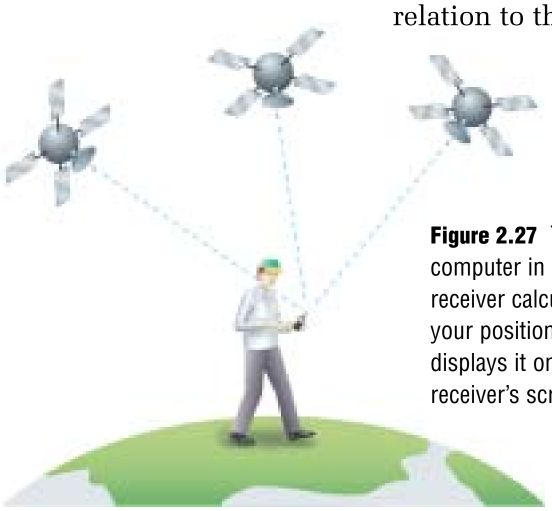


Figure 2.27 The computer in a GPS receiver calculates your position and displays it on the receiver's screen.

Figure 2.28 With 24 satellites in orbit, there are at least three above the horizon, relative to a person's location on Earth, at any one time.

SKILL PRACTICE

On Location with GPS

This activity illustrates in a two-dimensional way how the Global Positioning System uses satellite signals to determine the position of someone holding a GPS receiver. You will need a pencil and a geometry compass.

1. Your teacher will give you an enlarged copy of the map shown here . Imagine that you are standing in a location somewhere on this map when you turn on your GPS receiver.
2. Satellite 1 transmits a radio signal to the receiver in your hand and the GPS device calculates that you are 1000 km from the satellite. Using the compass, measure 1000 km on the scale provided.
3. Next, place the compass point on the position labelled Satellite 1 and draw a circle that has a radius equal to the distance from the satellite.
4. Repeat steps 2 and 3 for Satellites 2 and 3, using the information in the table.
5. The spot where all three circles meet on the map indicates your position on the ground.
6. Suggest how satellites know where their position is in relation to Earth.

Satellite	Distance to GPS Receiver
1	1000 km
2	300 km
3	940 km

"Space Age" Inspired Materials and Systems

Many items, materials, and systems originally designed for a space application have been put to practical use on Earth. Innovations to help us study our universe, travel out into it, or exist in the space environment can be found today in just about every aspect of our lives. The table below lists some of the spin-off applications of space technology.

Figure 2.29 Not all of the technology created for exploring or living in space is used only in space. The fire-resistant suits and compact breathing apparatus used today by firefighters are spin-offs from innovations developed for NASA astronauts.

Field	Space Use	Earth Use
Computer technology	• Structural analysis of spacecraft • Monitoring of air quality aboard spacecraft • Simulation of space environment for training	• Use of microelectronics in appliances and office equipment • Structural analysis of buildings, bridges, etc. • Analysis of smokestack emissions • Development of virtual reality software
Consumer technology	• Design of space food for astronauts on long flights • Study of aerodynamics and insulation	• Manufacture of enriched baby and freeze-dried foods • Design and manufacture of improved bike helmets, golf balls, running shoes, and ski goggles
Medical and health technology	• Design of electronics for the Hubble Space Telescope • Development of slow-release medication to control motion sickness • Design of microcircuitry for electronics • Development of communications and robotic systems	• Development of digital imaging for the detection and treatment of breast cancer • Manufacture of motion sickness medications • Development of a human tissue stimulator to control chronic pain • Development of voice-controlled wheelchairs
Industrial technology	• Development of microlasers for communication	• Application of microlasers for communication, and to cut and melt materials
Transportation technology	• Development of parachute material for the Viking space mission	• Improvement of traction on car winter tires
Public safety technology	• Development of computer robotics	• Design of emergency response robots for use in situations too dangerous for humans (e.g., to inspect explosive devices)

CHECK AND REFLECT

Key Concept Review

1. List three uses for satellites.
2. What does the abbreviation GPS stand for?
3. Name the satellite that Canada first launched to provide communications across the country. In what year was it launched?
4. What is remote sensing?
5. Some materials are referred to as "spin-offs" from space technology. What does that mean?

Connect Your Understanding

6. With GPS technology, why do you require at least three satellites to determine your position?
7. Do you agree or disagree with the statement "There is no location on Earth where GPS does not work"? Explain your answer.

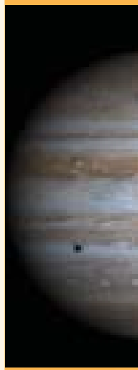
Extend Your Understanding

8. Study Figure 2.30, which shows a number of common spin-off objects whose origins lie in space technology. List six of the objects and the technology behind their development.

   Example: Airplane – satellite navigation and communication

Figure 2.30 Question 8

9. Consider a colony under the ocean where divers in deep-sea suits work on the ocean floor. Do you think that a GPS-like system for determining precise locations might work in this situation? Give reasons for your opinion.



Assess Your Learning

Key Concept Review

1. What is the only planet in our solar system that has not been visited by a space probe? Why is that?
2. List the three main types of spacecraft currently being used.
3. In a rocket, what does "payload" usually refer to?
4. What limits how long an astronaut can stay out in space in his or her space suit?

Connect Your Understanding

5. Why were animals used in the first test flights of vehicles launched to orbit Earth?
6. Place the events listed below in the order in which they occurred:
   a) first rocket into space
   b) rockets used in World War II
   c) Chinese use rockets to launch arrows
   d) rockets send mobile probe to Mars as part of *Pathfinder* mission
   e) rockets send humans to Moon and back
   f) first satellite launched
7. Explain why a space suit must have both a heating unit and a cooling unit.

Extend Your Understanding

8. Why is it necessary to recycle almost all of the water used on a spacecraft such as the International Space Station?
9. Draw a concept map starting with the term "space exploration." Use 10 other terms that you have learned in this unit to complete your map.

Focus On SCIENCE AND TECHNOLOGY

If humans are to travel great distances in space, problems must be solved and technologies developed through the collaboration of many countries. The International Space Station has only been made possible through the co-operation and technological expertise of countries from around the globe. Working with a partner or your class, consider the following questions:

1. Why is it essential that certain scientific principles be understood before a technological solution to a problem is developed?
2. Is it worthwhile for members of the scientific community to share information from their research? Explain your answer. Suggest an instance when not sharing scientific knowledge might be a good decision.
3. Can scientific knowledge and technology develop and advance without the sharing of knowledge?

3.0

Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

Key Concepts

In this section, you will learn about the following key concepts:

- technologies for space exploration and observation
- composition and characteristics of bodies in space
- communication technologies
- triangulation and parallax

Learning Outcomes

When you have completed this section, you will be able to:

- explain, in general terms, the operation of optical telescopes, including telescopes that are positioned in space environments
- explain the role of radio and optical telescopes in determining characteristics of stars and star systems
- describe and interpret, in general terms, the technologies used in global positioning systems and in remote sensing

About 170 000 years ago, a star in its last great gesture before dying exploded in a display a million times brighter than the Sun. The light generated did not reach Earth until 1987, where it was discovered by Canadian astronomer Ian Shelton, who was working in an observatory in Chile.

Just as the vast and seemingly limitless oceans beckoned the early maritime explorers, today the far reaches of the universe beckon modern adventurers. Although the mysteries of space have captivated human curiosity for thousands of years, it has been only in the past few decades that we have had the technology to give us access to places not on our home planet. Until it is physically possible for humans to travel to the "shores" of distant planets and galaxies, our technologies must be our eyes into the universe.

In this section, you will learn about the tools and technologies that are helping us solve the many puzzles of space. From Earth-based telescopes and Earth-orbit satellites, to sophisticated space probes that can cross vast distances and send images back to Earth, technology is letting us reach farther and farther out into space. The more we see, the more we learn.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Using Technology to See the Visible

Look up at a clear, cloudless night sky and with your unaided eyes you can see a few thousand stars. With binoculars, you would see thousands more. Use a telescope and millions of stars will be revealed. Use one of the most powerful telescopes available and billions of stars come into view. Telescopes allow us to see fainter and more distant objects in detail that cannot be detected by the unaided eye.

A number of different types of telescopes are described in this section. Each provides us with a variety of information about the objects that make up our universe.

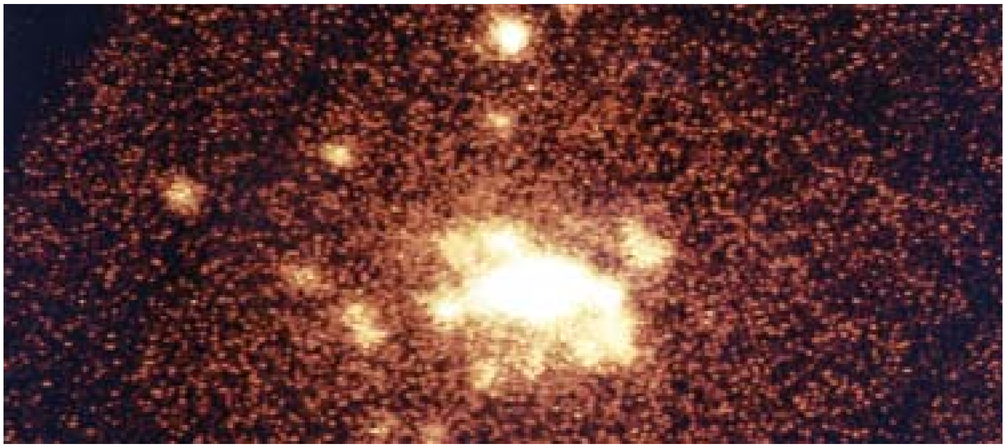


Figure 3.1 A highly magnified image of the Andromeda galaxy

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Magnificent Magnification

The first telescopes Galileo used had magnifications of only two or three. However, by making improvements to his lens-grinding and -polishing techniques, he was able to create lenses with longer focal lengths and so improve his telescopes' magnifications to 20 and 30 times.

SKILL PRACTICE

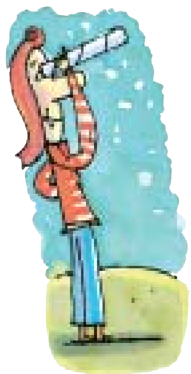
Sharpen Your Star-Gazing Skills

Pick a clear night on which to carry out this activity. All you will need is the cardboard tube from a roll of paper towel, a flashlight, a notepad, and a pencil. Here is a simple test of your observational skills.

Find a dark area away from house lights and street lights. (Make sure an adult knows where you are.) Wait a few minutes to let your eyes get used to the dark. Then focus your unaided eyes on a small portion of sky for about 1 min. Turn on the flashlight and write down your observations on the notepad.

When you are finished, turn off the flashlight and again let your eyes adjust to the dark. (If you put a red cellophane covering on the flashlight lens, your eyes will adjust more quickly.) Using the cardboard tube as a telescope, view the same patch of sky as you did before. What do you notice when you view the same area of sky using the cardboard tube?

Describe how the cardboard tube affected your observation, and explain why you think that happens.



Optical Telescopes

Optical telescopes have been in use for the past 400 years. In 1608, a Dutch optician named Hans Lippershey made one of the first telescopes, but it is Galileo who has been credited with first using the telescope to study the visible features of the night sky.

Think of optical telescopes as "light collectors." That is what their series of lenses and mirrors do: gather and focus the light from stars so that we can see it. The larger the area of the lenses or mirrors in a telescope, the greater the ability of the telescope to see the faint light of objects that are very distant.

The first telescope ever designed was a simple **refracting telescope**. Refracting telescopes use two lenses to gather and focus starlight (see Figure 3.3). There is a limit to how large a refracting telescope can be. Any diameter over 1 m causes the glass in the lens to warp under its own weight. Trying to see through a lens when that happens would be like trying to make out details of the Moon by looking through the bottom of a pop bottle.

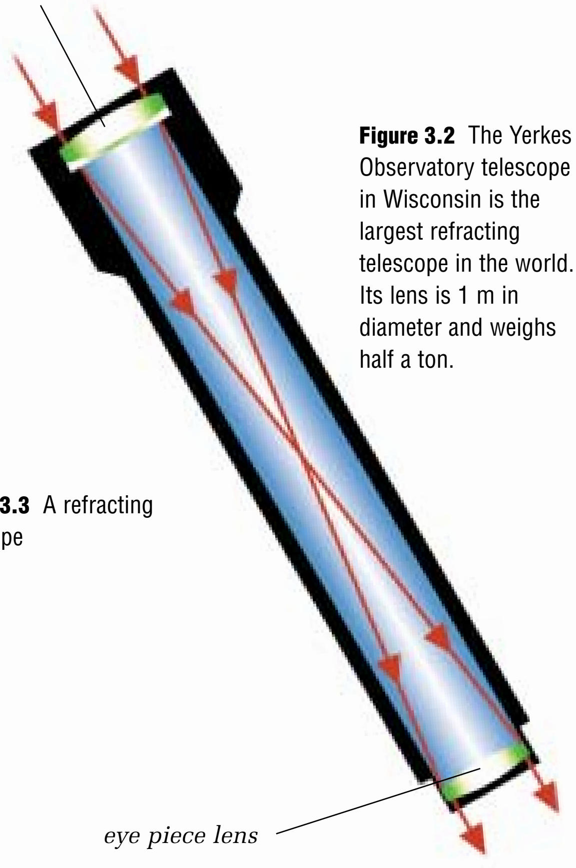


Figure 3.3 A refracting telescope

Figure 3.2 The Yerkes Observatory telescope in Wisconsin is the largest refracting telescope in the world. Its lens is 1 m in diameter and weighs half a ton.

Reflecting telescopes use mirrors instead of lenses to gather and focus the light from stars. At one end of a reflecting telescope is a large concave mirror, which is made from glass-like material that is coated with a thin layer of metal. The metal, such as aluminum, is polished to a shiny finish so that it can reflect the faintest light it receives.

Currently, telescope builders use a method called "spin casting" to form the largest mirrors. This process requires that molten glass be poured into a large spinning mould. Just as a rapidly turning amusement park ride swings its occupants outward, the spinning mould forces the melted glass to the mould's outside edge. After the glass cools and solidifies, technicians grind it into the desired shape for the telescope. This process is quicker and less costly than previous methods of making mirrors. One of the largest reflecting mirrors created this way is 6 m in diameter, built by the former Soviet Union.

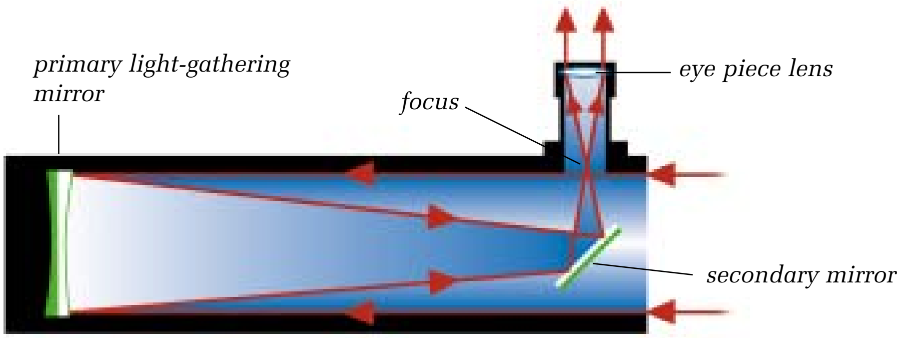


Figure 3.4 A reflecting telescope

Figure 3.5 The Canada-France-Hawaii Observatory, situated on Mauna Kea, Hawaii, operates a telescope with a 3.6-m mirror.

One of the newest innovations for ground-based optical reflecting telescopes is the use of segmented mirrors. A segmented-mirror telescope uses several lightweight segments to build one large mirror. The result is a large telescope with enormous light-gathering ability and resolving power (ability to distinguish details in an object). For example, each of the Keck I and Keck II telescopes atop Mauna Kea in Hawaii is 10 m in diameter, each made up 36 hexagonal mirrors.

Interferometry: Combining Telescopes for Greater Power

The resolution of the images seen with optical telescopes can be further improved when two or more of the telescopes are used together. This technique of using telescopes in combination is known as **interferometry**. On top of Mauna Kea, Keck I and Keck II are located 85 m apart from each other. When working together, they can detect objects in space with better clarity and at greater distances than any other current Earth-based observatories can. Another example is the Very Large Telescope of the European Southern Observatory, located high in the Andean Mountains in Chile. It is really four separate telescopes being used together. Astronomers are able to obtain much more detail in the images they collect by using interferometry than by using a single telescope.

Figure 3.6 One of the Keck Observatory's two telescopes, showing its 10-m mirror made of 36 hexagonal mirrors

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Hubble Insights

New discoveries about the universe are constantly being made with advances in technology. Search the Internet for the latest images from the Hubble Space Telescope. Explore how new information has changed our ideas about the universe. Begin your search at www.pearsoned.ca/scienceinaction.

The Hubble Space Telescope

Although remote mountains make excellent sites for building and operating telescopes away from light pollution and air pollution, astronomers are still at the mercy of the weather. Clouds, humidity (moisture in the air), and even high winds can interfere with star-gazing. The development of the **Hubble Space Telescope** offers a solution to these problems. Orbiting about 600 km above Earth, the Hubble Space Telescope (a reflecting telescope) uses a series of mirrors to focus light from extremely distant objects. Launched in 1990, the Hubble is cylinder-shaped, just over 13 m in length and 4.3 m in diameter at its widest point. It is modular in design. This allows shuttle mission astronauts to replace faulty or out-of-date instruments on the telescope without having to interrupt its other operations.

Each orbit that the Hubble makes around Earth takes about 95 min. While the telescope works 24 h a day, not all of that time is spent observing and sending data to Earth. Some time also goes to activities such as turning the telescope to focus on a new object of interest or switching data transmission modes. Commands for these tasks are sent from ground control several times a day.

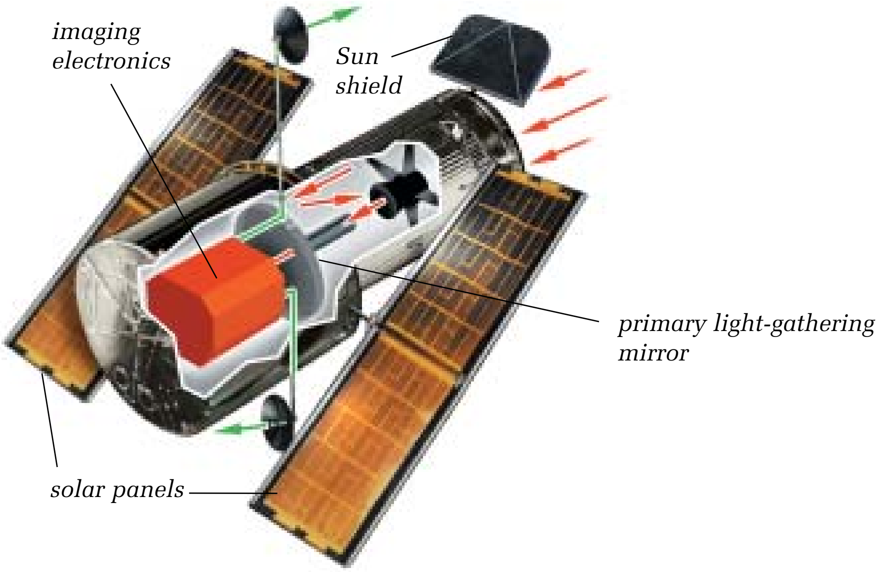

Figure 3.7 Cross-section of the Hubble Space Telescope

Figure 3.8 Earth-based telescopes are limited in their viewing ability by interference from moisture, clouds, air pollution, and light pollution.

Figure 3.9 Astronomers using the Hubble Space Telescope have discovered galaxies in parts of space where Earth-based telescopes see nothing but blackness.

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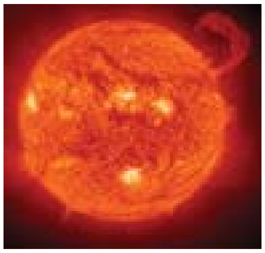
Our Eye on the Sun

The *Solar and Heliospheric Observatory* (SOHO) has been positioned about 1% of the distance from Earth to the Sun since 1996. Twelve different instruments provide details about the Sun's every action, day and night.



Check and Reflect

Key Concept Review

1. Why is there a need for telescopes?
2. What type of optical telescope uses mirrors to focus light?
3. Describe the advantage of using a segmented mirror telescope.
4. Describe the technique called interferometry.
5. The resolving power of a telescope is a measure of its:
   a) operating ability under poor weather conditions
   b) magnification
   c) ability to distinguish details in an object
   d) quality in general

Connect Your Understanding

6. Large ground-based telescopes are built with the ability to move to oppose the movement of Earth. Why is this necessary?
7. Describe two advantages of reflecting telescopes over refracting telescopes.
8. Why is the Hubble Space Telescope a reflector and not a refractor?
9. Even though it has a smaller mirror than many Earth-based telescopes, the Hubble Space Telescope can see objects more than 50 times fainter than what Earth telescopes can see. Explain why that is.

Extend Your Understanding

10. a) What happens to the detection capabilities of two reflecting telescopes working together?
    b) Would two refracting telescopes have the same capabilities? Explain your answer.
11. Imagine you had to construct an observatory on Earth for a ground-based reflecting telescope. Describe where the ideal location would be and why.

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Bee Vision

Bees and several other insects can see in the ultraviolet spectrum. Why do you think this would be an advantage for these insects?

3.2 Using Technology to See Beyond the Visible

Not all information from stars can be seen. Optical telescopes give us information based on visible light. However, objects in space, such as stars and galaxies, also emit radio waves, infrared (heat) waves, and X-rays. These are all forms of **electromagnetic energy**. This energy travels at the speed of light, 300 000 km/s, but has different wavelengths and frequencies from those of light. *Wavelength* is a measurement of the distance from one point on a wave (such as the crest) to the same point on the next wave. *Frequency* is the number of waves that pass a single point in one second.

Energy with a high frequency has a short wavelength. Gamma rays, for instance, have a high frequency (10^{20} waves per second) and a very short wavelength (less than a millionth of a centimetre). Radio waves have a low frequency, but wavelengths that can be several kilometres long.

The visible light we see all around us occupies a small section of the entire **electromagnetic spectrum**, which covers the whole range of electromagnetic energy (see Figure 3.10). Visible light has a wavelength measured in micrometeres (written as µm). One micrometre is 1 millionth of a metre.

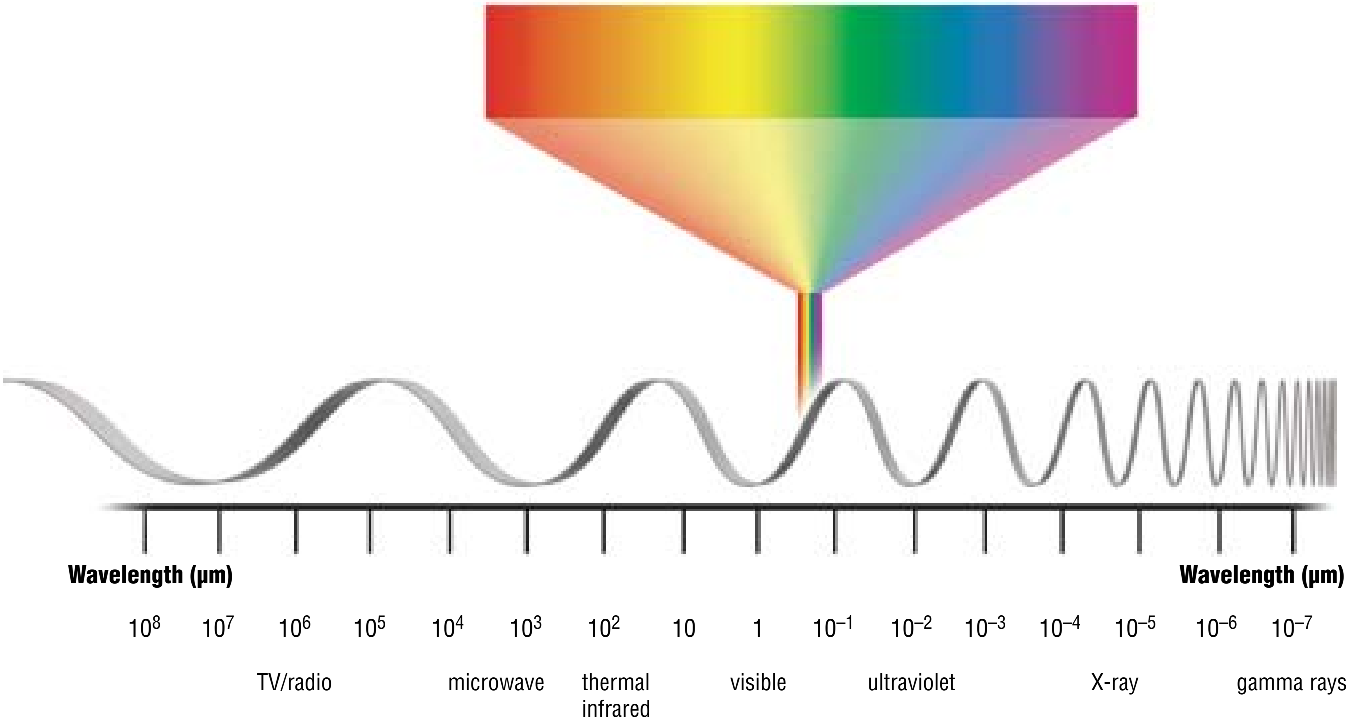

Figure 3.10 Objects in space emit a great variety of electromagnetic energy. Humans can only see the information provided in the visible spectrum, but technology enables us to detect all kinds of electromagnetic radiation.

QUICKLAB

Comparing Light Spectra

Purpose

To observe a variety of light sources and compare their spectra

Procedure

1. Your teacher will set up a number of spectroscopes and light sources in the lab or classroom.
2. In small groups, take turns observing the spectrum of each light source. Record any changes you notice between one spectrum and another in the variety of light sources you view.

Questions

3. What did you notice about the spectra for the different light sources?
4. Which light source produced the most distinct spectrum of all the sources? Why do you think that was the case?
5. Why won't your spectroscope allow you to see ultraviolet light or infrared?

Materials & Equipment

- spectroscopes
- a variety of light sources (fluorescent, incandescent, Bunsen burner, natural light, and other light sources)
- pencil and notebook

Radio Telescopes

Studying radio waves emitted by objects in space gives astronomers data that are not available from the visible spectrum. Radio waves are received from stars, galaxies, nebulae, the Sun, and even some planets—both in our own solar system and in others. These signals are mapped through the use of sophisticated electronics and computers.

With the development of **radio telescopes**, astronomers gained several advantages over optical telescopes. Radio waves are not affected by weather and can be detected during the day and at night. They are also not distorted by clouds, pollution, or the atmosphere as are light waves. Furthermore, by focussing their radio telescopes on areas of space that appear empty, astronomers have discovered much about the composition and distribution of matter in space—information that cannot be detected by optical equipment. For example, although neutral hydrogen (a large component of matter in space) emits no light, it does emit energy at a specific wavelength in the electromagnetic spectrum. Using radio telescopes, astronomers have been able to map the distribution of neutral hydrogen in the Milky Way galaxy. This is how they learned that the shape of our galaxy is a spiral.

Figure 3.11 Because the wavelengths of radio waves are so large, the antenna of a radio telescope must be large. This radio telescope in Arecibo, Puerto Rico, has a diameter of more than 300 m. That's almost the length of three football fields laid end to end.

Radio telescopes are typically made of metal mesh. Their shape resembles that of a satellite dish: they are curved inward, with a receiver at the middle. The curved portion of the dish is really a large antenna that intercepts and focusses radio waves before transmitting them to the receiver. There, the waves are transformed into an electrical signal that is fed into a computer for interpretation.

Radio Interferometry

Just as several reflecting telescopes can be combined for optical interferometry, so several small radio telescopes can be combined to achieve greater resolving power than one large radio telescope can achieve (see Figure 3.12). This technique, referred to as **interferometry**, improves the performance and accuracy of radio images. The results are radio maps with valuable detail.

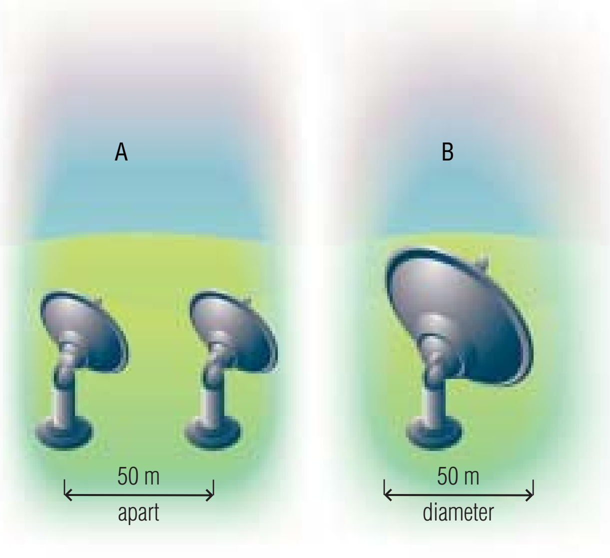

Figure 3.12 Combining information from two small radio telescopes located 50 m apart (A) simulates the resolving power of one telescope with a 50-m diameter (B). The bigger the separation between the telescopes, the more detail astronomers can measure.

The greater the distance between the radio telescopes arranged for this purpose, the more accurately they can measure position. The accuracy of measurement is increased even further if more telescopes are arranged into groups called *arrays*. The Very Large Array in Socorro, New Mexico, uses twenty-seven 25-m radio telescopes arranged in a Y pattern. The arms of the Y cover a distance of 61 km. The resolving capability of this array would be similar to that of a telescope with a diameter of 27 km!

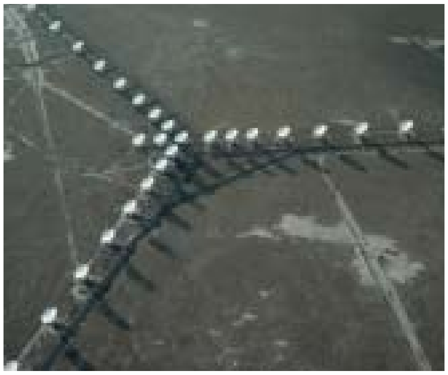

Figure 3.13 The Very Large Array simulates an antenna with a diameter of hundreds of metres.

Viewing More Than What the Eye Can See

The electromagnetic spectrum offers many more opportunities to understand the workings of space than can be obtained from looking only at the visible spectrum.

For example, much ultraviolet radiation is absorbed by the atmosphere and therefore cannot be studied very well from Earth. When observed through an optical telescope, a planet orbiting a distant star is practically invisible because of the light given off by the star. However, when viewed in the infrared spectrum through a radio telescope, the brightness of the star is reduced and the planet's brightness peaks. The Keck Observatory in Hawaii is equipped to make these observations and is actively searching for planets in other solar systems.

Astronomers have discovered a variety of radiations coming from various sources in space. These include fluctuations in microwave energy that is left over from the formation of the universe; X-rays that are being emitted from objects such as black holes and pulsating stars; and huge bursts of gamma rays that appear without warning and then fade.

Nations around the world have launched numerous satellites to study each of these phenomena.

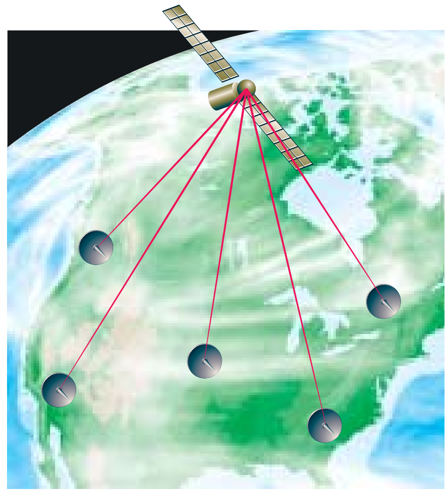

Figure 3.14 By connecting ground-based arrays with satellites in space, astronomers can simulate antennas with diameters tens of thousands of kilometres wide.

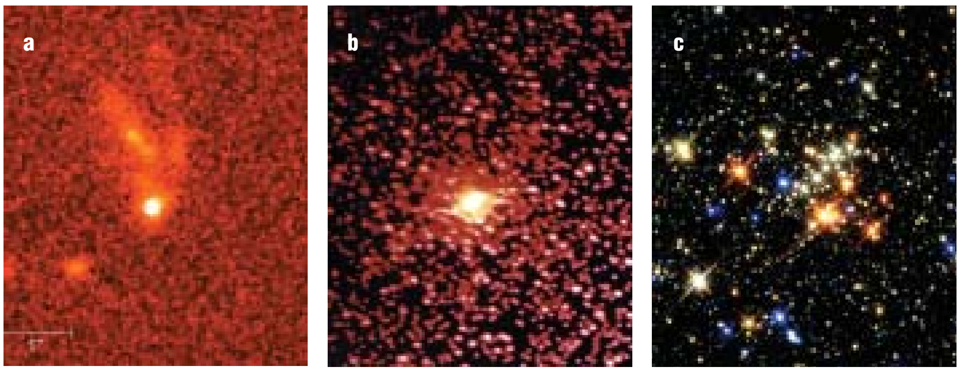

Figure 3.15 Radiation sources in space: **(a)** a gamma-ray burst, **(b)** X-rays from a black hole, and **(c)** infrared image of a young star cluster

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Gamma Ray Energy

Bursts of gamma rays occur unpredictably in different parts of space. Although they may last only a few seconds or minutes, they give off more energy than our Sun would produce in its entire 10-billion-year lifetime.

SPACE PROBES

Telescopes, optical or radio, cannot provide answers to all the questions we have about our solar system. Often it is necessary to send the observation equipment right to the object so that tests not possible to conduct by telescope can be done. In the past several decades, astronomers have done just that, sending numerous **space probes** to explore distant areas of our planetary neighbourhood. Space probes are unmanned satellites or remote-controlled "landers" that put equipment on or close to planets where it would be too difficult or dangerous to send humans to.

Space probes have been used to carry out remote sensing on Mercury and Jupiter, sample soil on Mars, land on Venus, and study the nature of Saturn's rings. For example, the *Galileo* probe, launched in 1995, was designed to gather information about the composition of Jupiter's atmosphere. The *Mars Pathfinder*, launched in 2000, took soil samples and performed geological tests on the planet's rocks. It then sent the data back to Earth for analysis. The data gathered by space probes is used to find out more about how planets form in our solar system, and how the characteristics of other planets compare with Earth's.

The table below lists some of the space probes sent in the last three decades and their missions.

Name of Space Probe	Date of Encounter	Mission
Mariner	1973–1975	Flyby of Mercury
Pioneer 11	1974–1979	Flyby of Jupiter and Saturn
Viking	1976	Mars landing
Voyagers I and *2*	1977 (launched)	Flyby of Jupiter, Saturn, Uranus, and Neptune
Venera	1982	Venus landing
Magellan	1994	Flyby of Venus
Galileo	1995	Flyby of Jupiter
Ulysses	1999	High latitude pass of Jupiter
Mars Global Explorer	2000	Orbiting of Mars
Mars Pathfinder	2000	Mars landing
Cassini	2004	Flyby of Saturn

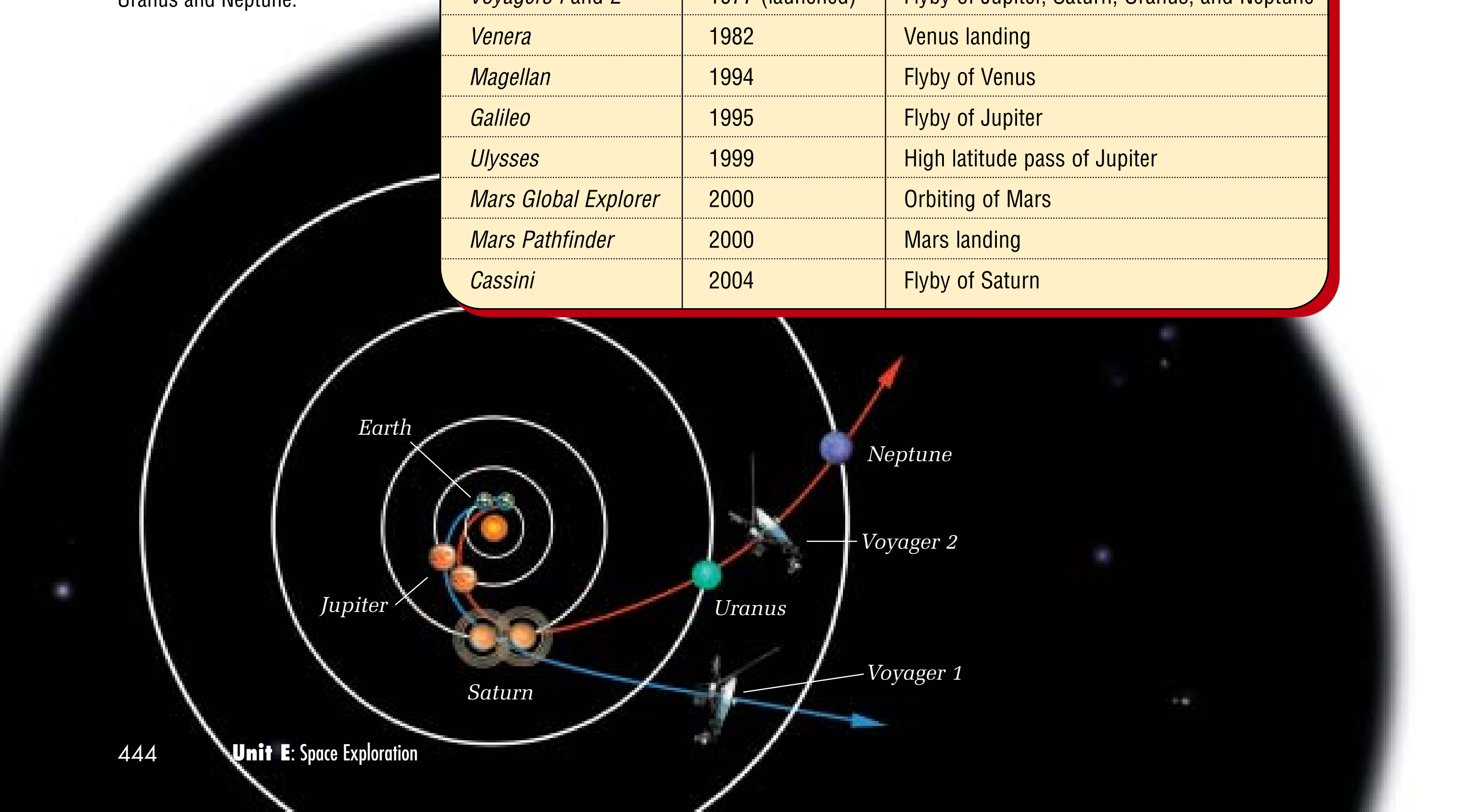

Figure 3.16 The flight paths of *Voyager 1* and *Voyager 2*. Both probes, launched from Earth in 1977, flew past Jupiter and then Saturn. At that point, *Voyager 1* was sent out of the solar system. *Voyager 2* flew on to investigate Uranus and Neptune.

Besides Earth, the only other body in the solar system that has been physically explored by humans is the Moon. That was first accomplished during the *Apollo 11* mission in 1969. Since that time, astronauts have walked across the Moon, driven a dune buggy on it, and taken a golf swing there. The lunar rocks they collected have been brought back to Earth.

The next great adventure in interplanetary exploration will be a manned flight to Mars and back. The entire journey could last up to three years and would be extremely dangerous. That is why it is essential to find out as much as possible by sending space probes and robot explorers to the planet first.

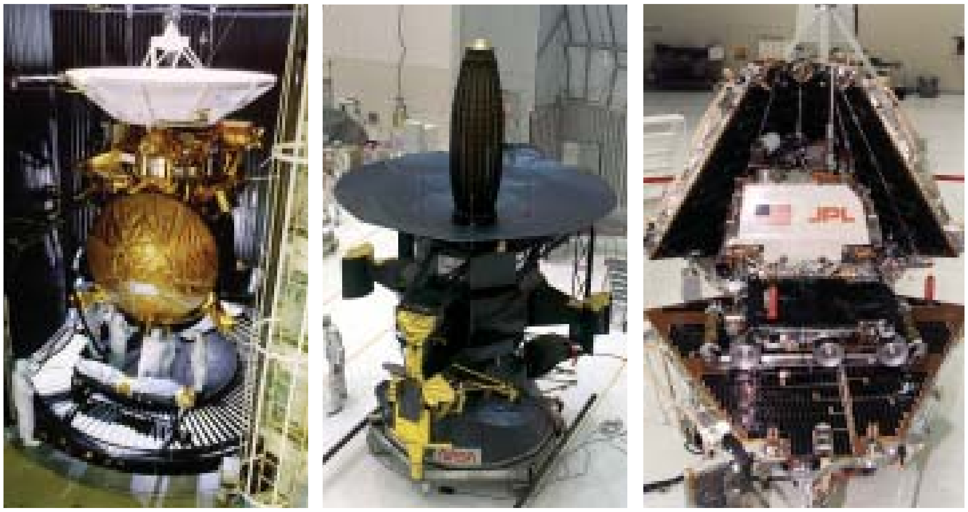

Figure 3.17 These photographs show the preparation of three different space probes. Each probe must be completely free of contamination, which is why all the workers visible in the photos are wearing specially designed hygienic suits.

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Satellite Specialties

You have been introduced to a variety of forms of electromagnetic radiation in this section. Research the names of some satellites that have been designed to observe and study a) infrared radiation; b) X-rays; and c) gamma rays. Find out about Canada's involvement in the development of these satellites. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is electromagnetic radiation?

2. Name four other forms of electromagnetic radiation besides visible light.

3. How is wave frequency related to wavelength? Support your answer with a sketch.

4. What advantages are there to using space probes rather than manned flights?

Connect Your Understanding

5. What are the sources of radio waves from space?

6. Why aren't television signals visible to us?

7. Explain two advantages of using radio telescopes instead of optical telescopes.

Extend Your Understanding

8. a) Explain how all forms of electromagnetic radiation are similar to each other.
b) Explain how each form is different from the others.

9. When combining information from multiple telescopes, the length of the distance between the telescopes is very important. Is there a limit to how far that distance can be: a) on Earth? b) in space?

3.3 Using Technology to Interpret Space

Telescopes tell us a great deal about the universe, but as you learned in section 3.2, there is much more information in addition to what we can see. Just by looking, we can't tell how far away a star is, what its composition is, or whether it is moving toward or away from us. To discover and understand these and other characteristics, we need to tackle the problem by technological means, whether by using a simple tool or machine or operating a highly complex system of instrumentation.

GIVE IT A TRY

LIGHT BULB STARS

Without the use of technology, we are limited in the amount of information we can get about stars. Still, that doesn't mean we can't get *any* information. Your teacher will put two small lamps, each with a different sized light bulb, on a desk or table at the front of the classroom. Your desk will be Earth and the light bulbs will represent stars far away. List all the things you can tell about the stars just by looking at them from Earth.

MEASURING DISTANCE

Triangulation and parallax are two ways of measuring distances indirectly, on the ground or in space.

Triangulation

Triangulation is based on the geometry of a triangle. By measuring the angles between a baseline and the target object (such as a tall tree or a water tower), you can determine the distance to that object.

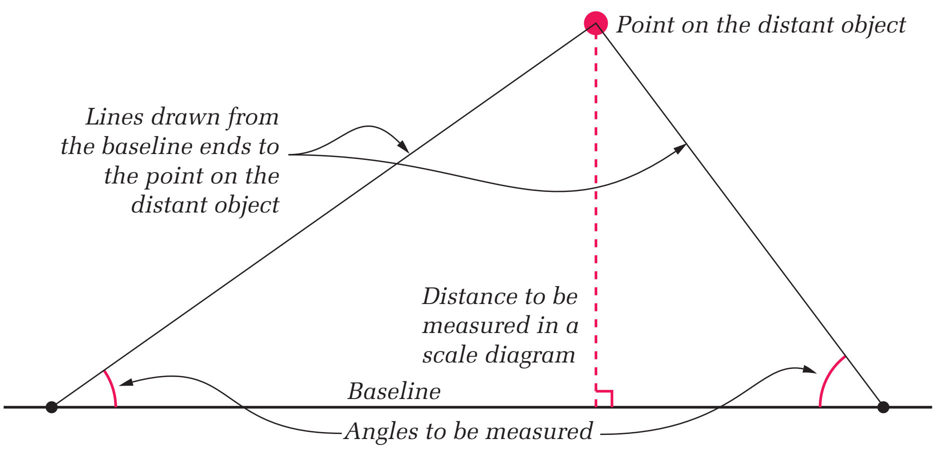
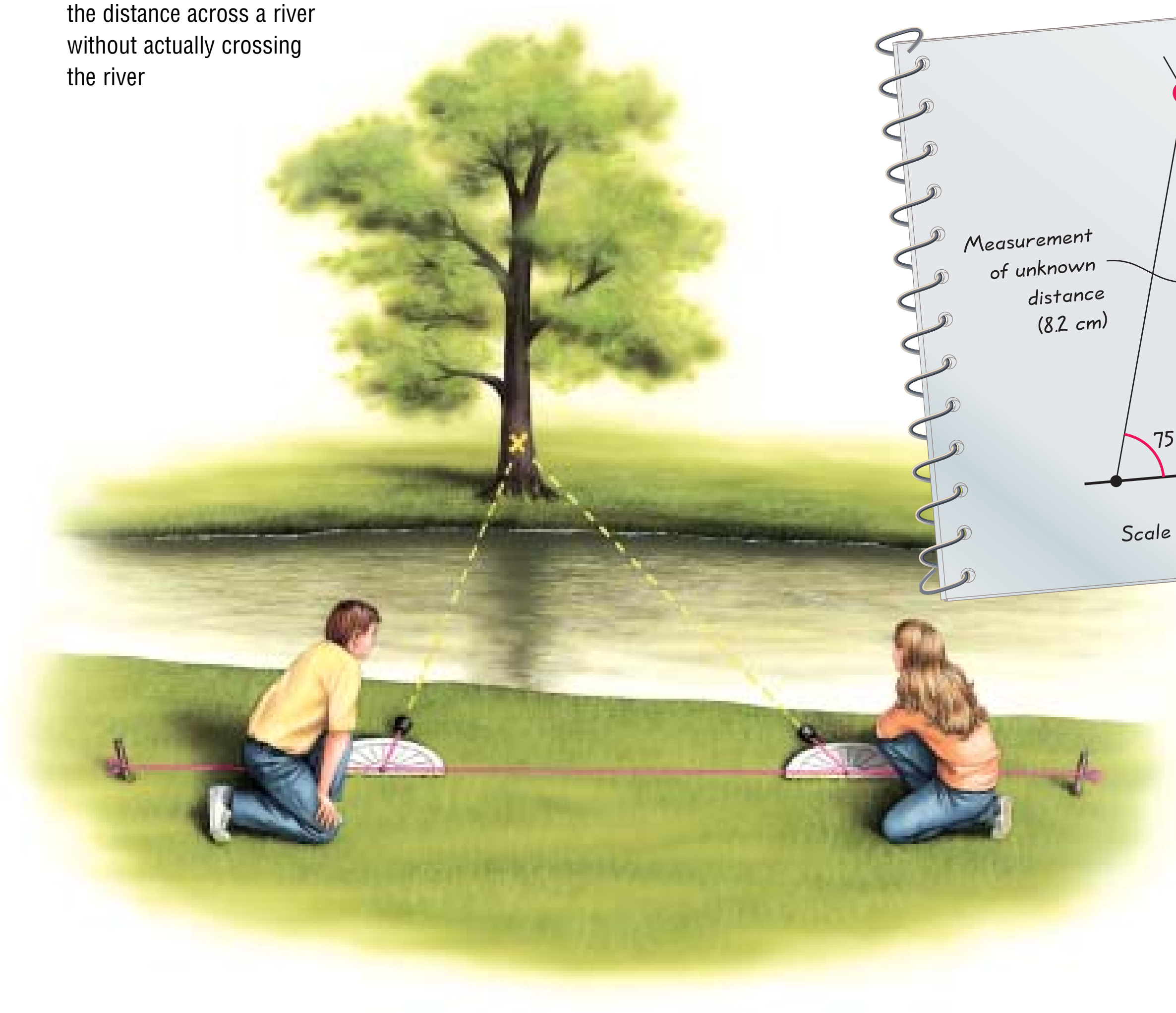


Figure 3.18 To measure a distance indirectly using triangulation, you must know the length of one side of the triangle (the baseline) and the size of the angles created when imaginary lines are drawn from the ends of the baseline to the same points on the distant object.

For instance, you could use triangulation to measure the distance across a river without actually crossing the river. The procedure is as follows:

1. On a flat area along the bank of the river, measure off an accurate baseline and mark each end of the line so that you can identify it easily.
2. Select an object to be your viewing target on the opposite bank.
3. Standing at one end of the baseline, use a protractor to determine the angle between your sight line to the object and the spot on the baseline where you are standing.
4. Stand at the other end of the baseline and again determine the angle from that spot to the object.
5. Make a scale drawing of a triangle using the length of the baseline and the two angles.
6. On your drawing, mark a perpendicular line from the baseline to the object. Measure this line and use the scale to convert it to actual length. This will give you the distance across the river.

Figure 3.19 Using triangulation to measure the distance across a river without actually crossing the river



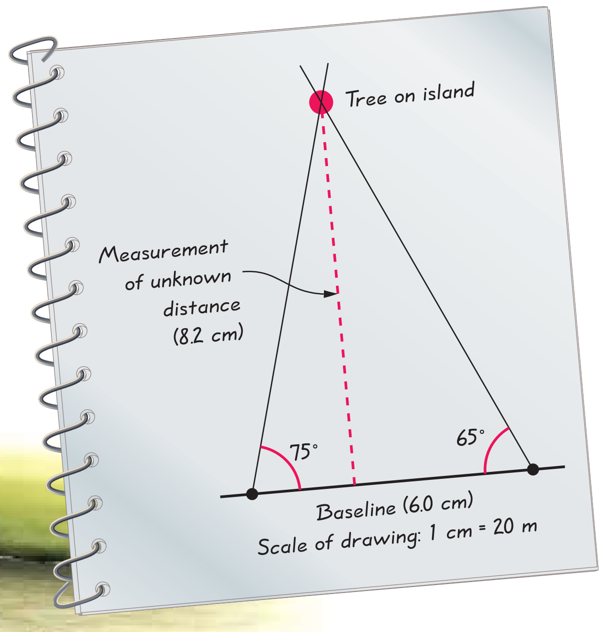


Figure 3.20 A scale drawing of the triangulation procedure

Activity E-6

Inquiry

How Far Is It?

Materials & Equipment

- measuring tape (at least 50 m long)
- two metre-sticks
- protractor
- paper
- pencil
- ruler

The Question

How accurately can the length of a playing field be measured using triangulation?

The Prediction

You will be calculating percent error for this activity. Predict the degree of accuracy that you expect. Example: *Our calculations will be off by 10%.*

Procedure

1. Copy the table below into your notebook.

Baseline length (m)	Angle from position (A) (°)	Angle from position (B) (°)	Calculated length of field (m)	Actual length of field (m)	Percent error (%)
10					
20					
50					

2. Go outside to a large flat area, ideally a soccer or football field.
3. Working in a small group, use the measuring tape to measure off a baseline of 10 m along the goal line of the field.
4. Stand a metre-stick in the ground at each end of the baseline to serve as guideposts (A) and (B).
5. Standing at one end of the baseline (A), looking directly at the right goal post at the far end of the field. Determine the straight line betweem A and the right goal post. Measure the angle between this line and the baseline. In your data table, record the angle you found. Repeat this step from the other end of the baseline (B) and again record the angle.
6. Repeat steps 3 to 5, using a baseline of 20 m and then one of 50 m.

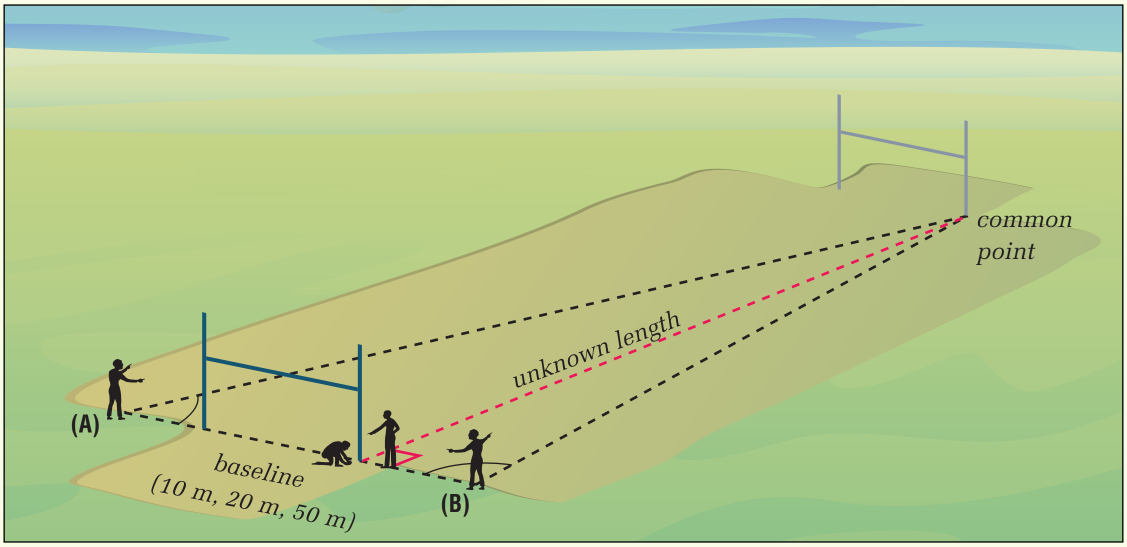


Figure 3.21 Step 5

Analyzing and Interpreting

7 For each baseline length, make a scale drawing of a triangle, using the two angles you measured each time. Use a scale of 1 cm = 5 m.

8 On each of your scale drawings, measure the length of the field and record your results in the table. Do you get the same length for all three baselines? Explain your answer.

9 Find the actual length of the field (either measure it directly, or ask the athletic director of your school). Add this information to your table.

10 Calculate the accuracy of your results for each baseline length. Use the percent error equation below. Record these figures in the table.

$$\text{percent error} = \frac{(\text{actual value} - \text{measured value})}{\text{actual value}} \times 100$$

11 Determine the average of your three lengths and calculate the percent error.

Forming Conclusions

12 How accurate was your calculated average length of the playing field?

13 Which baseline resulted in the most accurate field length? Explain why that was.

14 How close were you to your predicted error?

Applying and Connecting

For a technique like this to work, precise measurements must be made. With reference to your percent error, describe what you think may be sources of error in this activity. What are the limitations of using triangulation on the ground? How do these limitations compare with those that apply when one is using triangulation to find distances to stars?

Parallax

Parallax is the apparent shift in position of a nearby object when the object is viewed from two different places. For a quick example of parallax, hold out your arm and stick up your thumb. With your right eye closed, look at an object on the far wall behind your thumb. Now, look with your left eye closed. You will notice how the background to your thumb appears to have moved.

Astronomers use a star's parallax (that is, its apparent shift in position relative to the background stars) to determine what angles to use when they triangulate the star's distance from Earth. When triangulation calculations are made, the longer the baseline, the more accurate the results. The longest baseline we can use from Earth is the diameter of Earth's orbit. This means that measurements must be taken six months apart to achieve the maximum baseline length (see Figure 3.22).

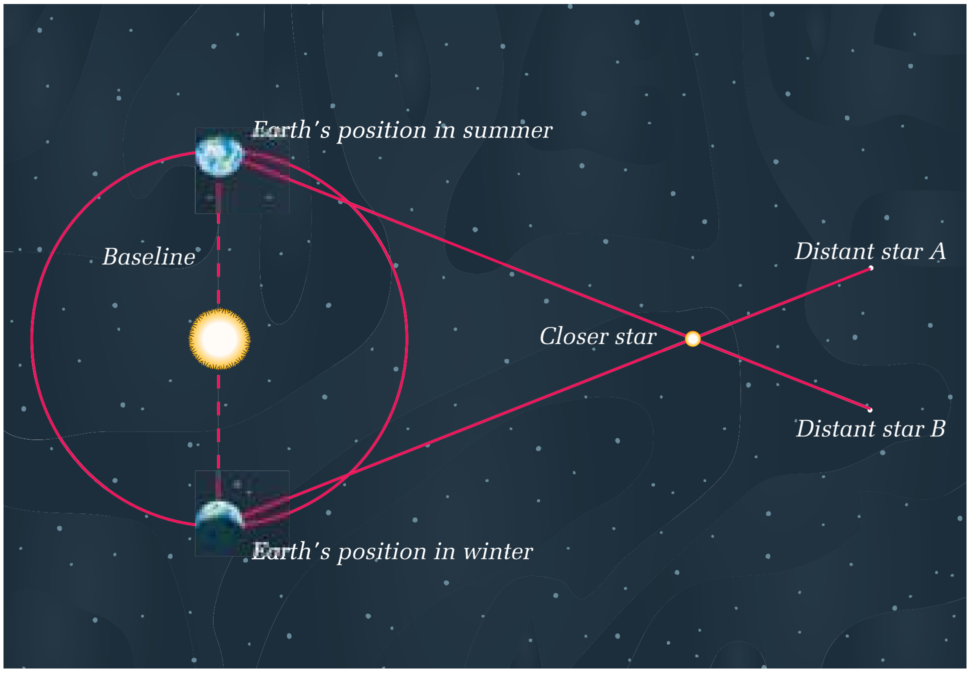


Figure 3.22 When viewed from Earth at different times of the year, a nearby star will appear to shift its position relative to different distant stars in the background. The angles between each end of Earth's baseline (the extreme ends of its orbit, six months apart) and the target star provide angles for triangulation.

ACTIVITY E-7

Inquiry

ANALYZING PARALLAX

The Question

Which show greater parallax: close objects or distant objects?

Materials & Equipment

- a tall candle (about 25 cm long)
- black board or white board
- paper and pencil

Procedure

1. Set the candle on a table 50 cm in front of the board.
2. On the board, draw 10 evenly spaced vertical lines and label them A through J.
3. From a position on the right-hand side of the classroom about 4 m back from the board, look at the candle using only one eye. Make a sketch of its apparent position relative to the reference lines drawn behind it.
4. Go to the other side of the classroom and repeat step 3. What changes in your observation did you notice from one position to the other?
5. Move 2 m closer to the candle and repeat steps 3 and 4. Make sketches of your observations each time. What changes do you notice from the sketches you made from the 4-m position?
6. Move 2 m back from your original position and repeat steps 3 and 4. What difference do you notice this time?
7. The teacher will now move the candle closer to the board. Stand at the very back of the classroom and again repeat steps 3 and 4.
8. Compile your observations in one table.

Figure 3.23 Step 1

Analyzing and Interpreting

9 Describe the apparent motion of the candle as you moved closer to or farther away from it. In which of your positions was the apparent shift of the candle the i) greatest? ii) least?

10 Draw an overall map-view sketch that illustrates the apparent shift in steps 3 and 4.

Forming Conclusions

11 Describe how distances to stars can be measured using parallax.

12 Is parallax more useful for measuring distances to near objects or distant objects? Explain your answer.

Applying and Connecting

Although the technique using parallax has been around for hundreds of years, it was not originally used for determining distances to stars. How do you think parallax could be used to measure short distances on the ground? What would be the limitations of using parallax to measure distances on Earth?

Determining a Star's Composition

As you recall from earlier studies, white light is actually a combination of all colours (the "rainbow" colours). White light can be separated into its component colours by being shone through a prism. The result is bands of colour, which together are referred to as the *visible spectrum*.

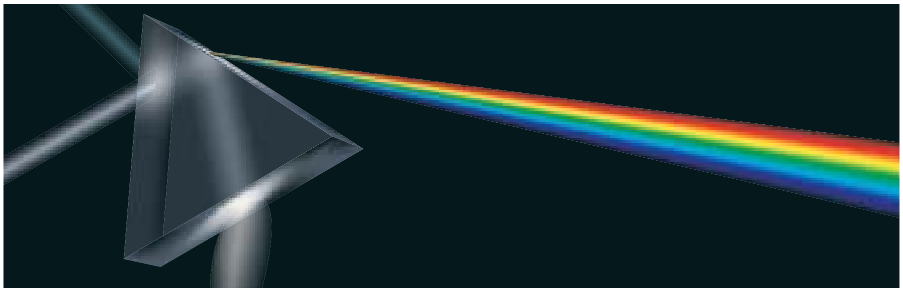


Figure 3.24 Like other light, starlight can be separated into its spectral colours. Isaac Newton was the first person to separate sunlight and analyze its spectrum.

When astronomers first began refracting the light from stars to examine it, they noticed that different stars had dark bands in distinct sequences and thicknesses on their spectra. They discovered that this happened because the various elements in a star absorb light in different ways. As a result, each element creates its own black-line "fingerprint." Astronomers compare the spectrum of a star with known spectra of elements to determine the star's composition. They use an instrument called a **spectrometer** to do this.

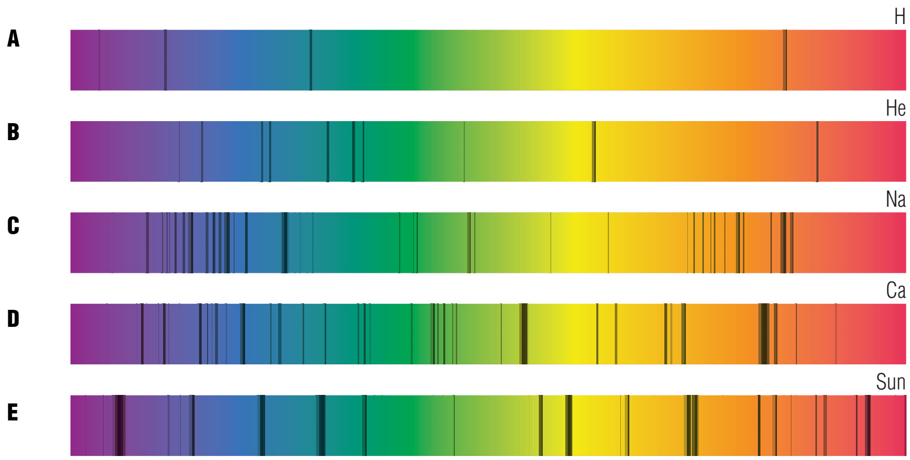


Figure 3.25 The spectra of (A) hydrogen, (B) helium, (C) sodium, and (D) calcium. The Sun's spectrum is shown in (E).

Determining a Star's Direction of Motion

Have you ever noticed how the sound of a siren on an emergency vehicle seems to change as it approaches, passes, and then moves away from you? The reason has to do with the changes in *pitch*, the frequency of sound waves. The pitch of the siren is higher as the vehicle comes toward you than it is after the vehicle goes by and moves away from you. This occurs because the sound wavelengths become compressed in front of the vehicle as the vehicle approaches, causing the pitch to rise. As the vehicle moves away, the wavelengths behind the vehicle are no longer squeezed. As they stretch out, the sound falls in pitch. This is called the **Doppler effect**.

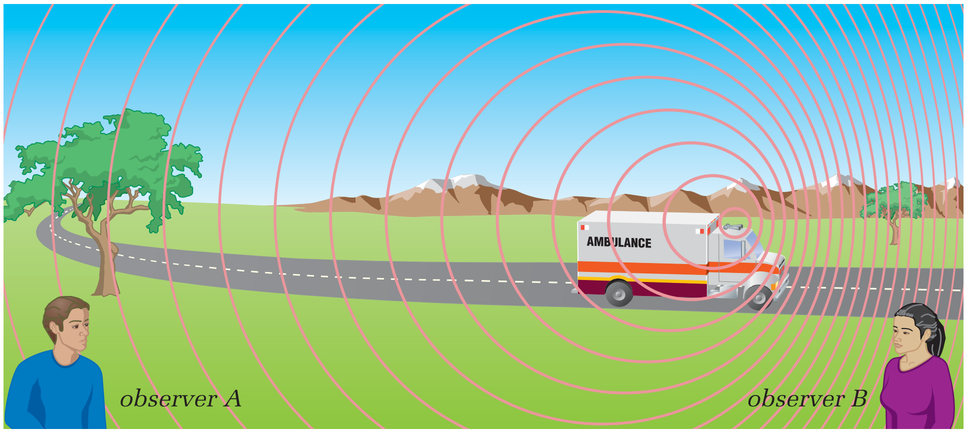


Figure 3.26 Even if you could not see an emergency vehicle, you would be able to tell by the sound of the siren whether the vehicle was moving, and approaching you or travelling away from you.

Like sound, light also travels in waves. Changes in those waves can be used to measure how fast and in what direction a light-emitting object is moving. Pitch refers to the shift in the sound waves of a moving object. The position of the dark bands in the light spectrum is what shifts in the light waves of a moving star. The spectrum of an approaching star shows the dark lines shifting to the blue end of the spectrum as the light's wavelengths become compressed. In the spectrum of a star moving away from Earth, the dark lines shift to the red end as the wavelengths stretch out. The amount of that shift shows up in observations of a star indicates the speed at which the star is approaching or receding.

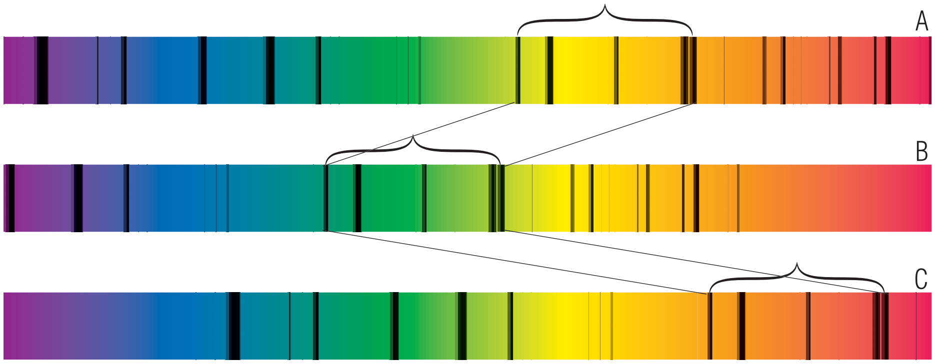


Figure 3.27 Analyzing the blue-shift and red-shift in the spectra of stars and galaxies shows astronomers whether the bodies are moving toward Earth (B) or away from Earth (C). No shift in the spectrum means that the star and Earth are moving in the same direction (A). The star is then said to be stationary.

The Doppler effect comes into play in a number of everyday applications. One of the most common is the radar gun used by police to detect drivers who are travelling above the speed limit. The radar gun emits a radio signal with a known wavelength. A moving car generates a returning wave whose wavelength is picked up by the radar gun. The size of the difference in the two wavelengths shows how fast the moving vehicle is travelling.

Figure 3.28 Radar guns used to enforce traffic speed limits were developed based on scientific understanding of the Doppler effect.

GIVE IT A TRY

Experiencing the Doppler Effect

(Teacher Demonstration)

The Doppler effect refers to the change in frequency of sound, light, and other waves, which results from the relative motion between an observer and the source of the waves. In this activity, you get the chance to experience the Doppler effect firsthand. You are the observer and the source of the sound waves is a noise-maker.

1 While you are seated at your desk, your teacher will stand in the centre of the classroom and swing a small battery-powered noise-maker overhead. Because the noise-maker will be tied to a long string, its circular path will be very wide.

2 As the noise-maker moves overhead, listen for the change in sound as the noise-maker approaches you and then moves away from you. How would you describe the differences in sound?

3 Listen again while the teacher spins the object, but this time close your eyes. Are you able to tell when the object is coming toward you and when it is moving away from you? Explain your answer.

4 In what ways is this apparent shift in sound similar to the shift that happens in a star's spectrum? Use a diagram to help you illustrate your answer.

Check and Reflect

Figure 3.29 These ripples show energy being transmitted from one place to another. How is this similar to the way in which visible light and other forms of electromagnetic radiation travel?

Key Concept Review

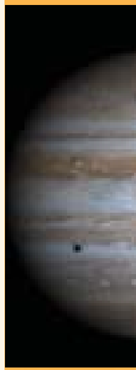
1. Explain the meaning of triangulation and give an example of a situation in which it might be used.
2. How is parallax used to measure distances in space?
3. a) What is a spectrum?
   b) What can a star's spectrum indicate about a star?
4. What is the Doppler effect? Give an example of its use.

Connect Your Understanding

5. When using the triangulation technique, why is it important to measure the baseline accurately?
6. How do astronomers determine the elements that make up a star?
7. Explain why the spectra of some stars shift.

Extend Your Understanding

8. What type of shift in the spectrum would you expect from a star that was:
   a) moving in the same direction as Earth, at the same speed as Earth?
   b) moving at right angles to the direction of sight?
9. What conditions would have to be met in order for an ambulance with its siren on not to exhibit the Doppler effect when it passes you?



Assess Your Learning

Key Concept Review

1. With the aid of two diagrams, describe how refracting and reflecting telescopes work.
2. Explain why infrared telescopes would not be useful for stargazing in a city.
3. What is the advantage of using telescopes set up in an array?
4. What is a spectrometer used for?
5. If you see a red-shifted star, what does that tell you about the direction in which the star is moving through space? Explain your answer.

Connect Your Understanding

6. You are the owner of a company that wants to build the largest optical telescope in the world. Which type would you choose and why?
7. Why can radio astronomers make observations at any time during the day, but optical astronomers are mostly limited to making their observations at night?
8. Why do different elements in a star display different patterns of lines in their spectra?
9. Why is the Doppler effect important to astronomers?

Extend Your Understanding

10. *Most professional astronomers spend little time looking through a telescope lens.* Explain why you agree or disagree with this statement.
11. Describe one limitation in using parallax to determine a star's distance from Earth.

Focus On SCIENCE AND TECHNOLOGY

The advance of space technology has been the result of hundreds of years of research and development. Ideas have developed over generations and have been improved on. This has helped answer many questions humans have had about the universe, while at the same time opening up even more mysteries. Consider the following questions:

1. What has motivated humans to advance the technology used to study the stars?
2. Why is it essential for ideas and technologies to be shared in order for humans to improve their understanding of space?
3. How could the advancement of space observation technology benefit society?

4.0

Society and the environment are affected by space exploration and the development of space technologies.

Key Concepts

In this section, you will learn about the following key concepts:

- space exploration risks and dangers
- technologies for space exploration and observation
- life support technologies
- ownership and use of resources in space

Learning Outcomes

When you have completed this section, you will be able to:

- recognize the risks and dangers associated with space exploration
- describe Canadian contributions to space research and development and to the astronaut program
- identify and analyze factors that are important to decisions regarding space exploration and development

From cancer treatments and pacemakers, to Teflon and flat-screen televisions, the technological benefits created by space research are now everywhere in our daily lives. All of these innovations—many developed for use in the International Space Station—got their start fulfilling a purpose in space exploration. Opportunities for the economic development of space resources are also being investigated today, including such ideas as offering tourist space flights, building hotels on the Moon, and mining minerals on asteroids.

At the same time, the study of space has made us aware of the many hazards that lie beyond Earth's protective atmosphere. For example, we are learning more about the destructive effects of solar radiation on life and equipment and about the danger of possible collision with comets and asteroids. As well, many environmental and ethical issues have arisen related to space exploration. Who owns space? Who is entitled to use its resources? Who is responsible for cleaning up the space environment? How can we justify spending billions of dollars to send a few people into space when millions of people on Earth do not have clean drinking water? These and other matters are discussed in this final section of the unit. You will also read about Canada's significant contributions to space research and the astronaut program.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 The Risks and Dangers of Space Exploration

Space exploration is an exciting endeavour. Yet, as for any journey into the unknown, there are dangers. Travel into space is an especially high-risk business. As you learned in Section 2.0, the space environment is not "human friendly." Only by understanding the dangers and developing technologies to overcome those obstacles have humans accomplished what they have. Unforeseen dangers still remain. Accidents related to space travel may result not only in loss of human life, but in immense economic loss and the loss of countless years of work.

In 1967, the three-member crew aboard Apollo 1 died during a training exercise when fire broke out on board the spacecraft. In 1986, the space shuttle *Challenger* experienced a catastrophic explosion shortly after take-off, killing all seven astronauts aboard. Both the Russians and Americans lost Mars probes shortly before the crafts arrived at the planet. In both of those cases, hundreds of millions of dollars and thousands of hours of labour were lost.

infoBIT

What Goes Up ...
By mid-2001, about 2700 satellites were known to be orbiting Earth. Only about one-third of those are actually working. The rest are "space junk," and most will eventually burn up during re-entry into Earth's atmosphere.

Figure 4.1 As the explosion of the space shuttle *Challenger* showed in 1986, space exploration is an extremely high-risk undertaking.

Nothing can be taken for granted during the preparation for a manned or unmanned space flight. Something as seemingly straightforward as calculating the amount of fuel needed for the flight requires the utmost attention to detail. During *Apollo 11's* mission to the Moon in 1969, the original landing site for the *Eagle* was found to be too rocky for the lunar module to set down safely. Faced with having to choose another place to land, the astronauts knew they had to find the right spot with one try. They didn't have enough fuel to change their minds and find another site—not if they wanted to get back to Earth after their visit to the Moon.

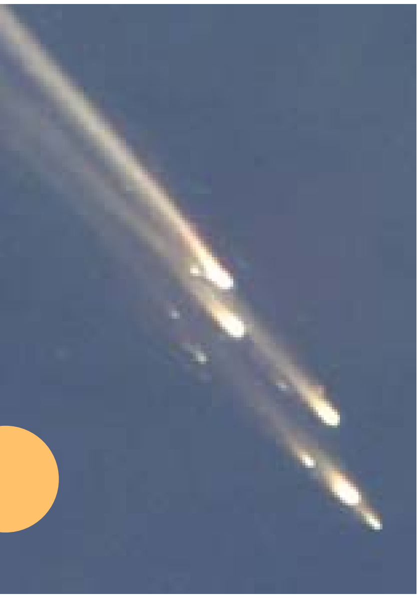


Figure 4.2 In early 2001, the abandoned Russian space station *Mir* came hurtling through Earth's atmosphere, burning up on re-entry.

The Dangers of Manned Space Travel

Sending humans into space has always been a dangerous proposition. First, just imagine the risks associated with being strapped into a small cockpit above several hundred tonnes of highly explosive fuel. Poor weather conditions, malfunctioning equipment, and even the presence of birds can interfere with launching a rocket.

Once a manned craft is in space, floating debris, meteoroids, and harmful doses of radiation must be faced. Outside of Earth's protective atmosphere, the effects of solar and cosmic radiation are magnified because there is no protection. For example, the huge blast of electrically charged particles that the Sun sometimes emits (in a "coronal mass ejection") can burn up the electronic circuits in a satellite. In humans, this dose of radiation also kills cells in vital organs and damages bone marrow. The occurrence of coronal mass ejections (solar flares) is monitored by NASA, and astronauts are warned so that they can protect themselves inside polyethylene shielding that absorbs the radiation.

Cosmic radiation comes from the Milky Way and other galaxies. The damage to human cells from this form of radiation is extreme.

Returning to Earth has its dangers too. The path that the spacecraft follows on re-entry into Earth's atmosphere must be perfect. If it is too shallow an angle, the craft can bounce off the atmosphere and back into space (like a stone skipping across the surface of a pond). If it is at too steep an angle, the craft can move too quickly through the atmosphere and burn up.

*info***BIT**

Stick to the Menu

Not finding the dehydrated "space food" very tasty, one of the early astronauts smuggled two corned beef sandwiches onto a space flight. Mission Control found out and was furious. The mass of the craft and its payload had been calculated to the nearest gram, and the fuel required for the flight had been calculated to the nearest millilitre.

Space Junk

Another legacy of the human presence in space is "space junk." **Space junk** refers to all the pieces of debris that have fallen off rockets, satellites, space shuttles and space stations, and remain floating in space. The debris includes bits as small as flecks of paint or a bolt, and large items such as dead satellites. Lost antennas, tools from past shuttle flights, and even a camera released by an astronaut are other examples. If the space garbage is just above the outer reaches of Earth's atmosphere, it can stay in orbit for thousands of years.

The Hazards in Space

Since 1957, more than 4000 missions have been sent into space. Each one has left its own bits of debris. The space shuttle and International Space Station are constantly being bombarded by tiny pieces of space debris called micrometeorites. These are very hard to detect in space, and travel with lethal velocities. A micrometeorite piercing the hull of a space craft would cause catastrophic damage.

A small washer or screw sounds insignificant compared to a satellite, space shuttle, or space station. However, if you consider that those items are moving 20 000 km/h, you can understand that the effects of a spacecraft colliding with even the smallest object would be devastating. That small object would have a higher impact velocity than a fired bullet.

Most space junk will burn up if it passes through Earth's atmosphere, but until it does, it will remain a very real threat to anyone or anything travelling into space.

The Hazards on Earth

Some space junk poses a risk to Earth as well. There is always the possibility that pieces of obsolete satellites can make their way back to Earth's surface. One such example occurred in January 1978, when a nuclear-powered Soviet satellite crashed into the Great Slave Lake area of the Northwest Territories. On re-entry to Earth's atmosphere, the satellite disintegrated, showering radioactive debris over 124 000 km^2. No lives were lost, but clean-up by Canadian and U.S. military personnel took almost eight months and cost $15 million (Cd.).

Figure 4.3 An impact crater (greatly magnified) on a window on the space shuttle *Challenger* following its 1983 mission. The pit contains traces of titanium oxide—which might have originated from a flake of paint.

reSEARCH

Fuelling a Spacecraft

Just getting into space requires tremendous amounts of fuel. Find out how much each solid fuel rocket tank on the American space shuttle holds. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Name four dangers faced by astronauts during space missions.
2. What happens to satellites that run out of power or just reach the limit of their usefulness?
3. What is meant by "space junk"? Provide examples in your answer.
4. Why must a spacecraft's angle of re-entry into Earth's atmosphere be carefully calculated?

Connect Your Understanding

5. For what reasons would NASA be concerned about something as small as a lens cap floating in space?
6. Why do astronauts on the space shuttles and working in the International Space Station receive more exposure to solar radiation than people on Earth do?
7. Explain why NASA monitors coronal mass ejections.

Extend Your Understanding

8. a) What causes the vast majority of space debris to burn up as it passes through Earth's atmosphere?
   b) Why does some space debris, such as a meteorite, not burn up totally as it passes through Earth's atmosphere?

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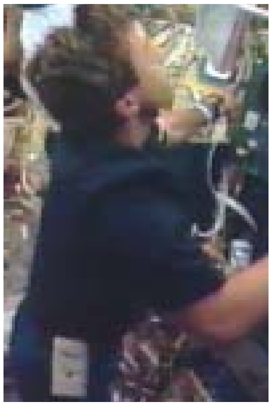
Robert Thirsk

In 1996, Canadian astronaut Robert Thirsk spent 17 days on board a space shuttle. Thirsk, who set his sights on space flight at a young age, holds four university degrees, including a Bachelor of Science from the University of Calgary.



4.2 Canadian Contributions to Space Exploration and Observation

Canada has had a proud involvement in the development of technology for space exploration and observation. One of its most famous contributions is the robotic arm, the "Canadarm," originally designed by Spar Aerospace. Since its debut in 1981 on the U.S. space shuttle *Columbia*, the Canadarm has proven to be one of the most versatile pieces of technology ever designed for the space shuttle program. Manipulated by remote control, the Canadarm has launched and retrieved satellites, helped fix optical apparatus on the Hubble Space Telescope, and put together modules of the International Space Station.

Figure 4.4 Canadarm 1 in action

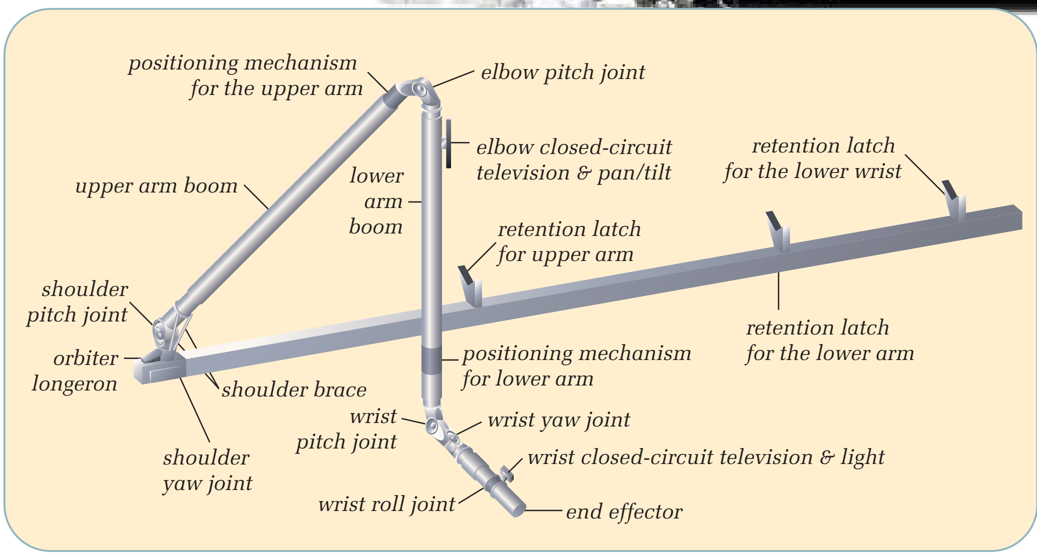


Figure 4.5 The parts of the Canadarm 1

When it launched *Alouette 1* in 1962 (pictured in Figure 2.5), Canada became among the first nations in the world to use a satellite for non-military purposes. A decade later, in 1972, Canada launched *Anik 1* from Cape Canaveral in Florida. That satellite gave the whole country telecommunications coverage for the first time. A year after that, Canada became the first country in the world to use satellites to broadcast television. Since then, the nation has continued to be a leader in the development and use of satellites for communication purposes.

The next generation of Canadian space robotics is the Canadarm 2. Not only can the arm bend around corners and grasp objects with its computer-controlled fingers, it can also move itself around the outside of the International Space Station, crawling like a caterpillar and making every part of the space station accessible.

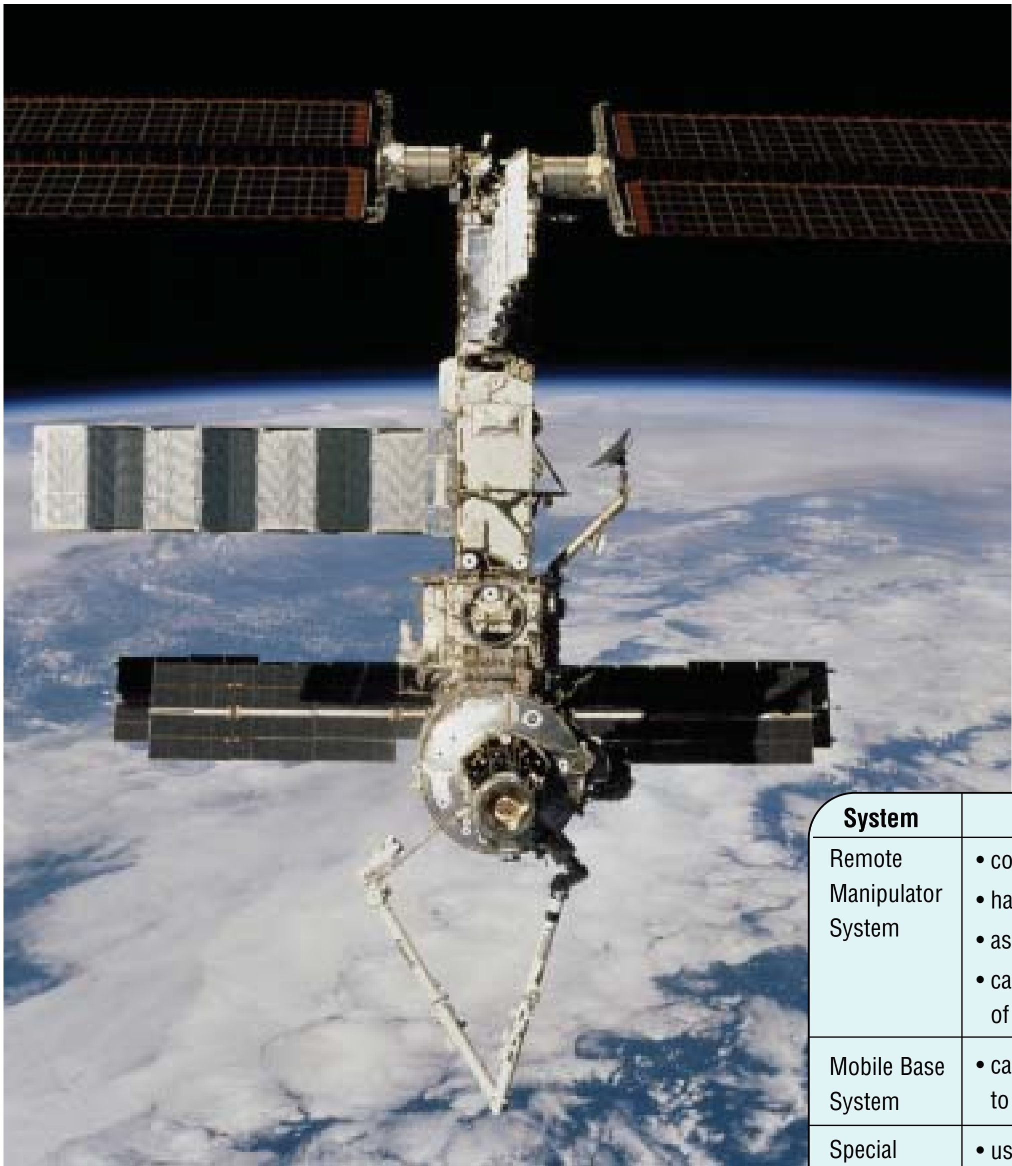


Figure 4.6 Canadarm 2, shown here in position on the International Space Station, is bigger, stronger, and smarter than its predecessor, Canadarm 1.

System	Description
Remote Manipulator System	• contains seven motorized joints • handles large payloads • assists with docking the space shuttle • can move itself around different parts of the station
Mobile Base System	• can travel along a rail system to move to different positions on the station
Special Purpose Dexterous Manipulator	• uses its two-armed robotic hand for delicate assembly work

Figure 4.7 Three main systems of the Canadarm 2

GIVE IT A TRY

WHAT DOES IT TAKE TO BECOME AN ASTRONAUT?

Millions of dollars are spent to train people for the astronaut program and to send a few of them into space. Added to that large financial cost are the thousands of hours of work put in by hundreds of support personnel (researchers, technicians, engineers, physiologists, and others). Obviously, choosing suitable candidates for the astronaut program is critical in making this investment of time and money worthwhile. Candidates cannot just be randomly selected from a list of all applicants. What special education, skills, and other qualifications does someone need to become an astronaut?

1 In a small group, brainstorm a list of criteria that you think a candidate should have to be the "ideal astronaut."

2 Research the Canadian Space Agency's requirements for a person to become an astronaut.

3 Research the biographies of three Canadian astronauts of your choosing. Make note of any patterns or similarities you notice in their backgrounds.

4 Compare your initial brainstorming list with the actual requirements from the Canadian Space Agency. How did your list compare with your research on the backgrounds of actual Canadian astronauts?

5 Present your findings to the class.

6 As a class, discuss whether or not there is such a thing as an "ideal" candidate to be an astronaut.

7 With reference to your research, explain why you would or wouldn't make a good candidate to be an astronaut.

Materials & Equipment

- computer with Internet access
- library (school or public)
- pencil and paper

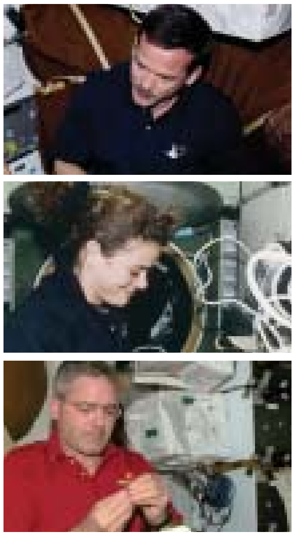


Figure 4.8 From top to bottom, Canadian astronauts Chris Hadfield, Julie Payette, and Marc Garneau

Figure 4.9 Headquarters of the Canadian Space Agency

Canada's rich history in the field of space technology includes the following highlights:

- In 1839, Sir Edward Sabine established the first magnetic observatory at the University of Toronto. He discovered that the aurora borealis was associated with sunspot activity.
- In 1962, Canada became the third nation on Earth to launch a satellite, *Alouette 1*.
- When *Apollo 11* made its historic first manned flight to the Moon in 1969, landing gear built in Canada ensured that the astronauts would safely touch down.
- The first Canadian in space was Marc Garneau, who participated in the space shuttle mission in October 1984.
- Roberta Bondar was the first Canadian female astronaut to fly on a shuttle mission, in 1992.
- Canada provided technology for the *Mars Pathfinder* mission. It was a Canadian-designed ramp that the *Sojourner* rover rolled down in 1997.
- In April 2001, Chris Hadfield became the first Canadian to walk in space when he helped deliver Canadarm 2 to the International Space Station.

reSEARCH

Which Astronaut Is She?

In the early summer of 1999, this astronaut became the eighth Canadian in space. She was the second Canadian female astronaut and only one of three Canadians to operate the robotic space arm. Find out who she is and how she became an astronaut. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. When was Canada's satellite *Alouette 1* launched? What was unique about it?
2. What was Canada's technological contribution to the shuttle program?
3. What is the common name of the Canadian-designed and -built Remote Manipulator System on the International Space Station?
4. Name one of the unique qualities of the Remote Manipulator System.

Connect Your Understanding

5. What Canadian technology contributed to the success of the Moon expedition in 1969?
6. What was the Canadian contribution to the *Mars Pathfinder* mission?
7. Using information provided in section 4.2, create a timeline depicting Canada's contributions to space exploration.

Extend Your Understanding

8. Would the Canadarm 1 design be suitable for the International Space Station? Explain your answer.
9. Imagine that NASA had a lottery in which the first prize was a ride in the shuttle. There would be no training, or studying at all. The winner would simply join the shuttle astronauts the next day for a launch into space. List several reasons why this would be a foolish venture for the individual who won and for the space agency.

*info***BIT**

The Moon and Life Support

Volcanic material on the Moon contains trapped oxygen. Some scientists believe that heating this material would allow the oxygen to be released and captured. They also believe that both oxygen and water could be extracted from the ice at the lunar poles. "Mining" the oxygen and water in this way could support future long-term settlement by humans.

4.3 Issues Related to Space Exploration

Debate rages today over the huge amounts of money, time, and resources that are being expended on sending equipment and people into space. In the United States and Canada alone, the space program costs billions of dollars every year.

The Pros and Cons of Space Exploration

Some people argue that, because there are so many problems on Earth to be solved (such as poverty, hunger, pollution, and disease epidemics), countries should not be spending huge sums of money to explore new regions. Instead, they say, that money should go to relieving the suffering of citizens on our own planet. Other people argue that space is the "last great frontier," and that what we learn by exploring it could help us find ways of improving life on Earth.

Figure 4.10 How do you think money and resources should be spent: to address problems on Earth, or to explore space?

These and other factors must be taken into account when decisions are being made about the future of space exploration and development.

Some forecasters suggest that the population of Earth will continue to increase for the next 50 years before stabilizing. This increase, combined with continued growth in our standard of living, means that the demand for natural resources (such as minerals and fossil fuels) will rise. Instead of looking to Earth to find more of those resources, technology is allowing scientists to look to space for them.

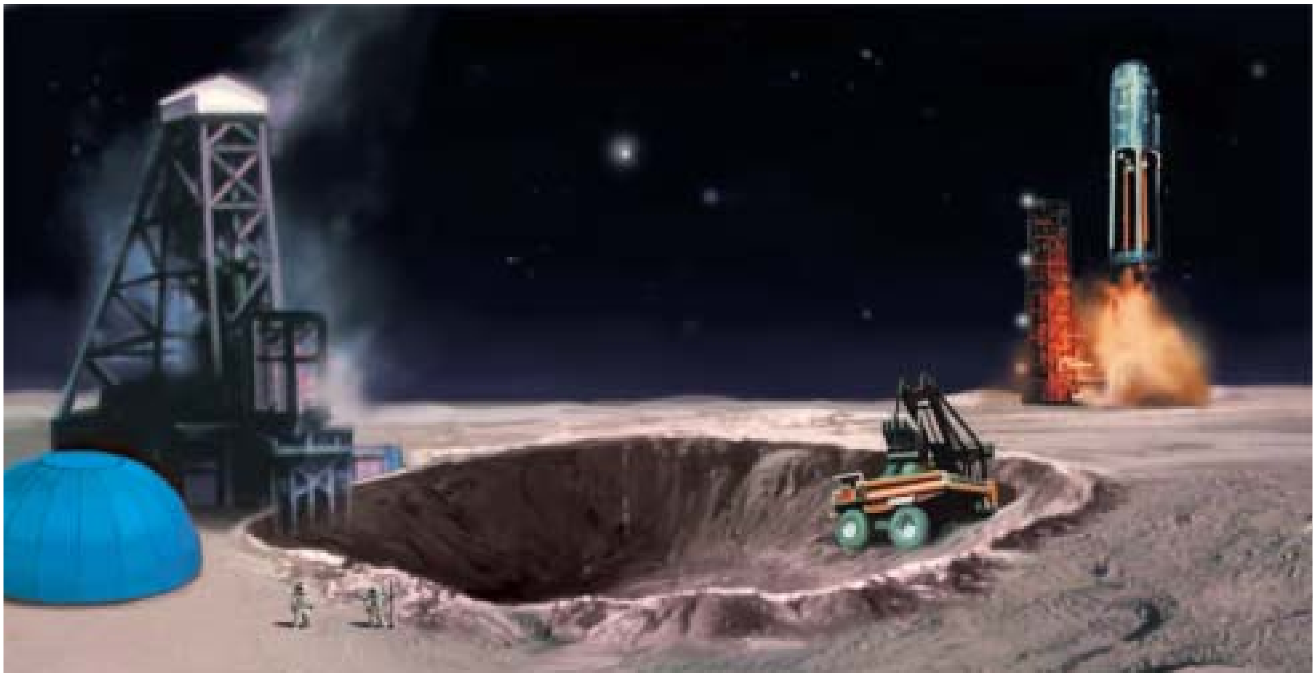


Figure 4.11 As technology has allowed us to study and navigate space safely and efficiently, we have discovered that space is not a barren place. With the right technology, many valuable resources may be readily available.

The Potential Value of Space's Resources

Why would we even need to use resources from space? The reasons are economic.

First, with the resources space has to offer, our energy needs on Earth could be satisfied for a long time. For example, scientists are looking for ways of capturing solar energy in space and beaming it to Earth. As well, space is a boundless source of mineral resources. The asteroid belt that lies between Mars and Jupiter, for instance, contains hundreds of thousands of rocky chunks floating in space. Asteroids have been found to contain iron, as well as gold and platinum group metals. At present market value, a 200 000-t asteroid would yield more than $350 billion worth of mineral resources.

Second, the cost of space travel could be cut substantially. It costs a great deal of money to transport fuel and materials from Earth into space. If materials for the construction of space vehicles, supplies, and fuel can be found where they are to be located in space, costs would be reduced.

The first place scientists looked for resources in space was our closest neighbour, the Moon. Both hydrogen and oxygen can be easily processed from Moon rock. The hydrogen could be used as fuel for lunar bases and space travel. The oxygen could be used for life support. Combine the two and you have a readily available supply of water. Our Moon is not the only source of material. Phobos and Deimos, the moons of Mars, could be used to supply shuttles to that planet.

Activity E-8

Decision Making

Should We Continue Investing in Space Exploration and Research?

The Issue

Every year, there are new, bold projects proposed for the study and exploration of space. Humans continue to push the boundaries of the imagination, from building more sophisticated satellites to planning manned space flights to Mars. Ultimately, we will not be limited by our creativity, but by our ability and willingness to pay for costlier ideas.

Background Information

Throughout this unit, you have learned a great deal about the progress of technology designed to enable us to observe and explore space. You have seen how space research has helped people directly (for example, with satellite communications) and indirectly (with spin-offs such as protective clothing and health care equipment). In this section, you are learning about the great cost of space exploration and the many risks. Should we continue investing in space? Can we afford to keep doing it? Can we afford not to?

1. Working in small groups, brainstorm the pros and cons of human investment in space endeavours.
2. Research each of the items on your list in more detail, using such sources as the Internet, books, magazines, journal articles, and local experts.
3. Individually, summarize your findings in a short report. Conclude the report by stating whether you agree or disagree with humans continuing to invest in space exploration and research. Explain your view. Be sure to consider observations and ideas from a number of sources before drawing your conclusions.

Analyze and Evaluate

4. Present your findings and position on the issue to the class. Be prepared to defend your opinions using the results of your research. Use any format you wish (for example, posters, flip chart, handouts) to communicate your ideas.
5. Listen to your classmates' presentations and be ready to ask questions based on your research.
6. After all the presentations have been made, re-evaluate your position on the issue. Did any of the arguments made by others who held the opposite point of view to yours make you want to reconsider your view? Explain why or why not.

Figure 4.12 Debate the issue of investing in space exploration and research.

Political, Ethical, and Environmental Issues

Although it is widely agreed that valuable resources can be found in space, who owns them and who has a right to use them will become major matters of debate in future plans related to space development. There are also ethical and environmental issues to consider, as the table below summarizes.

Issues

Political	Ethical	Environmental
• Who owns space? • Who has the right to use the resources in space? • Who will determine how space will be used?	• Is it right to spend money on space exploration rather than on solving problems on Earth? • Do we have a right to alter materials in space to meet our needs? • How can we ensure that space resources will be used for the good of humans and not to further the interests of only one nation or group?	• Who is responsible for protecting space environments from alteration? • Who is responsible for cleaning up space junk, and who should pay for doing it?

math Link

The Value of an Asteroid

Find out what minerals an asteroid contains, and research the current market value ($) of each mineral. Using that information, calculate the value of an asteroid if it yielded 100 000 t of minerals. Assume that all the minerals found in the asteroid exist in the same proportion (e.g., five minerals, each 20 000 t = 100 000 t).

GIVE IT A TRY

Who Owns Space?

As travelling into space becomes safer, easier, and more economical, questions arise about the nature of our journeys. In this activity, you are asked to consider some ethical issues on the exploration of space. In a small group (three to four students), discuss the following questions. One person should record the group's ideas.

1 Are the resources of a moon, planet, or asteroid the property of the first nation to land on it or claim it?

2 Should space resources be owned only by nations rich enough to be able to afford the costs of reaching the site of those resources?

3 If we journey to other planets, should we go as eco-tourists, only to observe the planet, leaving it in the condition we found it, or as pioneers, to settle and change the planet to meet human needs?

When you have finished your discussion, compare your group's ideas with those of the other groups in the class. Be prepared to defend your position on each question.

reSEARCH

Moon Marketing

Use the Internet to find out who the entrepreneurs are who are advertising trips to the Moon. Begin your research at www.pearsoned.ca/scienceinaction.

On Earth, similar issues were debated over Antarctica. Though not to the same degree as space, Antarctica is a hostile, remote environment that has valuable resources. No one country, however, could lay claim politically to those resources for itself. In 1959, however, the 12 nations that had bases on the continent signed a treaty to share the resources of the area. Part of the Antarctica Treaty System reads, "Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord." The concept requires that all nations work collaboratively to resolve differences. A space treaty could have the same requirements.

Figure 4.13 The flags of many nations are planted at the South Pole.

Check and Reflect

Key Concept Review

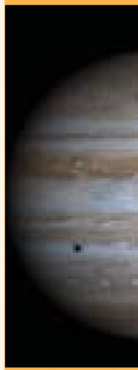
1. Why might asteroids be of interest in space exploration?
2. What two elements can be processed from material on the Moon?
3. How could the elements processed from Moon-material be used?
4. Name two concerns that some people have about exploiting resources in space.

Connect Your Understanding

5. How do left-over materials in space pose a threat to people on the ground?
6. Explain a political concern that exists about space and its resources.
7. Describe an environmental concern about the exploration and exploitation of space.

Extend Your Understanding

8. List three costs of space exploration, and three benefits.
9. Give two reasons why resources should be extracted and processed in space. Give two reasons why they shouldn't.



Assess Your Learning

Key Concept Review

1. Describe three major hazards that astronauts could encounter on their journey from Earth to the International Space Station.
2. Suggest one solution to the space junk problem.
3. List two benefits of Canada collaborating with other countries in space exploration.
4. How are the exploration of Antarctica and the exploration of space similar?

Connect Your Understanding

5. Sixteen different nations are represented in the International Space Station. In your view, who owns space and the resources found there?
6. Besides space junk, give another negative effect of space exploration.
7. Why would mining asteroids or the very small Martian moons be more appealing to a mining company than mining on Mars itself?

Extend Your Understanding

8. Describe a way in which space exploration could benefit all people on Earth.
9. In point form, write your own space treaty. Consider the ethical, political, and environmental issues involved in the exploration of space.

Focus On SCIENCE AND TECHNOLOGY

Fulfilling the dream of human exploration of space only makes sense if it can be done safely, economically, and in a socially and ethically acceptable way. Technological advances, some contributed by Canadian scientists, have made it easier to send people and materials into space. However, as has always been the case in the past on Earth, colonizing new environments leads to dramatic changes. As human influence spreads throughout the solar system and beyond, issues such as ownership, stewardship, and ethical responsibility must be addressed.

1. How has the advancement of technology made space travel safer?
2. Why is it advantageous for Canada to contribute space technologies to international projects rather than to pursue space exploration by itself?
3. As technology makes it easier for humans to get into space, what issues about ownership must be addressed?

Unit Summary: Space Exploration

Key Concepts	Section Summaries
1.0 • technologies for space exploration and observation • reference frames for describing the position and motion of bodies in space • distribution of matter through space • composition and characteristics of bodies in space	**1.0 Human understanding of both Earth and space has changed over time.** • Ancient cultures explained their observations of bodies in space with myths and legends. • Technology used to study space has evolved throughout history. With each technological advance came better explanations for what was observed. • The planet Earth orbits a star that is one of billions of stars in a spiral galaxy called the Milky Way. • Years of accurate data collection and advances in telescope technology have improved our scientific understanding of the solar system. • A star's position when viewed from a particular point, can be determined given the compass direction (azimuth) and the altitude.
2.0 • technologies for space exploration • life support technologies • communication technologies	**2.0 Technological developments are making space exploration possible and offer benefits on Earth.** • Space transport technology began with simple rockets, and today's spacecraft are still launched using the same principles. • For humans to live outside of Earth's atmosphere, the basic requirements for life must be met in space. This means that food, shelter, water, and air must be produced artificially. • Satellites orbiting Earth transmit information to us about weather, agriculture, and natural resources. We can also use space technology to locate our exact position on Earth. • Many concepts designed for use in space have found applications on Earth. These include materials used for communication, medicine, entertainment, and transportation.
3.0 • technologies for space exploration and observation • composition and characteristics of bodies in space • communication technologies • triangulation and parallax	**3.0 Optical telescopes, radio telescopes, and other technologies advance our understanding of space.** • Reflecting and refracting are two types of optical telescopes. Reflecting telescopes use mirrors to focus light. Refracting telescopes use lenses to focus light. • Visible light is only one part of the electromagnetic spectrum. This spectrum includes infrared, X-ray, ultraviolet, and gamma radiation. Specific technologies are designed to detect these forms of radiation that come to us from space. • By observing the shift in the spectrum of a star, we can tell if it is moving toward or away from Earth. • Triangulation and parallax are two techniques for measuring distances in space.
4.0 • space exploration risks and dangers • technologies for space exploration and observation • life support technologies • ownership and use of resources in space	**4.0 Society and the environment are affected by space exploration and the development of space technologies.** • There are many dangers associated with both manned and unmanned space exploration. Some of those dangers are posed by debris floating in space around Earth and by solar and cosmic radiation. • Canada has had a long and proud history of participation in space research and exploration. • Many issues concerning ownership of space and its resources are yet to be resolved. These include political, environmental, and ethical issues.

Babies Beyond Gravity's Grip

The Issue

The International Space Station is just the first step in human colonization of space. In the not-too-distant future, permanently manned space stations and bases on the Moon are likely to be the next step in space exploration. Some scientists predict that within two decades, the first inhabited colony on Mars will be established. The first colonists will probably include families, which means that babies might, for the first time ever, be born in a place other than on Earth. Numerous health, social, and emotional issues would surround such a significant historical occurrence.

Physical Health Issues	• How would the space environment physically affect a new baby? • Are there concerns other than microgravity that could affect the health of a developing baby? • How would a child born and raised on the Moon, Mars, or an orbiting space station be physically affected by moving to Earth?
Social Issues	• What would be the nationality of a baby born in space? • What nation would be responsible for providing the child with any social and medical support it needed? • How socially connected to Earth would a person raised in space feel?
Emotional and Psychological Issues	• How would living in small, cramped conditions with limited freedom to move around affect a young child growing up? • What effects, if any, would a child experience from living apart from a natural environment that has air, grass, trees, rain, and birds? • How would a child who is born and raised on the Moon, Mars, or an orbiting space station be emotionally and psychologically affected by moving to Earth?

Go Further

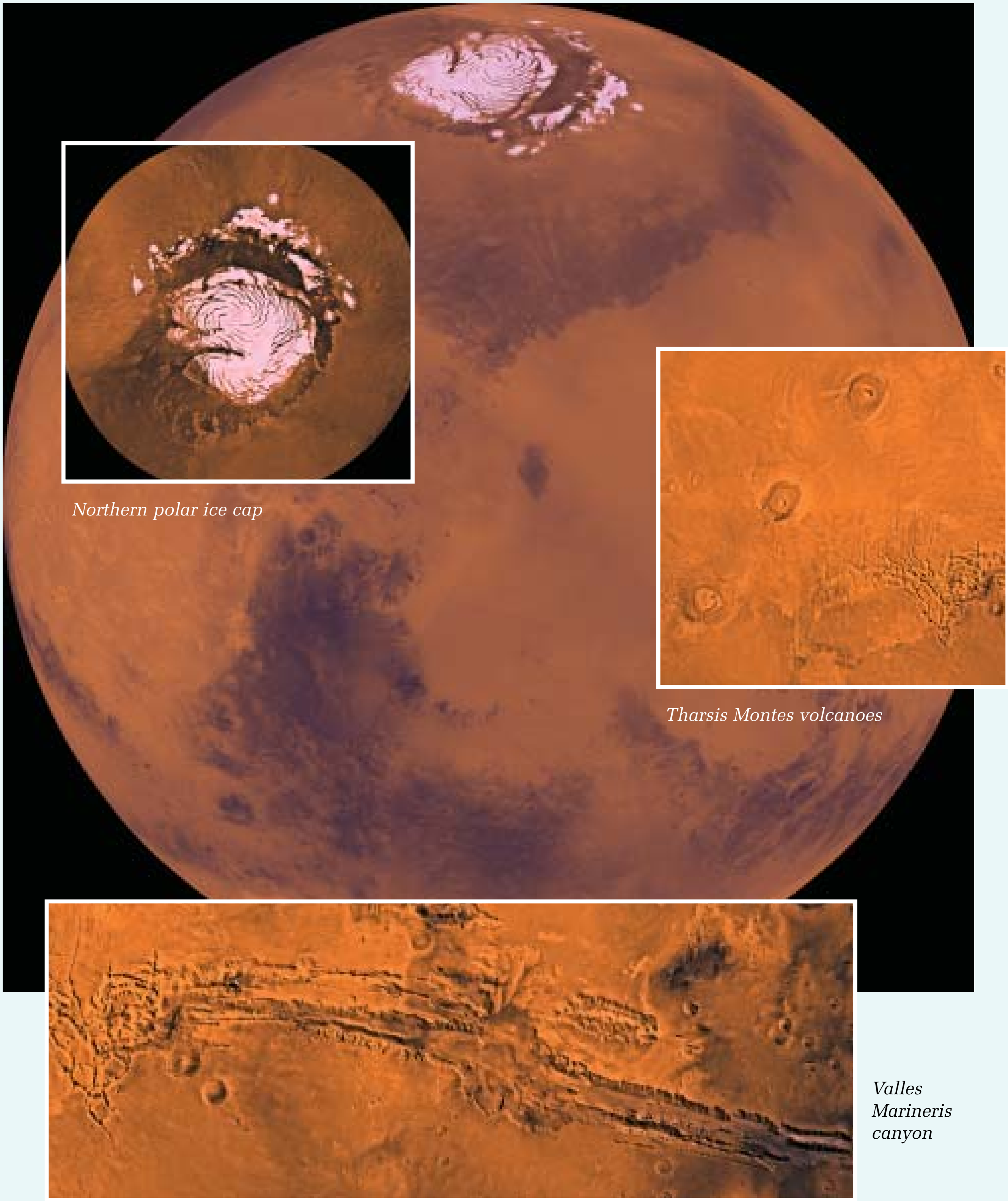
Now it's your turn. Look into the following resources for information to help you form an opinion about what health issues might affect babies and children raised away from Earth.

- Search the Web: Check the Internet for information about space travel and the effects of microgravity on the human body.
- Ask the experts: Talk to a doctor or a nurse at your local hospital or medical clinic about how microgravity conditions would affect the development of a baby and child.
- Check journals and magazines: Search for current stories related to travelling in space for long periods and the effects of low to microgravity.

Analyze and Address the Issue

Imagine you were one of the first children to be born in space. (Assume for this case study that, thanks to technological advances, conditions for safe delivery were created for you and your mother.) Your life so far has been spent in space, but now, as a young teenager, you are moving to Earth. Write a series of first-person diary entries chronicling your adjustment to Earth. Start with your first day arriving on the planet. Compare and contrast your life in space with your life on Earth, and consider both the emotional and physical impacts. Be sure to use your research material to support your ideas.

MISSION TO MARS



Northern polar ice cap

Tharsis Montes volcanoes

Valles Marineris canyon

Getting Started

We have learned much about Mars from telescopes, robotic probes, and satellites, but to really understand the nature of the planet, we will have to see it for ourselves. This project will allow you to apply what you have learned in this unit about space exploration, the requirements of living in space, and the way in which technology and science go hand in hand to advance our knowledge about the universe. You will be designing the first mission to Mars. Where you land is up to you. You can choose between the Valles Marineris canyon, the Tharsis Montes volcanoes, and the northern polar ice cap.

Your Goal

The project has three parts.

- First, design an unmanned probe that will safely touch down and explore the target area on Mars that you have selected.
- Second, design a base camp for a team of eight astronauts (four women and four men) who will be the first humans to colonize Mars. Scale models must be made for both the probe and the base camp.
- Third, decide which feature to study and how.

What You Need to Know

The mission to Mars will last approximately 22 months. That time includes the eight months it will take to travel there, six months to explore the surface, and eight months to return to Earth. In addition to what you learned about the nature of Mars in subsection 1.4, you should keep in mind that dust storms with winds up to 900 km/h can cover most of the planet for weeks. Also, communication signals from Mars can be expected to take about 8 min to reach Earth. Your base camp design must include laboratories, food, water and air supplies, and living space. It must also reflect which feature your mission is going to study and how.

Steps to Success

1. Working with two or three partners, select the area of Mars that will be the focus of your mission. Brainstorm ideas for both the type of landing probe you wish to design and the style of base camp. Using a variety of sources, research the characteristics of the surface feature your mission is going to study. With your partners, identify problems resulting from the conditions on Mars and discuss possible design solutions.
2. Complete two scale drawings, one for the probe, and one showing the layout of the base camp. Include ideas about how the astronauts will travel on the surface of the planet.
3. Construct scale models of your probe and the base camp using materials of your choice.
4. Write descriptions of a) the tasks to be performed during the mission, b) the features of your landing probe, and c) the features of your base camp.
5. Present your work to the class and explain the rationale behind your designs.

How Did It Go?

6. In your notebook, answer each of the following questions in a paragraph.
   a) How did your research influence your design for each part of the mission?
   b) Did you use current technology, or did you design your own technology to meet the needs of the mission?
   c) How effective was the group decision-making process? How were disagreements resolved?
   d) After seeing your classmates' presentations, are there any changes you would make to your designs? Explain your answer.

Unit Review: Space Exploration

Unit Vocabulary

1. Make a brief sketch that illustrates each of the following vocabulary words or terms:
   geocentric
   heliocentric
   elliptical
   black hole
   constellation
   galaxy
   solar system
   comets
   meteors
   astronomical unit
   light-year
   Hubble Space Telescope
   spectrum
   space junk

Key Concept Review

1.0

2. What information did constellations provide early sky-watchers?
3. What is the first stage in a star's life called?
4. All stars start from the same "building blocks." What element forms these building blocks?
5. Define a light-year.
6. a) How many stars are estimated to be in the Milky Way galaxy?
   b) How many galaxies are estimated to be in the universe?
7. Explain why you could not locate a star by knowing only its altitude in the sky.

2.0

8. Draw a rocket and label its main parts. What propels a rocket forward?
9. List five basic requirements for humans living in space.
10. Describe some of the effects on the human body that result from living in microgravity .
11. How does the Global Positioning System work? Illustrate your answer.
12. Name four materials or items we use on Earth that were originally designed for use in space.

3.0

13. What part of the electromagnetic spectrum can humans detect?
14. Explain how astronomers use multiple small telescopes to imitate one large telescope.
15. What is the Doppler effect and how is the principle applied in determining star motion?
16. Explain how the process of triangulation can determine distances on the ground.
17. What aspect of Earth makes it difficult to observe the X-rays, gamma rays, and ultraviolet rays that come from space?

4.0

18. Name four risks associated with space exploration.
19. List three different contributions Canada has made to the space industry.
20. Why is space junk an issue in space exploration?

Connect Your Understanding

21. Describe what you consider to be the most important issues facing space exploration.

22. Describe how space exploration, or its spin-off products, have affected you personally.

23. In the late 1970s, when Skylab was due to re-enter Earth's atmosphere, insurance companies were offering policies to insure people who might get hit by pieces of the space station that reached Earth's surface. Explain why it would be highly unlikely for anyone to ever need to use such an insurance policy.

24. If space technology and exploration affect the planet as a whole, how should decisions regarding their use be made?

Extend Your Understanding

25. Explain why looking at stars in the night sky is considered looking into the past.

26. As soon as a comet gets close enough to the Sun to feel the Sun's effects, the gases in the comet begin to bubble (effervesce) and it leaves a trail along the path it has followed. When a comet's tail is visible, it always points away from the Sun. Explain why this occurs.

27. If we knew a galaxy was moving away from Earth, but we see a star in the galaxy with a spectrum shifted towards the blue, what would we conclude?

Practise Your Skills

28. Sketch a diagram that illustrates your understanding of the differences between reflecting, refracting, and radio telescopes.

29. Construct a Venn diagram that compares and contrasts the characteristics of Mars and Earth.

30. Sketch how an ellipse changes in shape when the foci (the two pins that you used in the activity on page 375) are moved farther apart from each other. Relate this to the orbits of planets around the Sun.

Self Assessment

31. Describe three facts that you found most interesting in this unit which you did not know before.

32. What are two questions that you have about technology used for space exploration and travel?

33. Has your opinion about the value of space exploration changed in the course of reading this unit? Explain your answer.

34. Which spin-off of the space industry has had the greatest effect on your life?

Focus On — Science and Technology

In this unit, you have investigated science and technology related to space exploration. Consider the following questions.

35. As improvements are made to technology, our understanding of the universe around us advances. Should decisions that could potentially affect the entire planet be made by only a handful of scientists? Explain your answer.

36. Describe three ways in which the technology from space exploration has potential to benefit all people in the future. What drawbacks to the development of this technology can you think of? Give reasons to support your answer.

37. When making decisions about space exploration and the exploitation of resources in space, what do you feel are essential questions to ask?

TOOLBOX

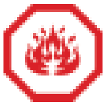
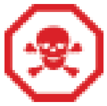
SAFETY IN THE LABORATORY

Safety First

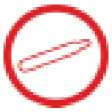
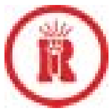
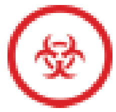
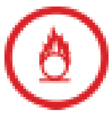
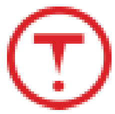
You have probably seen some of the hazard symbols below on products at home. They are a warning that many substances can be harmful or dangerous if handled improperly.

Each hazard symbol can come in either a yellow triangle (which means "caution"), an orange diamond (which means "warning"), or a red octagon (which means "danger").

Here are some of the more common symbols.

Symbol	Caution	Symbol	Caution
	Flammable Hazard: Materials could ignite (catch on fire) if exposed to flames, sparks, or friction.		Corrosive Hazard: The material may corrode ("eat away at") clothing, skin, or other materials.
	Explosive Hazard: The materials or equipment could explode.		Biological Hazard: Be alert to the possibility of poisoning or infection from microscopic and other organisms.
	Toxic Hazard: The material is very poisonous and could have immediate and serious effects.		Electrical Hazard: Be alert to the possibility of an electric spark or shock.

Here are some other symbols you might see on the materials you use in your classroom. These symbols are called **Workplace Hazardous Materials Information System (WHMIS)** symbols. They are placed on hazardous materials used at job sites and school laboratories.

Symbol	Caution	Symbol	Caution
	compressed gas		flammable and combustible material
	dangerously reactive material		biohazardous infectious material
	oxidizing material		corrosive material
	poisonous and infectious causing immediate and serious toxic effects		poisonous and infectious causing other toxic effects

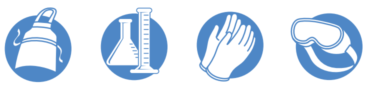
Can you identify the symbols that are similar to the household symbols above? Discuss with your teacher what some of the other symbols mean.

Continued on next page →

Common-Sense Safety Checklist

Your teacher may have safety instructions to add to the list below. Discuss or note your ideas about why each of these is an example of common-sense safety.

- Learn to recognize the warning symbols on this and the previous page.
- Keep your work area uncluttered and organized.
- Know the location of fire extinguishers and other safety equipment.
- Always wear safety goggles and any other safety clothing as requested by your teacher or this book.
- If you have long or loose hair, tie it back. Roll up long shirt sleeves.
- Don't wear any jewellery when doing laboratory activities.
- Inform your teacher if you have any allergies or medical conditions.
- Report any safety concerns you have, or hazards you see (such as spills) to your teacher.
- Handle all glassware carefully. If you see broken glass, ask your teacher how to dispose of it properly.
- Never smell any material or substance directly. Instead, gently wave your hand over it to bring its vapours toward your nose.
- Never take chemicals directly from the container. Transfer a small amount to a labelled beaker and take your sample from it. This will prevent contamination of chemicals and possible reactions.
- Symbols are used throughout this book to tell you when to use safety equipment and when caution is needed in performing an activity.



- Heat solids and liquids only in heat-resistant glass beakers and test tubes.
- When you heat test tubes, make sure that the open end is pointing away from you and anyone else in the room.
- When heating a substance, make sure the container does not boil dry.
- Follow your teacher's instructions to safely dispose of all waste materials.
- Always wash your hands well with soap, preferably liquid soap, after handling chemicals or other materials.
- Make sure you close the containers of chemicals immediately after you use them.
- Make sure that any water or wet hands are kept away from electrical outlets or sockets.
- When you have finished an experiment, clean all the equipment before putting it away. Be careful with hot plates and equipment that have been heated as they may take a long time to cool down.

Say "Yes!" to Safety

Are you willing to

✔ follow the safety instructions outlined by your teacher and this book?

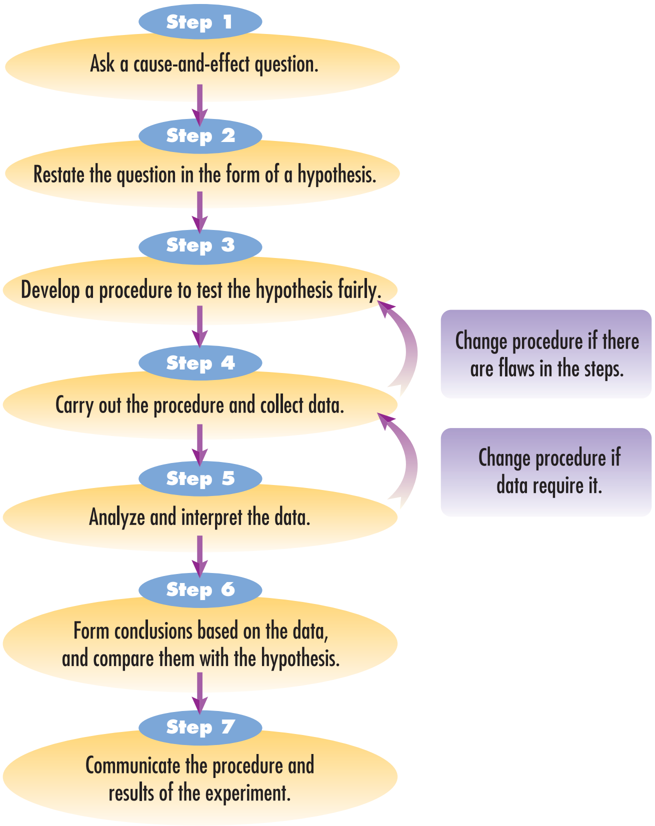
✔ keep an eye open for possible hazards and report them immediately?

✔ show respect and concern for your own safety and the safety of your classmates and teachers?

THE INQUIRY PROCESS OF SCIENCE

Scientists are always asking a lot of questions. They are always inquiring. They want to understand why the things they observe, and wonder about, happen. Experiments are important tools scientists use to help them answer their questions.

When scientists plan experiments, they usually follow a simple set of steps.



Hints

- Answers may lead to additional questions. New questions often lead to new hypotheses and experiments. Don't be afraid to ask questions, or to re-think the ones you've already asked.
- Science grows when scientists ask questions, answer them, and are willing to question those answers. Scientific knowledge is always growing and changing.

Step 1 Ask a cause-and-effect question.

Asking questions is easy. Asking questions that lead to reliable answers is more challenging. That's the reason scientists are especially fond of asking cause-and-effect questions. Here are a few examples.

- How does the concentration of laundry detergent in wash water affect the cleanliness of clothing?
- How do different temperatures affect the growth of seedlings?
- How does the amount of moisture affect the growth of mould on bread?

Notice how the causes—the detergent, temperature, and moisture—are things that are changeable. For example, you can have different concentrations of detergent, different temperatures, and different amounts of moisture. Causes are manipulated or independent variables. They are factors that you change when you investigate a cause-and-effect question.

The results are changeable, too. For example, some clothes may become cleaner than others, or not clean at all. Some seedlings may grow better than others, or some might not grow at all. Some bread samples may have lots of mould, some may have less, and some might not have any. Results are responding or dependent variables. They change because of the manipulated variable.

When you ask a cause-and-effect question, you should include only one manipulated variable in your question. This allows you to see the effect of that variable on the responding variable.

Continued on next page →

Step 2 Restate the question in the form of a hypothesis.

A hypothesis is a way of restating a cause-and-effect question so that it gives a reasonable, possible answer. Basically, a hypothesis is an intelligent guess at the solution to a problem or question. It is usually in the form of an "If ... then" statement and states the relationship between the manipulated and responding variables. A "null hypothesis" states that a manipulated variable will *not* have an effect on the responding variable.

Here are hypotheses for the questions outlined in Step 1.

- If the concentration of the detergent is high, then clothing will become cleaner.
- If the temperature is decreased, then the seedlings will not grow as well.
- If the amount of moisture is increased, then the bread will get mouldier.

Hints

A hypothesis is an early step in the experiment-planning process. Your hypothesis can turn out to be "right," but it doesn't always. That's what the experiment is for—to test the hypothesis.

Step 3 Develop a procedure to test the hypothesis fairly.

When you develop a procedure, you need to ask yourself some questions. Here are some questions you should think about. These questions are answered for the seedling example.

- Which manipulated variable do you want to investigate? For the seedling experiment, the manipulated variable is temperature.
- How will you measure this variable (if it is measurable)? You can measure temperature with a thermometer.
- How will you keep all other variables constant (the same) so they don't affect your results? In other words, how will you *control* your experiment so it is a fair test? To control the seedling experiment, these variables should be kept constant: the amount of light the seedlings receive; the amount and temperature of water applied to the seedlings; the kind of soil the seedlings are planted in.
- What materials and equipment are needed for the experiment? For the seedling experiment, you'd need seedlings, soil, growing pots or containers (same size), water and a watering can, a light source, a thermometer, and a ruler or other measuring device.
- How will you conduct the experiment safely? For the seedling experiment, some of the safety factors you should consider include putting the seedling pots in a place where they would not be disturbed, washing your hands after handling the materials, and making sure you don't have any allergies to the soil or seedlings you use.
- How will you record the data you collect? You could divide your seedlings into groups (e.g., three seedlings for each temperature) and grow each group at a certain temperature. You would keep track of how much each seedling in a group grew over a specified amount of time (e.g., four weeks) and calculate the average for the group.
- What sample size will you need to test? Is it enough to grow only one seedling at each different temperature? Is three enough?

Step 4 Carry out the procedure and collect data.

Depending on the kind of experiment you have planned, you may choose to record the data you collect in the form of a chart or table, a labelled sketch, notes, or a combination of these. For example, a good way to record the seedling data would be in a table like the one below (one for each week of the experiment).

Week 1: Height of Seedlings Grown at Different Temperatures

Temperature seedlings grown at (°C)	Height of seedling 1 (cm)	Height of seedling 2 (cm)	Height of seedling 3 (cm)	Average height (cm)
20				
15				
10				

Hints

Analyzing the data you collect is the only way you have to assess your hypothesis. It's important that your record keeping be organized and neat.

Step 5 **Analyze and interpret the data.**

Scientists look for patterns and relationships in their data. Often, making a graph can help them see patterns and relationships more easily. (Turn to Toolbox 7 for more about graphing.) Provide any calculations required to show the relationships in your observations. Interpret your results and make a statement that indicates the relationship between the manipulated and responding variables.

A graph of the seedling data would show you if there were a relationship between temperature and growth rate.

Hints

If you have access to a computer, find out if it has the software to help you make charts or graphs.

Step 6 **Form conclusions based on the data, and compare them with the hypothesis.**

Usually, this is fairly straightforward. Either your data will support your hypothesis or they won't. Either way, however, you aren't finished answering your cause-and-effect question.

If your data support your hypothesis, you need to repeat your experiment several times to see if you get the same results over and over again. Doing your experiment successfully many times is the only way you and other scientists can have faith in your data and your conclusions.

If your data do not support your hypothesis:

- Your experimental plan may be flawed and needs to be re-assessed and possibly planned again.
- Your hypothesis was incorrect and needs to be re-assessed and modified.
- Sources of error may need evaluating, which may help explain some of your results.

If the seedlings did not grow as well in cooler temperatures, the hypothesis could be a good one. If the seedlings grew better in the lower temperatures, you would have to re-think your hypothesis, or look at your experiment for errors. Do certain seedlings grow better at lower temperatures than others? Do different types of soil have more of an effect on growth than temperature? These are some of the questions that could be asked after doing the seedling experiment. Every experiment is different and will result in its own set of questions and conclusions.

Hints

- If you don't have in-class time to repeat your experiment several times, you could ask your teacher about scheduling after-school time.
- You could also enlist the help of your classmates. If other scientists get the same results, the conclusions are usually reliable. If not, the hypothesis must be modified.

Step 7 **Communicate the procedure and results of the experiment.**

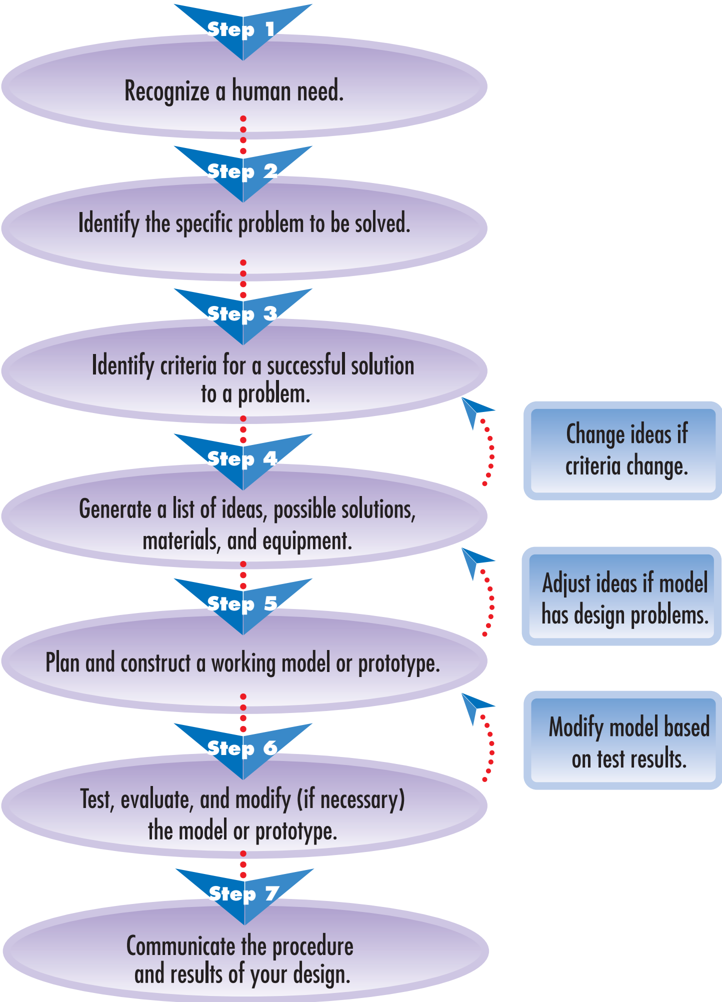
Scientists always share the results of their experiments with other people. They do this by summarizing how they performed the first six steps. Sometimes, they will write out a formal laboratory report stating their purpose, hypothesis, procedure, observations, and conclusions. Other times, they share their experimental results verbally, using drawings, charts, or graphs. (See Toolboxes 6, 7, and 8 for hints on how to prepare your results.)

When you have finished your experiment, ask your teacher how he or she would like you to prepare your results so you can share them with the other students in your class.

THE PROBLEM SOLVING PROCESS FOR TECHNOLOGICAL DEVELOPMENT

When you plan an experiment to answer a cause-and-effect question, you follow an orderly set of steps. The same is true for designing a prototype that solves a practical problem.

When people try to solve practical problems, they usually follow a simple set of steps.



Step 1 **Recognize a human need.**

This involves recognizing what the problem is. For example, suppose you observe that a rope bridge across a ravine at a local park is very unstable and swings back and forth when crossed. This might be fine for people who want a thrill, but you find that most people are not comfortable crossing the bridge and don't get to enjoy one of the nicer areas of the park. You wish there were a way to make the bridge more stable so more people would use it. That is the situation or context of the problem.

Step 2 **Identify the specific problem to be solved.**

When you understand a situation, you can then define the problem more exactly. This means identifying a specific task to carry out. In the situation with the bridge, the task might be to build a new bridge or add support to the existing bridge.

Step 3 **Identify criteria for a successful solution to a problem.**

You have defined the problem and now you must look for solutions. But how will you know when you have found the best possible solution? Before you start looking for solutions, you need to establish your criteria for determining what a successful solution will be.

One of your criteria for success in the bridge example would be the completion of a stable bridge. The criteria you choose do not depend on which solution you select—whether to reinforce the old bridge or build a new bridge. In this case, whatever the solution, it must result in a stable bridge.

When you are setting your criteria for success, you must consider limits to your possible solutions. For example, the bridge may have to be built within a certain time, so rebuilding completely may not be possible. Other limitations could include availability of materials, cost, number of workers needed, and safety.

If you are building a product or device for yourself, you may set the criteria for success and the limitations yourself. In class, your teacher will usually outline them.

Hints

Always consider safety. This includes safe handling and use of materials and equipment, as well as being aware of possible environmental impacts of your ideas. Discuss with your teacher and fellow students how your solution might affect the environment.

Step 4 Generate a list of ideas, possible solutions, materials, and equipment.

Brainstorming, conducting research, or both, are key components of this step. When you brainstorm, remember to relax and let your imagination go. Brainstorming is all about generating as many ideas as possible without judging them. Record your ideas in the form of words, mind maps, sketches—whatever helps you best.

Conducting research may involve reading books and magazines, searching the Internet, interviewing people, or visiting stores. It all depends on what you are going to design.

One idea for the rope bridge would be to anchor the bridge with strong rope or thick metal wire to large rocks or to the hillside at either end of the bridge. Sketches and diagrams would help to generate different ideas for the bridge design.

Hints

Humans have been inventors for tens of thousands of years—so take advantage of what has already been developed. When you're solving a problem, you don't have to "reinvent the wheel." See how others have solved the same problem before and use their efforts as inspiration. You can also look for ways to "build upon" or improve on their ideas.

Step 5 Plan and construct a working model or prototype.

Choose one possible solution to develop. Start by making a list of the materials and equipment you will use. Then make a working diagram, or series of diagrams, on paper. This lets you explore and troubleshoot your ideas early on. Your labels should be detailed enough so that other people could build your design. Show your plans to your teacher before you begin construction work.

A simple model of the bridge could be made to show how and where components such as stabilizing wires could be added.

Hints

If things aren't working as you planned or imagined, be prepared to modify your plans as you construct your model or prototype.

Step 6 Test, evaluate, and modify (if necessary) the model or prototype.

Testing lets you see how well your solution works. Testing also lets you know if you need to make modifications. Does it meet all the established criteria? Does it solve the problem you designed it for?

Invite your classmates to try your product. Their feedback can help you decide what is and isn't working, and how to fix anything that needs fixing. Perhaps the stabilizing wires on the bridge model could be anchored elsewhere. Maybe more wires could be added.

Hints

For every successful invention or product, there are thousands of unsuccessful ones. Sometimes it's better to start over from scratch than to follow a design that doesn't meet its performance criteria.

Here's an old saying you've probably heard: "If at first you don't succeed, try, try again." Remember, there can be many possible solutions to a practical problem.

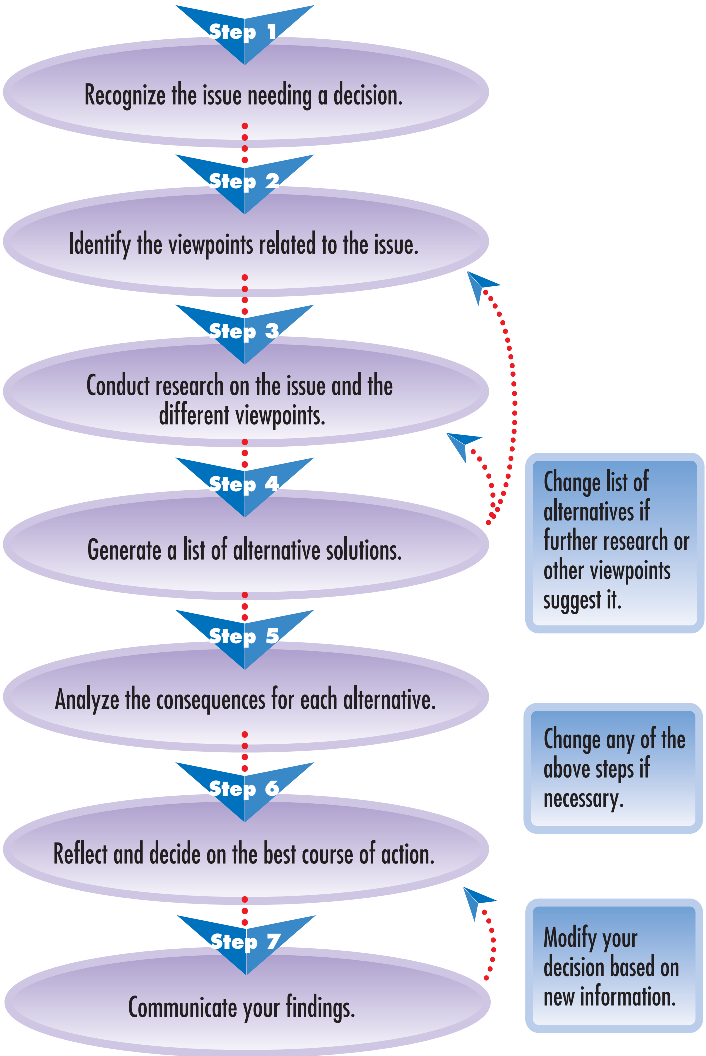
Step 7 Communicate the procedure and results of your design.

Inventors and engineers create things to meet people's needs. When they make something new, they like to show it to other people and explain to them how it works. Sometimes they will use a carefully drawn diagram of the new device and write about how they performed the first six steps. Other times, they will show the device to people and explain verbally how it works and how they built it. Your teacher will tell you how to prepare your results so you can exhibit the new device you make.

The Decision Making Process for Social and Environmental Issues

People can have many different viewpoints or perspectives about social and environmental issues. This usually means that an issue has more than one possible solution. Scientific and technological information can be used to increase our understanding of an issue and help resolve it.

When people try to make a decision or reach a consensus about an issue, they need to use a decision making process. Here are the steps in one possible process.



Step 1 Recognize the issue needing a decision.

This involves recognizing that an issue exists. An issue is a controversy that needs to be resolved. It may have more than one possible solution, but the chosen one is usually the one that satisfies the most people. For example, suppose you and your friends want to have some trees in a public park cut down in order to make space for a playing field. Some members of your community feel that the trees should be preserved for the birds that nest there. The local environmental specialist says that when it rains, the trees protect a nearby stream by reducing run-off, so they should be left standing. Other people say that your idea of building a playing field is too expensive.

Step 2 Identify the viewpoints related to the issue.

The viewpoints expressed in the example in step 1 are **recreational** (you and your friends), **ecological** (people who wish to leave the trees as they are), and **economic** (people who think that the cost would be too high).

People often evaluate issues using one or more viewpoints. Some of these viewpoints are:

- Cultural: interest in the customs and practices of a particular group of people
- Ecological: interest in the protection of the natural environment
- Economic: interest in the financial aspects of the situation
- Educational: interest in acquiring and sharing knowledge and skills
- Esthetic: interest in the beauty in art and nature
- Ethical: interest in beliefs about what is right and wrong
- Health and safety: interest in physical and mental well-being
- Historical: interest in knowledge dealing with past events
- Political: interest in the effect of the issue on governments, politicians, and political parties
- Recreational: interest in leisure activities
- Scientific: interest in knowledge based on the inquiry process of science (Toolbox 2)
- Social: interest in human relationships, public welfare, or society
- Technological: interest in the design and use of tools and processes that solve practical problems to satisfy peoples' wants and needs (Toolbox 3)

Step 3 Conduct research on the issue and the different viewpoints.

You will be able to suggest an appropriate solution to an issue only if you understand the issue and the different viewpoints. It's important to gather unbiased information about the issue itself and then consider the information provided by people with different viewpoints.

Develop specific questions that will help to guide your research. Questions for the playing field issue might be:

- How many people will use the playing field?
- Is there another more suitable site for the playing field?
- What kind of birds nest in these trees? Could they nest elsewhere in the area?
- What is run-off and why is it a problem?
- What would be the full cost of building the playing field (including the cost of removing the trees)?

Conducting research may involve interviewing people, reading books and magazines, searching the Internet, or making a field trip. It is important to evaluate your sources of information to determine if there is a bias and to separate fact from opinion. In this step, you are trying to gain a better understanding of the background of the issue, the viewpoints of different groups, the alternative solutions, and the consequences of each alternative.

Step 4 Generate a list of alternative solutions.

Examine the background of the issue and the viewpoints in order to generate a list of alternative solutions. Brainstorming can be a useful component of this step. Use your research to help guide your thinking.

Examples of possible alternatives for the issue in step 1 might be as follows:

- Cut the trees and build the playing field.
- Leave the park as it is.
- Find another more suitable location.
- Modify the plan in the existing park.

Step 5 Analyze the consequences for each alternative.

Decide how you will measure the risks and benefits for the consequences of each alternative solution. You may decide to examine the importance, likelihood, and duration of each possible consequence. The importance of the consequence and the likelihood of its occurrence can be ranked high (3), moderate (2), low (1), or none (0). Duration is considered short term (S) if it is less than 50 years or long term (L) if it is longer than 50 years. Ask how many people will benefit from the alternative and how many will be affected negatively. Make sure to consider health and safety.

For the playing field example, you could analyze the consequences of each alternative solution in a table like the one shown below.

Analysis of Consequences: Alternative 1— Build the playing field in the park.

Consequence	Importance (3,2,1,0)	Likelihood of occurrence (3,2,1,0)	Duration (S,L)
Trees cut	2	3	l
Run-off	3	3	S
Birds move	2 to 1	3	l
Playing field well used	2	2	possibly l
Development and maintenance cost	2 to 1	3	l

Step 6 Reflect and decide on the best course of action.

Evaluate your decision making process to ensure that each step is completed as fully as possible. Consider the consequences of the alternative solutions and how people will respond to each one. Then decide on what you think is the best course of action.

Step 7 Communicate your findings.

Communicate your findings in an appropriate way. For example, you may prepare a written report, a verbal presentation, or a position for a debate or a public hearing role-play. Defend your position by clearly stating your case and presenting supporting evidence from a variety of sources.

MEASUREMENT

Observations from an experiment may be **qualitative** (descriptive) or quantitative (physical measurements). **Quantitative** observations help us to describe such things as how far away something is, how massive it is, and how much space it takes up. Quantitative observations are the most useful and require the use of accurate measurements.

Measuring in SI

Most countries and scientific communities have agreed on the use of one system of measurement, making worldwide communication much more efficient. This system is called “le Système international d’unités” or SI for short. SI is based on the metric system. Base units are used, and prefixes are added to change the base units by multiples of ten. Conversion from one unit to another is relatively easy if you know the base units and the meaning of the prefixes. The table below shows the prefixes, their symbols, and their meanings. A kilometre for example is equal to 1000 m and 1 millimetre is 0.001 m or 1 m = 1000 mm.

Common Metric Prefixes

Prefix	Symbol	Meaning	Exponential form
giga	G	billion	10^9
mega	M	million	10^6
kilo	k	thousand	10^3
hecto	h	hundred	10^2
deca	da	ten	10
deci	d	one tenth	10^{-1}
centi	c	one hundredth	10^{-2}
milli	m	one thousandth	10^{-3}
micro	µ	one millionth	10^{-6}

Scientific Notation

Scientific notation is often used to express either very large or very small numbers. It is based on the use of exponents. A number between one and ten is followed by 10 raised to a power.

Example 1: A cell diameter of 0.000 15 mm could be written as 1.5×10^4 mm.
Example 2: The speed of light is 3.00×10^8 m/s or 300 000 000 m/s.

SI Base Units

Measurement	Base unit	Symbol
mass	kilogram	kg
length	metre	m
temperature	Kelvin	K
time	second	s
electric current	ampere	A
amount of substance	mole	mol
intensity of light	candela	cd

Converting SI Units

It is important to know how to convert from one SI unit to another. The following steps will help you convert between units.

1. Begin by writing the measurement that you want to convert.
2. Multiply by a factor that shows the relationship between the two units you are converting. Write this relationship as a fraction, putting the units you are converting *to* in the numerator. This will allow you to cancel the given units you started with.
3. The conversion may sometimes require two or more steps. (see example 2) This method of solving problems is referred to as **unit analysis**.

Example 1: 56 cm = ________ m

$$56\ \cancel{\text{cm}} \times \frac{1\ \text{m}}{100\ \cancel{\text{cm}}} = \frac{56\ \text{m}}{100} = 0.56\ \text{m}$$

Example 2: 3200 cm = ________ km

$$3200\ \cancel{\text{cm}} \times \frac{1\ \cancel{\text{m}}}{100\ \cancel{\text{cm}}} \times \frac{1\ \text{km}}{1000\ \cancel{\text{m}}} = \frac{3200\ \text{km}}{100 \times 1000} = 0.3200\ \text{km}$$

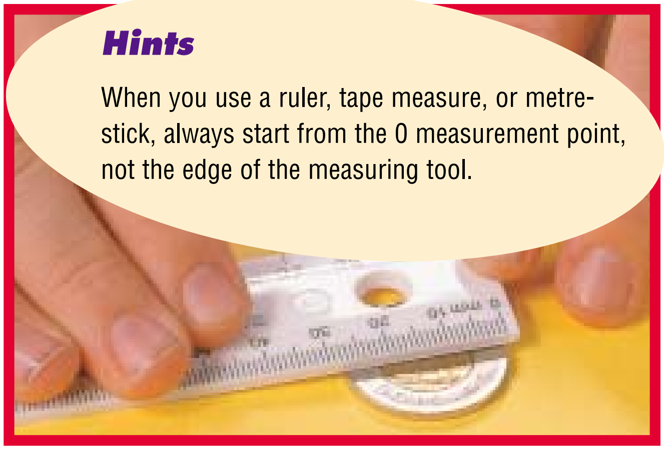
Measuring in SI

Length

Length indicates the distance between two points. The metre is the base unit for measuring length. Long distances are measured in kilometres (km) and small distances are commonly measured in centimetres (cm) or millimetres (mm). The instrument that you use will determine the number of decimal places in your measurement. The last digit of any measurement is always uncertain.

CHECK IT YOURSELF

Which length unit would you use for each of the following? Why?
- the height of a table
- the depth of a lake
- the width of a dime
- the length of a skating rink
- the distance from Lethbridge, Alberta, to Truro, Nova Scotia
- the distance from Earth's core to its surface



Hints

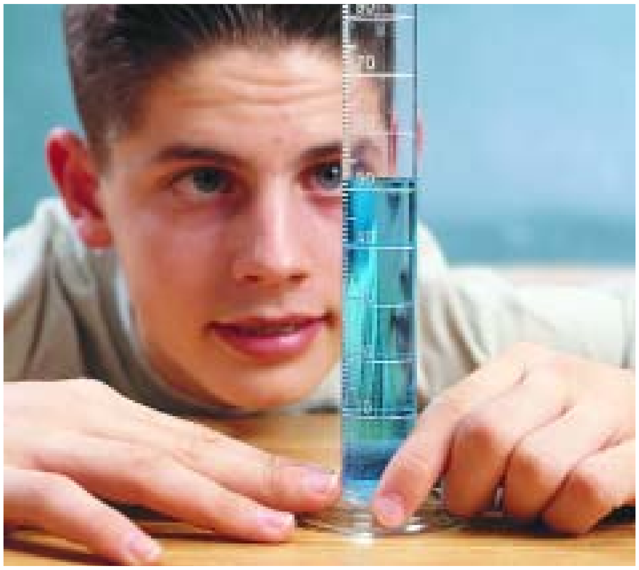
When you use a ruler, tape measure, or metre-stick, always start from the 0 measurement point, not the edge of the measuring tool.

When you use a measuring tool such as a ruler, look directly in line with the measurement point, not from an angle. This coin measures 28.0 mm or 2.80 cm.

Volume

Volume indicates the amount of space that something takes up or occupies. Volume is called a derived unit because there is no base unit. Common units used to measure volume include litres (L) for liquids and cubic centimetres (cm^3) for solids. Remember that 1 mL = 1 cm^3.

At home, you often use a measuring cup to determine the volume of something. At school, you usually use a graduated cylinder. Here, "graduated" means a container that has been marked with regular intervals for measuring. For example, a measuring cup, a beaker, and a thermometer are all graduated, but the accuracy of the measurement is different with each measuring instrument or tool.



When you add a liquid to a graduated cylinder, the top of the liquid is curved near the sides of the cylinder. This curve is called a *meniscus*. To measure the liquid's volume properly, you need to observe the liquid's surface from eye level so you can see the flat, bottom portion of the curve. Ignore the sides. The volume in this cylinder is 52 mL.

CHECK IT YOURSELF

1. Which of the following tools would give you a more accurate measurement of volume? Explain why.
   - a measuring cup
   - a teaspoon
   - a graduated cylinder
2. Explain how you could determine the volume of a small irregularly shaped rock?

Mass and Weight

The terms mass and weight do not mean the same thing, even though they are often used that way. The mass of something tells you the amount of matter it contains. The weight of an object is a measure of the force of gravity acting upon it.

The base unit for mass is the kilogram. It is the only base unit in the SI system that has a prefix. This is because the gram is such a small unit of measurement. The mass of objects is, however, often measured in grams using different types of balances. You may have a triple beam balance, an equal arm balance, or an electronic scale in your school.

Continued on next page →

The equal arm balance and triple beam balance basically work in the same way. You compare the mass of the object you are measuring with standard or known masses (or their mass equivalent values on the triple beam).

equal arm balance

An equal arm balance has two pans. You place the object whose mass you want to know on one pan. On the other pan, you place standard (known) masses until the two pans are balanced (level). Then, you just add up the values of the standard masses. The total is the mass of the object you are measuring.

triple beam balance

A triple beam balance has a single pan. You place the object you are measuring on the pan. You adjust the masses on the beams until the beam assembly is level. Then, you add up the mass equivalent values of the beam masses from the scales on the beam.

Electronic balances allow you to **tare** or zero the balance with an object on it. For example, this allows you to ignore the mass of a beaker and measure the mass directly. You do not have to subtract the mass of the beaker.

You can use a spring scale to measure weight. A spring scale is sometimes called a force meter and measures force in newtons. A newton is a derived unit and is equal to 1 kg/m^2.

A spring scale has three main parts: a hook, a spring, and a measuring scale. The hook at the end is used to attach the object to the scale. The spring pulls on the object. As the spring pulls, the pointer moves along the measuring scale.

spring scale

To measure the weight of an object, first hang the spring scale from a clamp on a retort stand. Then hang the object from the hook of the spring scale. Once the pointer stops moving, record the measurement.

CHECK IT YOURSELF

1. The object on the triple beam balance is a water-filled beaker, so the balance is measuring the mass of the water plus the mass of the beaker. What if you wanted to measure just the mass of the water in the beaker? Describe, step-by-step, how you would do it.
2. How would you measure the mass of an apple? How would this be similar to and different from measuring the mass of a pile of salt?

Temperature

The Celsius temperature scale is commonly used in the metric system, even though the Kelvin degree is the base unit. You will use the Kelvin scale later as you learn more about matter in higher grades. Water boils at 100°C and freezes at 0°C.

Estimating

It is important to be able to estimate or guess the length, mass, or volume of various objects before you measure. This process will allow you to decide whether your measurements are accurate or if there is instrument error. It will also help you to decide which tool to use. Sometimes, you can estimate by comparing one object with another object that has known measurements. For example, if you are asked to estimate the volume of your drink, you could estimate by comparing it with a large jar of mayonnaise in your fridge (which has its volume marked on the label).

For a large object or distance, you might divide it up into portions in your mind and guess the length, volume, or mass of one portion. You then multiply that guess by the number of imaginary portions to estimate the measurement of the whole.

Sometimes, it is useful to estimate the measurement of an object before you actually measure it. You might do this to help you decide which units of measurement and which measuring tool to use. In other cases, you might not be able to measure an object at all. In this case, an estimate of its length, volume, or mass might be the best you can do.

Try to estimate the measurements of the items listed below. Include the measurement units that you think should go with your estimates. Then, measure them to see how close your estimates were to the real values. Did you choose the correct measurement units? If you don't have some of these items in your classroom, check at home.

Object	Length	
	estimate (cm)	actual value (cm)
pencil		
height of your teacher's desk		
length of your classroom		

Object	Mass	
	estimate (g)	actual value (g)
this textbook		
banana from someone's lunch		
piece of chalk		

Object	Volume	
	estimate (mL)	actual value (mL)
amount of water poured into an empty jar		
marker cap		
drink thermos		

WRITING REPORTS

Toolbox 2 shows you how to plan a science experiment. Toolbox 3 shows you how to do technological design, and Toolbox 4 shows you how to use a decision making process for social and environmental issues. This toolbox will help you write a report so you can communicate the procedure and results of your work.

Here is a list of things you should try to do when writing your science reports.

- Give your report or project a title.
- Tell readers why you did the work.
- State your hypothesis or describe the design challenge.
- List the materials and equipment you used.
- Describe the steps you took when you did your experiment, designed and made your product, or considered an issue.
- Show your experimental data, the results of testing your product, or the background information on the issue.
- Interpret and analyze the results of your experiment.
- Make conclusions based on the outcome of the experiment, the success of the product you designed, or the research you did on an issue.

Give your report or project a title.

Write a brief title on the top of the first page of your report. Your title can be one or two words that describe a product you designed and made, or it can be a short sentence that summarizes an experiment you performed.

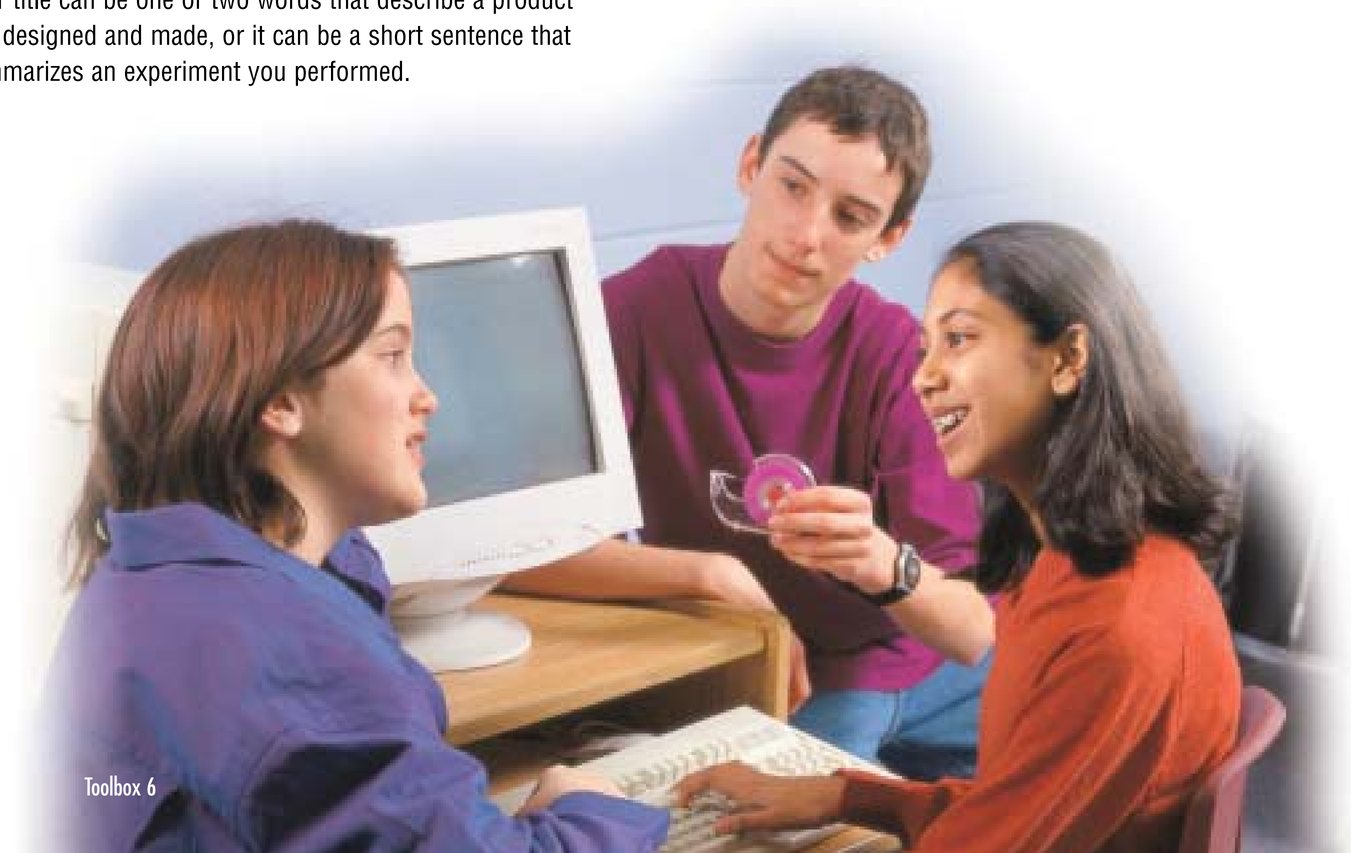
Tell readers why you did the work.

Use a heading such as "Introduction" or "Purpose" for this section. Here, you give your reasons for doing a particular experiment, designing and making a particular product, or considering a specific issue. If you are writing about an experiment, tell readers what your cause-and-effect question is. If you designed a product, explain why this product is needed, what it will do, who might use it, and who might benefit from its use. If you were considering an issue, state what the issue is and why you have prepared this report about it.

State your hypothesis or describe the design challenge.

If you are writing about an experiment, use a heading such as "Hypothesis." Under this heading, you will state your hypothesis. Your hypothesis must indicate the relationship between the manipulated and responding variable. Remember, your hypothesis is your guess at the solution to a problem or question. Your hypothesis makes a prediction that your experiment will test.

If you are writing about a product you designed, use a heading such as "Design Challenge." Under this heading, you will describe why you decided to design your product the way you did. Explain how and why you chose your design over other possible designs.



List the materials and equipment you used.

This section can come under a heading called “Materials and Equipment.” List all the materials and equipment you used for your experiment or design project. Your list can be in point form or set up as a table or chart. Remember to include the exact amounts of materials used, when possible (for example, the number of nails used in building a model or the volumes and masses of substances tested in an experiment). Include the exact measurements and proper units for all materials used.

Also include diagrams to show how you set up your equipment or how you prepared your materials. Remember to label the important features on your diagrams. (See Toolbox 8 for drawing tips.)

Describe the steps you took when you did your experiment, designed and made your product, or researched the issue.

Under a heading called “Procedure” or “Method,” describe, in detail, the steps you followed when doing your experiment, designing and making your product, or considering an issue. List only one step per line and number each step. If you made a product, describe how you tested it. If you had to alter your design, describe in detail how you did this.

Show your experimental data, the results of testing your product, or the background information on the issue.

Give this section a heading such as “Data,” “Observations,” or “Background Information.” In this section, you should show the data or information you collected while performing the experiment, testing your product, or researching an issue. In reporting about an issue, use only a summary of the essential information needed for a reader to understand the issue and different viewpoints about it.

Use tables, diagrams, and any other visual aids that show the results of your tests. If you performed your experiment a few times, give results for each trial. If you tested different designs of your product, give results for each design.

Interpret and analyze the results of your experiment.

Interpret and analyze the data you collected in your experiment. Calculations, graphs, diagrams, charts, or other visual aids may be needed. (See Toolbox 7 for graphing tips.) Explain any calculations or graphs that you used to help explain your results.

Make conclusions based on the outcome of the experiment, the success of the product you designed, or the research you did on an issue.

You can call this last section of your report “Conclusions.” In one or two paragraphs, explain what your tests and experiments showed, or what decision you made as a result of your research.

If you did an experiment, explain if your results were predicted by the hypothesis. Describe how you might adjust the hypothesis because of what you learned from doing the experiment, and how you might test this new hypothesis. Evaluate the sources of error in the experiment you performed and evaluate the design. How could you change things to get more reliable results?

If you made a product, explain if your design did what it was supposed to do, or worked the way it was supposed to work. If you changed the design of your product, explain why one design is better than another.

Describe the practical applications your product or experiment might have for the world outside the classroom.

If you considered an issue, explain why you made the decision that you did. Briefly summarize the supporting evidence for your decision. If necessary, explain how your decision responds to different viewpoints on the issue.

GRAPHING

Creating Data Tables

Science and technology often involve collecting a lot of numerical data. It is important to record these data or observations in an organized, meaningful manner. Data tables are helpful tools for organizing information.

First give your data table a title that accurately describes the information you will be recording. Next list the manipulated variable in the first column of your table. As the experimenter, you will decide the intervals for the collection of the results. The responding variable is the heading of the next column. The units of measurement for each of the variables are included with this heading and are not written with each measurement. Additional columns are added to record other related data. It is important to design a data table before you conduct your experiment. A data table will help you become aware of the variables and provide you with an organized place to record your results.

For example, here are some data collected by a group of students investigating temperature changes. They poured hot water into a large container (container A) and cold water into a smaller container (container B). After recording the starting temperatures in each container, they placed Container B inside Container A and took measurements every 30 s until there were no more temperature changes.

EVIDENCE

Temperature of Water in Container A and Container B

Time (s)	Temperature (˚C) of water in Container A	Temperature (˚C) of water in Container B
0	51	0
30	45	7
60	38	14
90	33	20
120	30	22
150	29	23
180	28	24
210	27	25
240	26	26
270	26	26
300	26	26

Creating Line Graphs

Sometimes, however, it's difficult to see if there are any patterns in the numbers. That's when it's useful to reorganize the data into graphs. Graphs help to interpret data collected during an experiment.

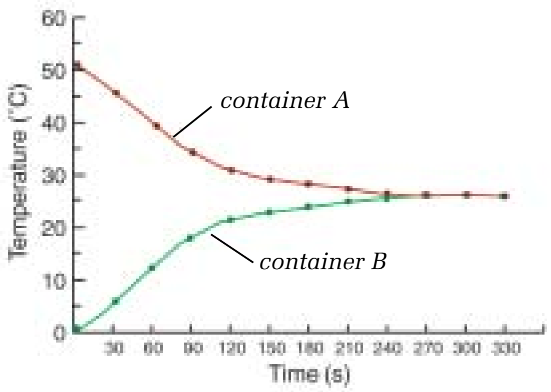
A graph is similar to a picture or diagram that shows more easily how numbers are related to one another. You have probably drawn a lot of graphs over the years in your studies of mathematics, geography, and, of course, science and technology.

Line graphs are good for exploring data collected for many types of experiments. Using line graphs is a good way to analyze the data of an experiment that are continually changing.

Here are the data the students investigating temperature changes collected shown as a line graph. On the graph, they put the manipulated variable, time, on the *x*-axis, and the responding variable, temperature, on the *y*-axis.

ANALYSIS

Temperature of Water in Container A and Container B



Always look for a pattern on the graph after the individual points are plotted and before you connect the points. If you observe a pattern, draw a "line of best fit" with the points evenly located either on or around the line. This process is called **interpolation**.

If there is more than one line on the graph, you will need a legend to explain what each line represents.

Extrapolation is used in graphing to make predictions. When you extrapolate you extend the line you obtained from your experimental data to show the relationship between the data for values that were not experimentally determined. This assumes that the trend that was observed will continue further, which is not always the case.

Check It Yourself

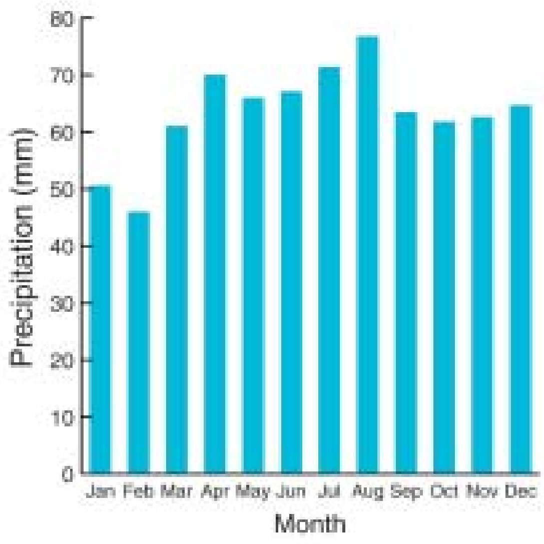
1. The axes are the two number lines that run horizontally and vertically. Which is the *x*-axis and which is the *y*-axis? Which axis is used for the manipulated variable? Which is used for the responding variable?
2. Why would you use a sharp pencil and a ruler to draw the axes and plot the graph lines?
3. How was the scale for each axis chosen?
4. How was each point on the graph plotted (placed on the graph)?
5. Why were the graph lines drawn where they are?
6. Is there anything missing or anything else you would add to this graph?

Creating Bar Graphs

Bar graphs are useful for showing relationships between separate sets of data. For example, the chart below shows the monthly average precipitation (both snow and rain) for a city in Canada. Compare the data in this chart with how they "look" when they are reorganized in the form of a bar graph. On the graph, they put the manipulated variable, month, on the *x*-axis, and the responding variable, precipitation, on the *y*-axis.

Month	Average Precipitation (mm)
January	50.4
February	46.0
March	61.1
April	70.0
May	66.0
June	67.1
July	71.4
August	76.8
September	63.5
October	61.8
November	62.7
December	64.7

Average Precipitation



Hints

Scales for bar graphs are often rounded off to the nearest whole number.

Check It Yourself

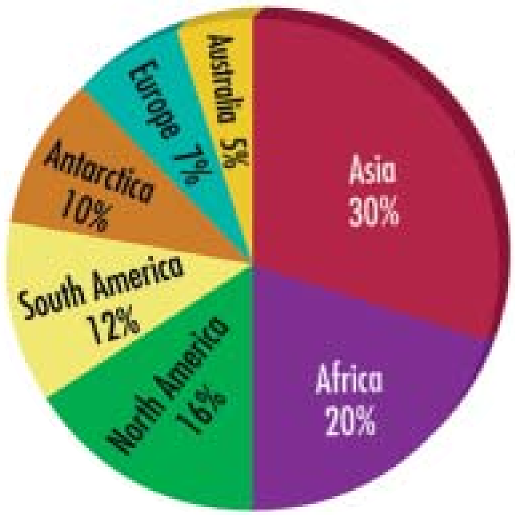
1. Which axis is used for the manipulated variable? Which is used for the responding variable?
2. How was the scale for each axis chosen?
3. The yearly average precipitation for this city is 761.5 mm. How would you modify the bar graph to include this additional information?

Creating Circle (Pie) Graphs

A circle graph is useful when you want to display data that are part of a whole. For example, in the circle graph on page 494, the "whole" is Earth's total land area. The "parts" are the approximate percent of land made up by each continent.

Continued on next page →

Percentage of Earth's Land Area



Hints

You might consider using a computer to draw your circle graphs. Some computer drawing programs allow you to use different colours for the different sections of your graph, making it easier to read.

Compare the data in this chart with how they "looked" when they were organized in the form of a circle graph on the previous page. Which can you interpret more easily and more quickly?

Continent	Percentage of Earth's Land Area
Asia	30%
Africa	20%
North America	16%
South America	12%
Antarctica	10%
Europe	7%
Australia	5%

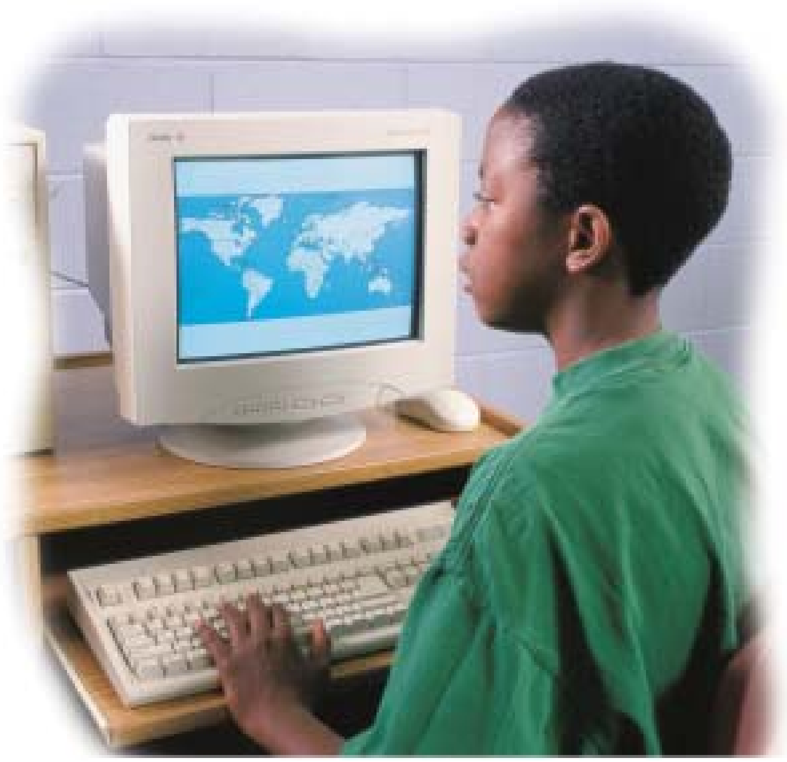
CHECK IT YOURSELF

1 How were the angles in the circle graph determined? Use the Hints information below if you would like some help to start.

Hints

- The angle at the centre of a circle is 360˚.
- To calculate the percentage for Antarctica, for example, you need to determine what 10% of 360˚ is. 10% is the same as 10/100, which is the same as 0.1. So 0.1 × 360˚ = 36˚.

2 How could you use this information to hand-draw your own circle graph?



DIAGRAMS

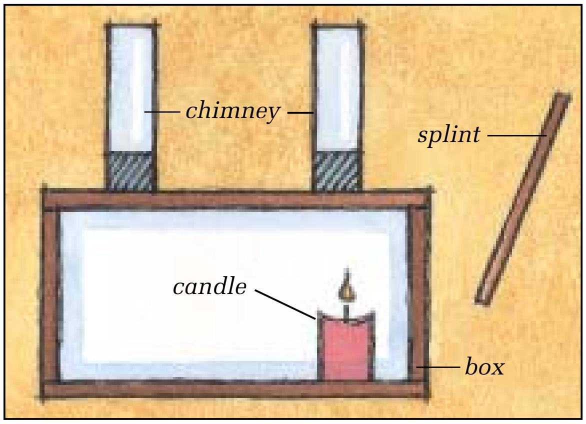
Have you heard the saying, "a picture is worth a thousand words"? In science, a picture can be worth even more. A carefully done diagram can help you express your ideas, record important information, and experiment with designs.

Four types of diagrams you can use include: a Simple Sketch, a Technical or Scientific Diagram, an Orthographic (Perspective) Diagram, and a Computer-Assisted Diagram (CAD). Examples of each type of diagram are shown. A side view and a top view for a simple sketch are also shown. These different views can be made for each type of drawing.

Practise making the four types of diagrams on your own.

This photo shows the set-up of an experiment. Practise drawing it using one or several of the diagram types presented here. What labels would you include? Would your labelling choices change depending on the style of diagram you make?

A Simple Sketch (Front View)



TOOLS OF THE TRADE

You will need the following equipment for each type of diagram.

Hand-drawing tools

- a sharp pencil or mechanical pencil
- a pencil sharpener or extra leads
- an eraser
- a ruler

For simple diagrams

- blank, white paper

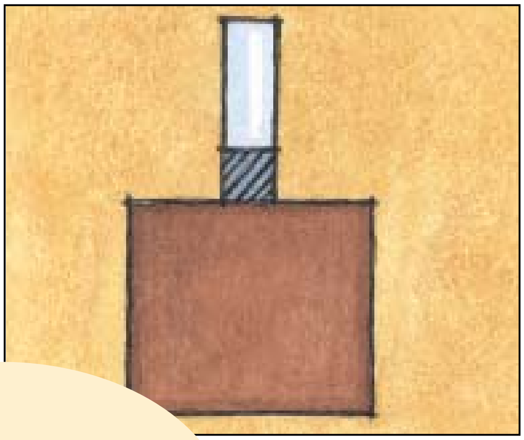
For technical and orthographic diagrams

- blank graph paper

For computer-assisted diagrams

- blank diskette
- access to computer and software

A Simple Sketch (Side View)



Hints

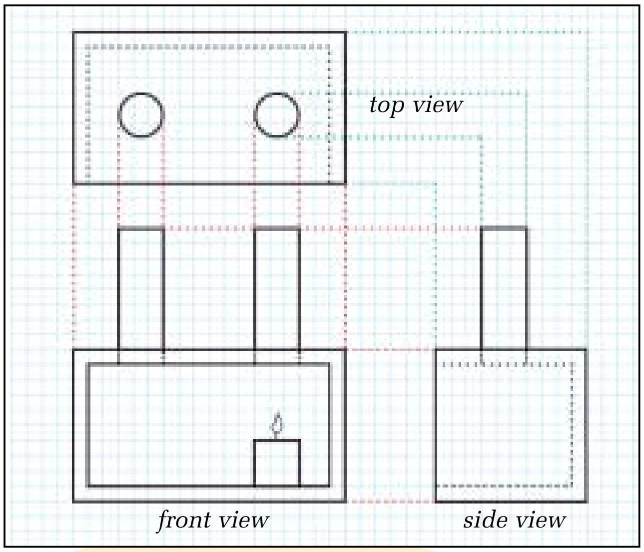
If you're going to use your diagram to help you design a structure, include a top, side, and front view.

Continued on next page →

REMEMBER!

- Give your diagram a title at the top of the page.
- Use the whole page for your diagram.
- Include only those details that are necessary, keep them simple, and identify them by name.
- If you need labels, use lines, not arrows. Place your labels in line with the feature being labelled, and use a ruler to keep your lines straight.
- Don't use colour or shading unless your teacher asks you to.
- Include notes and ideas if the sketch is a design for a structure or an invention.

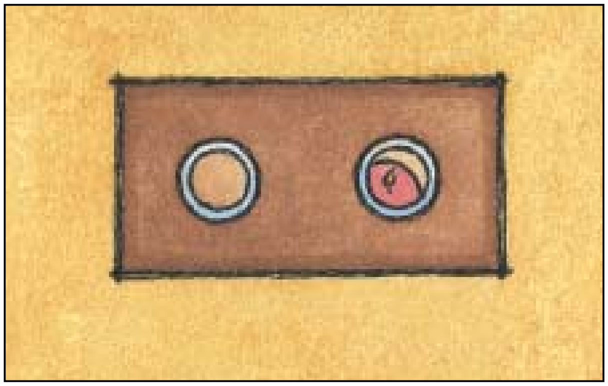
A Technical Diagram



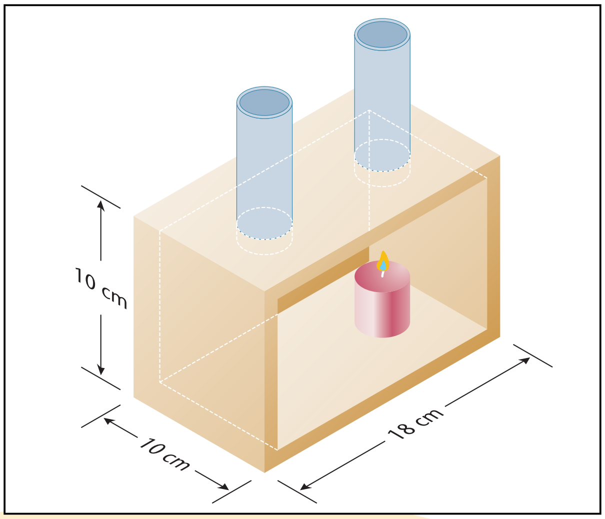
Hints

You can use the squares of your graph paper to make the scale of your orthographic diagram accurate. For example, suppose that each square stood for 1 cm. If what you're drawing is 14 cm long, you would use 14 squares to represent its length.

A Simple Sketch (Top View)



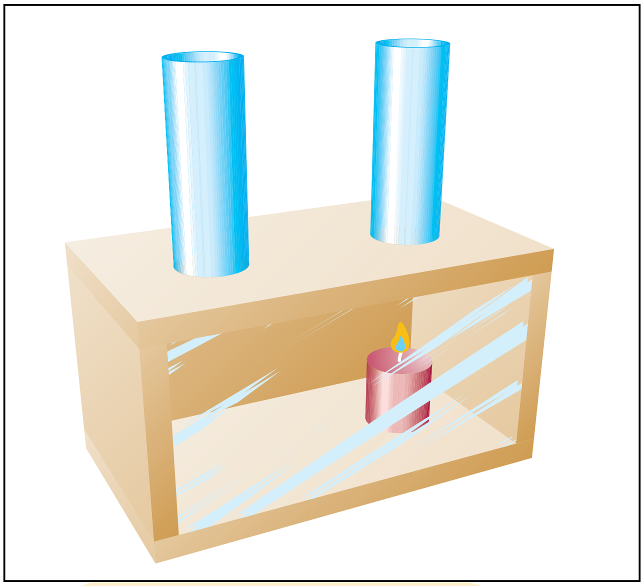
An Orthographic (Perspective) Diagram



Hints

Use graph paper to help you with the details of your diagram if you don't have a ruler handy.

A Computer-Assisted Diagram



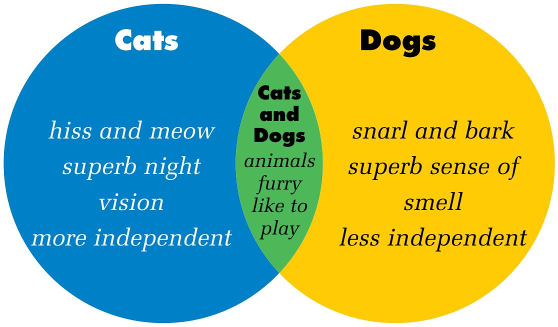
Hints

One advantage of using a computer is that you can easily change your work. After saving your original, practise making changes and moving the image around.

VISUAL ORGANIZERS

Many people find it helpful to view, share, gather, organize, and explore information in the form of pictures or diagrams. You have probably learned and used several of the techniques shown here. Try out the ones that are less familiar to you. You may find that some help you open up your thinking in new and creative ways.

Venn Diagram



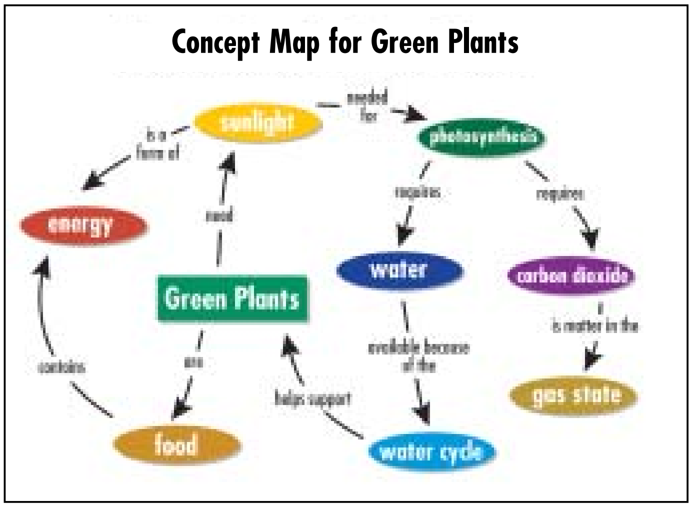
This is often used to compare two things. To use a Venn diagram, ask yourself questions such as:

- What things do I want to compare?
- What do they have in common?
- In what ways are they different?

Hints

You can use Venn diagrams to compare more than two things. Try it and see!

Concept Map



A concept map, or a mind map, is a kind of web diagram with many uses. For example, you can use it to:

- review something you already know
- gather information about something you don't know
- explore new ways of thinking about something
- outline plans for an essay, a song, an experiment, a design challenge, a science project, and multimedia presentations

To use a concept map, ask yourself questions such as:

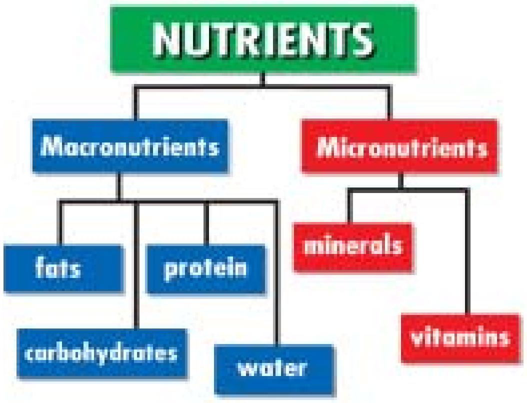
- What is the key idea, word, question, problem, or issue to build the map around?
- What words, ideas, objects, or questions come to mind when I think about the item at the centre of my map?

Hints

If you have access to a computer, find out if it has the software to help you make your visual organizers.

Continued on next page →

Tree Diagram



Tree diagrams allow you to see how things originate or how larger things can be broken down into their smaller components. Tree diagrams also allow you to organize or group concepts and things. Knowing about the parts of something helps you to better understand the concept or thing you are studying.

Comparison Matrix

Things to Compare	Characteristics: can move	needs food	can communicate	can breathe
goat	X	X	X	X
tree		X		
rock				
person	X	X	X	X

This is often used to compare the characteristics or properties of a number of things. To use a comparison matrix, ask yourself questions such as:

- What things do I want to compare?
- What characteristics will I choose to compare?
- How are the things I'm comparing similar and how are they different?

Hints

A comparison matrix can be useful for brainstorming.

Note Taking Chart

A note taking chart helps you understand how the material you are reading is organized. It also helps you keep track of information as you read.

Your teacher will assign several pages for you to read. Before you begin reading, look at each heading and turn it into a question. Try to use "how," "what," or "why" to begin each question. Write your questions in the left hand column of your chart. Leave enough space between each question so that you can record information from your reading that answers your question.

For example, you may be assigned several pages about the scientific meaning of work. These pages contain the following headings:

- The Meaning of Work
- Calculating Work
- Energy and Work

Here's what a note taking chart might look like for this reading:

Questions from Headings	Answers from Reading
What is the meaning of the word "work"?	– work is done when a force acts on an object to make the object move – If there's no movement, no work is done – just trying to push something isn't work—it's only work if the object moves
How do you calculate work?	
How are energy and work related?	

RESEARCHING TOPICS

Research involves finding out something about a topic or subject. That means going to certain resources that will give you *accurate* information. Information can be found just about anywhere: from your home bookshelves to the public library, from asking experts to looking on the Internet. Here are the steps you need to follow when you do your research.

Choosing a Topic

In some situations your teacher may give you the topic to research. Other times, you will have to select one of your own. If you have trouble coming up with a topic, try brainstorming ideas either by yourself or with a group. Remember, when you brainstorm, there are no right or wrong answers, just "ideas." Here are some brainstorming suggestions to get you started:

- List two or three general topics about science that interest you.
- For each topic, write down as many words or ideas that relate to that topic. They don't have to be directly connected to science. (Just spend a few minutes.)
- Share your list with others and ask them to suggest other possibilities.
- Now you have to "filter" your idea list to find a topic to research. In other words, go through your ideas until you find two or three that interest you. To help you narrow your idea list, try grouping similar words or ideas, modifying what you've written, or even writing down a new idea. Sometimes, too, working with other people will help to focus your thoughts.
- When you settle on an idea for your topic, write it down. Try to explain it in a couple of sentences or a short paragraph. Do that for each of your two or three topic ideas.
- Have your teacher approve your topics. Now you're ready to go!

The next thing you have to do is settle on one topic. (Remember, you should start your research with two or three topic ideas.) One way to help you decide is to determine how easy it will be to find information on your topic.

- Use some of the resources listed on the next page to do your research.
- If you can't easily find at least *four* references for a topic, consider dropping it and going on to the next idea.

Hint

Sometimes topics are too broad in scope or too general to make good research reports (for example, "transportation" instead of just "bicycles"). Try rewriting your topic to narrow its focus.

If all the topics are easy to research, then you'll need some other criteria to help you decide.

- Which of your topics interest you the most?
- Which topic is *not* being researched by many students in your class?
- Which topics interest you the least? (Eliminate them.)

Which Topic Should I Choose?

"How does product design help sell a product?"

"How do gears improve the performance of a bicycle?"

How Hard Will It Be to Find Information?

How Camera Lenses Are Manufactured

How Mirrors Are Used in Some Optical Devices

Continued on next page →

Once you've finally chosen your topic, you might want to work with other students and your teacher to:

- finalize its wording
- make sure it matches the project or assignment you are doing

Finding Information

There are many resources that you can use to look up information. Here is a suggested list. You'll find some of these resources:

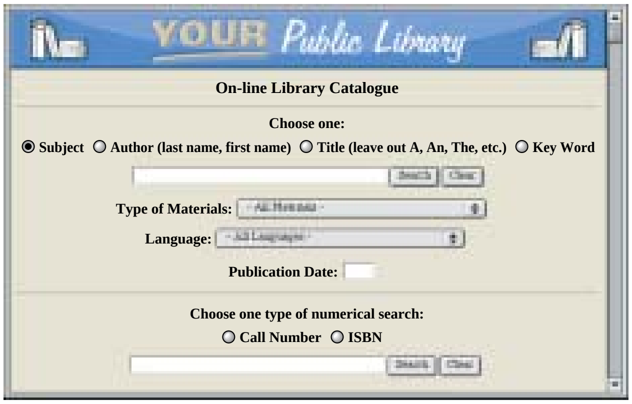
- in your school
- in your community (such as your public library)
- on the Internet
- in CD-ROM encyclopedias and databases

Resource	✓	Details
Books		
CD-ROMs		
Community Professionals or Experts		
Encyclopedias		
Films		
Government Agencies (local, provincial, and federal)		
Internet Sites		
Journals		
Laser Disks		
Library Catalogue		
Newspapers		
Non-profit Organizations		
Posters		
Videos		

Searching Tips

Finding Information at Your Library

Library computer catalogues are a fast way to find books on the subjects you are researching. Most of these electronic catalogues have four ways to search: *subject*, *author*, *title*, and *key words*. If you know the *author* or *title* of a book, just type it in. Otherwise, use the *subject* and *key words* searches to find books on your topic.



- If you're doing a *subject* search, type in the main topic you are researching. For example, if you're searching for information on solar energy, type in "solar energy." If there are no books on that topic, try again using a more general category, like "renewable resources," or just "energy."
- If you're doing a *key words* search, type in any combination of words that have to do with your topic. For the solar energy example, you could type in words such as: "renewable energy sun solar panels." Using several key words will give you a more specific search. Using only one or two key words, like "sun" and "energy," will give you a more general search.

Hint

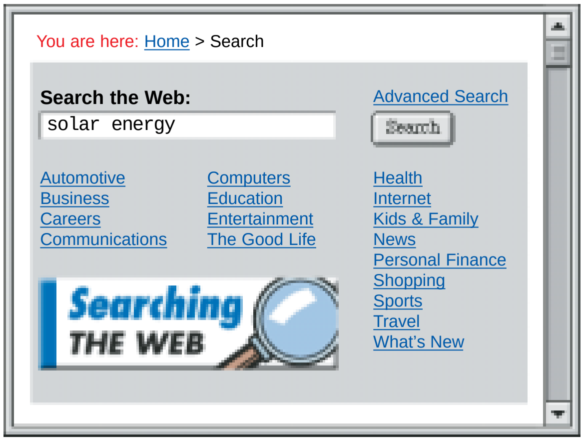
The library may also have a way to search for magazine articles. This is called a *periodical search*. It's especially useful for searching for information on events and/or discoveries that have taken place recently. Ask your librarian how to do a periodical search.

Also, your library will probably have a reference section where all the encyclopedias are kept. There you may find science and technology, environmental, or even animal encyclopedias, as well as other reference books.

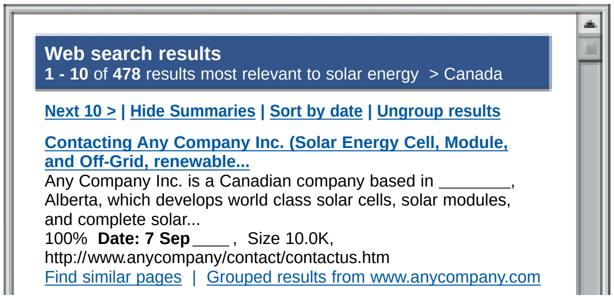
Finding Information on the Internet

On the Internet, you can use searching programs, called *search engines*, to search the Internet on just about any subject. To find a search engine, ask your teacher or click on the search icon found at the top of your Internet browser. Here are some suggestions on how to search the Internet:

- Once you reach a search engine Web page, type in key words or phrases that have to do with your topic. For solar energy, you could type in "solar energy," "solar panels," "renewable resources," or any combination of these and other similar words.



- The search engine will display a list of Web pages it has found that have these words or phrases somewhere in them. Click on any Web page on the list that looks interesting.
- Quite often you will get a long list of possible Web pages to look at. You may need to make your search more specific. This can be done by adding other key words to your search. For example, if you were looking for solar energy examples in Canada and used the key word "solar energy," you may want to do a second search of these results with the key word "Canada" added.
- Don't forget to record the addresses of any interesting Web pages you find. Why not work with a friend? One person can record the addresses of Web pages while the other person searches on the computer. Or you can save it as a *bookmark*. Your Internet browser allows you to save Web pages for easy future access. Check with your teacher or librarian to find out how to save and organize your bookmarks.



Before You Start!

Check with your teacher to find out what your school's policy is about acceptable use of the Internet. Remember to follow this policy whenever you use the Internet at school. Be aware as you use the Internet that some Web sites may be strongly biased toward a specific point of view. If you are looking for scientific or technical information, educational or government Web sites are generally reliable.

Recording Your Information Sources

An important part of researching a topic is keeping track of where you obtain information. As you do your research, you are reading through or viewing a variety of different sources. Some may be in print, such as magazines and books. Others may be electronic, such as Web sites and CD ROMs. And others may be visual, such as videos and photos. No matter what sources you use, you should keep track of them.

With this information, you can easily go back and check details. You can also use it to help you respond to any questions about the accuracy or completeness of your report. Your record of information sources should include at least the following basic information:

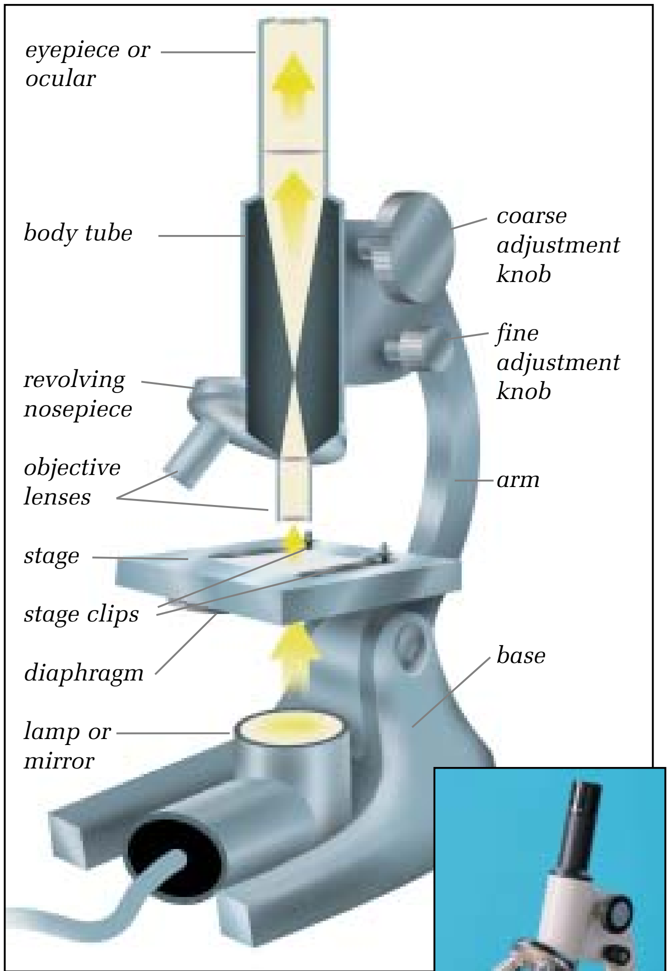
- title or name of the source (e.g., if you read a chapter of a book, you would write down the book's title; for a Web site, you would include the address)
- author's name, if known
- publisher (e.g., for a Web site, this would be the name of person or organization who has put up the site)
- date of publication
- pages consulted

When you prepare your report, your teacher may want you to list your information sources in a specific format. Check what this format will be before you begin your research so that you can collect the details you need to complete your reference list later. You may want to do your own research on formats for such reference lists or bibliographies.

USING A MICROSCOPE

Classroom microscopes are compound microscopes. They are called "compound" because they have two or more lenses for viewing and magnifying objects. To view an object with a microscope, light must travel through the object. For this reason, the full name for your microscope is *compound light microscope*. Usually, it's shortened by leaving the word "light" out.

Before using a microscope, make sure you are familiar with its different parts and their uses. Take a look at the diagram below to remind yourself. Notice the path that light takes through a microscope to your eye.



The microscope you use in class will probably look like this one. Note the use of a mirror instead of a lamp.

How to Use the Microscope

1 Plug in the microscope and turn on the light source. If your microscope uses a mirror instead of a lamp, be very careful *not* to reflect direct sunlight into the microscope. You could badly damage your eyes.

2 Rotate the revolving nosepiece until the low-power objective lens (the smallest one) is pointing at the stage.

3 Place your slide on the stage. Use the stage clips to hold your slide in place.

4 Watch the stage from one side of the microscope. Carefully turn the coarse adjustment knob until the lens is as close to the slide as possible without touching it. Make sure you don't hit the slide with the lens.

5 Look through the eyepiece. Slowly turn the coarse adjustment knob to move the lens away from the stage. This will focus the image.

6 Use the fine adjustment knob to sharpen the focus of the image.

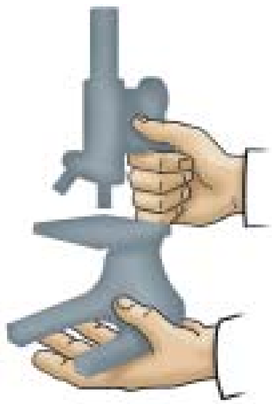
7 When your slide is in focus, try using the medium-power objective lens. Watch from the side of the microscope. Carefully rotate the nosepiece to move the medium-power lens so that it points at the stage. You should hear a "click" when it is in place. Use the fine adjustment knob to focus the image.

Caution!
Never use the coarse adjustment knob with the medium- and high-power objective lenses.

8 When your slide is once more in focus, try using the high-power objective lens. Repeat step 7 to change the lens from medium to high power. Make sure you watch from the side of the microscope to avoid hitting the slide with the lens.

Handling Hints

When using and handling a microscope, be sure to follow these rules:



- Always use both hands to hold and carry a microscope. Support its base with one hand and hold it by the arm with your other hand.
- Place your microscope away from the edge of your desk or work area.
- Except for your notebook, writing tools, and microscope-related equipment such as glass slides, keep your desk or work area clear and neat.
- When you aren't using your microscope, always keep it in an upright position.
- Always hold glass slides by their edges, between your thumb and forefinger.
- Try keeping both eyes open when you look through the microscope. You'll be able to observe longer without tiring the muscles around your eyes.
- When you are finished using your microscope, switch back to the low-power objective, put its plastic cover on, and return it to the place where you got it.

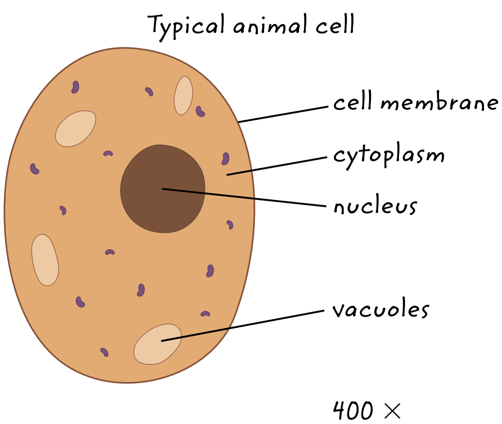
Magnification Calculation

Calculate the magnification power of your microscope by multiplying the power of the eyepiece by the power of the objective lens that you have in position above the specimen. The eyepiece usually has a magnification power of ×10. Objective lenses usually are ×4 (low power), ×10 (medium power), and ×40 (high power). The total magnification possibilities of this microscope would therefore be ×40, ×100, or ×400.

Drawing Hints

Here are some basic guidelines for drawing what you see through the microscope. Your teacher may have other suggestions as well.

1 Start with a sharp pencil and a blank, unlined piece of paper (or a clean page in your notebook). Use the whole page for your drawing.
2 Draw only what you see. Keep your details simple and straightforward. (You don't need to add colouring or shading.)
3 Add labels that identify features by name (if you know them) or with brief notes. Always draw your label lines with a ruler. Arrange your labels and label lines clearly and neatly on the page.
4 Give your drawing a title at the top of the page.
5 The magnification power of your microscope should be indicated in the title of the diagram or under the diagram to the right.



Chemistry Backgrounder

The three tables provided here are designed to help you in your study of chemistry. The first table lists the properties of elements of the first 20 elements of the periodic table, along with several other common elements. The second table gives the chemical names and formulas and main uses of a range of common elements and compounds. The third table is a one-page periodic table for easy reference.

Properties of Elements 1 to 20 and Selected Common Elements

Atomic Number	Name	Colour	Melting Point (°C)	Boiling Point (°C)	Density (g/cm^3)	State and Other Properties
1	H hydrogen	colourless	−259	−253	0.09	gas, reacts with oxygen when ignited with a spark
2	He helium	colourless	−272	−269	0.18	gas, unreactive, odourless
3	Li lithium	fresh-cut surface is silvery	181	1342	0.54	solid, soft, reacts with water to form hydrogen
4	Be beryllium	lead grey	1287	2469	1.85	solid, resists oxidation in air
5	B boron	black	2076	3927	2.46	solid, semiconductor
6	C carbon	graphite is black, diamond is colourless	3527	4027	2.27	graphite is soft solid, diamond is very hard solid, unique in the vast number of compounds it can form
7	N nitrogen	colourless	−210	−196	1.25	gas, odourless, does not react with air or water
8	O oxygen	gas is colourless, liquid is pale blue	−218	−183	1.43	gas, very reactive
9	F fluorine	pale yellow	−220	−188	1.70	gas, most reactive element
10	Ne neon	colourless	−249	−246	0.90	gas, very inert
11	Na sodium	silvery	98	883	0.97	solid, soft, reacts with water to form hydrogen
12	Mg magnesium	silvery white	650	1090	1.74	solid, burns brightly in air, does not react with water
13	Al aluminum	silvery	660	2519	2.70	solid, non-toxic, soft
14	Si silicon	dark grey with a bluish tinge	1414	2900	2.33	solid

Atomic Number	Name	Colour	Melting Point (°C)	Boiling Point (°C)	Density (g/cm^3)	State and Other Properties
15	P phosphorus		44	277	1.82	solid, white phosphorus spontaneously ignites in air
16	S sulfur	lemon yellow	115	445	1.96	solid, odourless, brittle, insoluble in water
17	Cl chlorine	yellowish green	−102	−34	3.21	gas, reacts with nearly all elements, respiratory irritant
18	Ar argon	colourless	−189	−186	1.78	gas, odourless, very inert
19	K potassium	silvery white	63	759	0.86	solid, very soft, reacts with water to produce hydrogen
20	Ca calcium	silvery white	842	1484	1.55	solid, burns in air when ignited, reacts slowly with water, fairly hard
26	Fe iron	lustrous grey	1538	2861	7.87	solid, reactive
28	Ni nickel	lustrous silver	1455	2913	8.91	solid, hard, malleable, ductile, somewhat ferromagnetic, fair conductor
29	Cu copper	shiny reddish	1085	2927	8.92	solid, malleable, ductile, good conductor
30	Zn zinc	bluish pale grey	420	907	7.14	solid, brittle at room temperature, tarnishes in moist air, does not react with water
35	Br bromine	red-brown	−7	59	3.12	liquid, volatile, unpleasant odour, irritates membranes
47	Ag silver	shiny silver	962	2162	10.49	solid, very ductile and malleable, highest conductivity, tarnishes when exposed to air containing sulfur
50	Sn tin	silvery grey	232	2602	7.31	solid, malleable, somewhat ductile, does not react with water
79	Au gold	shiny yellow	1064	2856	19.30	solid, most malleable and ductile metal, good conductor, does not react with air or water
80	Hg mercury	silvery white	−39	357	13.55	liquid, poor conductor of heat relative to other metals, fair conductor of electricity, alloys easily
82	Pb lead	lustrous bluish white	327	1749	11.34	solid, very soft, highly malleable, ductile, relatively poor electrical conductor

Continued on next page →

Common Elements and Compounds

Common Name	Scientific Name	Chemical Formula	Main Uses
Acetic acid	ethanoic acid	$CH_3COOH_{(aq)}$	vinegar
Acetone	propanone	$(CH_3)_2CO_{(l)}$	nail polish remover
Ammonia water	ammonia	$NH_{3(aq)}$	cleansers, deodorizers, etching of aluminum
ASA	acetylsalicylic acid	$CH_3COOC_6H_4COOH_{(s)}$	pain reliever
Aspartame	aspartyl-phenylalanine methyl ester	$C_{14}H_{18}N_2O_{5(s)}$	artificial sweetener
Baking soda	sodium hydrogen carbonate	$NaHCO_{3(s)}$	raising agent in food
Battery acid	sulfuric acid	$H_2SO_{4(aq)}$	car batteries
Bleach/chlorine	sodium hypochlorite	$NaOCl_{(aq)}$	laundry bleach, disinfectant for swimming pools, water supply
Bromine	bromine	$Br_{2(g)}$	fumigants, water purification, flame proofing agents, pesticides
CFCs (e.g., freons)	chlorofluorocarbons (e.g., trichlorofluoromethane)	e.g., $CCl_3F_{(l)}$	refrigerants, asthma inhalers, circuit board cleaners
Chlorine	chlorine	$Cl_{2(g)}$	water treatment, production of paper, dyes, textiles, cleansers
Citric acid	2-hydroxy-1,2,3-propanetricarboxylic acid	$C_3H_4OH(COOH)_{3(s)}$	large amounts in citrus fruits, pH control in foods
Dry ice	carbon dioxide	$CO_{2(s)}$	carbonated beverages
Fluorine	fluorine	$F_{2(g)}$	uranium production, HCFC production
Glucose	glucose	$C_6H_{12}O_{6(s)}$	energy source for organisms
Graphite	carbon	$C_{(s)}$	metal production, pencils
Gypsum	calcium sulfate dihydrate	$CaSO_4{\cdot}2(H_2O)_{(s)}$	drywall
Hydrogen	hydrogen	$H_{2(g)}$	rocket fuel, hydrogenation of oils, cryogenics
Iodine	iodine	$I_{2(s)}$	wound disinfectant, internal medicine, photography, nutrient
Lime	calcium oxide	$CaO_{(s)}$	mortar, steel and glass making, smoke-stack scrubbers
Limestone	calcium carbonate	$CaCO_{3(s)}$	cement and mortar, chalk, marble

Common Name	Scientific Name	Chemical Formula	Main Use
Milk of magnesia	magnesium hydroxide	$Mg(OH)_{2(s)}$	antacid medication
MSG	monosodium glutamate	$C_5H_8NO_4Na_{(s)}$	flavour enhancer
Muriatic acid	hydrochloric acid	$HCl_{(aq)}$	tile cleaner, etching of masonry and marble surfaces
Natural gas	methane	$CH_{4(g)}$	fuel
Oxygen	oxygen	$O_{2(g)}$ and $O_{3(g)}$	rocket fuel, respiratory aid, steel production, cellular respiration, ozone filters out UV rays
PCBs	polychlorinated biphenyls	$C_{12}H_{10-n}Cl_n$	electrical transformers
Peroxide	hydrogen peroxide	$H_2O_{2(aq)}$	antiseptic, disinfectant, bleaching agent
Potash	potassium chloride	$KCl_{(s)}$	fertilizer
Road salt	calcium chloride	$CaCl_{2(s)}$	de-icing and dust control of roads
Rotten egg gas	hydrogen sulfide	$H_2S_{(g)}$	dye, tanning, wood pulp industries
Rubbing alcohol	2-propanol	$CH_3CHOHCH_{3(l)}$	antiseptic
Silica sand	silicon dioxide	$SiO_{2(s)}$	glass
Silver nitrate	silver nitrate	$AgNO_{3(s)}$	antiseptic, photography, treatment of warts
Soda ash	sodium carbonate	$Na_2CO_{3(s)}$	glass, paper, and detergent production
Sugar	sucrose	$C_{12}H_{22}O_{11(s)}$	sweetener, preservative, food for yeast
Table salt	sodium chloride	$NaCl_{(s)}$	flavour
Urea (carbamide)	urea	$NH_2CONH_{2(s)}$	fertilizers, pharmaceuticals, and resins
Vitamin C	ascorbic acid	$C_6H_8O_{6(s)}$	production of connective tissue, antioxidant
Washing soda	sodium carbonate decahydrate	$Na_2CO_3{\cdot}10H_2O_{(s)}$	laundry detergent booster

Continued on next page →

Periodic Table

Key: atomic number — 8; symbol — O; name — Oxygen; atomic mass — 16.0; ion charge — 2−

Solid: S | Liquid: Br | Gas: He

Metal | Metalloid | Non-metal

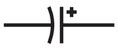
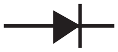
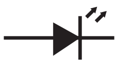
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.0 (1±)																	2 He Helium 4.0
2	3 Li Lithium 6.9 (1+)	4 Be Beryllium 9.0 (2+)											5 B Boron 10.8 (3+)	6 C Carbon 12.0 (4+, 2+)	7 N Nitrogen 14.0 (3−, 5+)	8 O Oxygen 16.0 (2−)	9 F Fluorine 19.0 (1−)	10 Ne Neon 20.2
3	11 Na Sodium 23.0 (1+)	12 Mg Magnesium 24.3 (2+)											13 Al Aluminum 27.0 (3+)	14 Si Silicon 28.1 (4+, 2+)	15 P Phosphorus 31.0 (3−)	16 S Sulfur 32.1 (2−, 4+, 6+)	17 Cl Chlorine 35.5 (1−)	18 Ar Argon 39.9
4	19 K Potassium 39.1 (1+)	20 Ca Calcium 40.1 (2+)	21 Sc Scandium 45.0 (3+)	22 Ti Titanium 47.9 (3+, 4+)	23 V Vanadium 50.9 (2+, 5+)	24 Cr Chromium 52.0 (2+, 3+, 6+)	25 Mn Manganese 54.9 (2+, 7+)	26 Fe Iron 55.8 (3+, 2+)	27 Co Cobalt 58.6 (2+, 3+)	28 Ni Nickel 58.7 (2+, 3+)	29 Cu Copper 63.5 (1+, 2+)	30 Zn Zinc 65.4 (2+)	31 Ga Gallium 69.7 (3+)	32 Ge Germanium 72.6 (4+, 2+)	33 As Arsenic 74.9 (3−, 5+)	34 Se Selenium 79.0 (2−, 4+, 6+)	35 Br Bromine 79.9 (1−)	36 Kr Krypton 83.8
5	37 Rb Rubidium 85.5 (1+)	38 Sr Strontium 87.6 (2+)	39 Y Yttrium 88.9 (3+)	40 Zr Zirconium 91.2 (4+)	41 Nb Niobium 92.9 (5+, 3+)	42 Mo Molybdenum 95.9 (6+, 2+)	43 Tc Technetium (98) (7+, 3+)	44 Ru Ruthenium 101.1 (3+)	45 Rh Rhodium 102.9 (3+)	46 Pd Palladium 106.4 (2+, 3+, 4+)	47 Ag Silver 107.9 (1+)	48 Cd Cadmium 112.4 (3+)	49 In Indium 114.8 (3+, 1+)	50 Sn Tin 118.7 (2+, 4+)	51 Sb Antimony 121.8 (3−, 5+)	52 Te Tellurium 127.6 (2−, 4+, 6+)	53 I Iodine 126.9 (1−)	54 Xe Xenon 131.3
6	55 Cs Cesium 132.9 (1+)	56 Ba Barium 137.3 (2+)	57 La Lanthanum 138.9 (3+)	72 Hf Hafnium 178.5 (4+)	73 Ta Tantalum 180.9 (5+)	74 W Tungsten 183.8 (6+, 2+)	75 Re Rhenium 186.2 (7+, 3+)	76 Os Osmium 190.2 (2+, 3+, 4+)	77 Ir Iridium 192.2 (2+, 3+, 4+)	78 Pt Platinum 195.1 (2+, 4+)	79 Au Gold 197.0 (1+, 3+)	80 Hg Mercury 200.6 (1+, 2+)	81 Tl Thallium 204.4 (1+, 3+)	82 Pb Lead 207.2 (2+, 4+)	83 Bi Bismuth 209.0 (3−, 5+)	84 Po Polonium 209 (2±, 4+)	85 At Astatine 210 (1−)	86 Rn Radon 222
7	87 Fr Francium (223) (1+)	88 Ra Radium (226) (2+)	89 Ac Actinium (227) (3+)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Uun Ununnilium 269	111 Uuu unununium 272	112 Uub Ununbium 277						

58 Ce Cerium 140.1 (3+, 4+)	59 Pr Praseodymium 140.9 (3+, 4+)	60 Nd Neodymium 144.2 (3+)	61 Pm Promethium (145) (3+)	62 Sm Samarium 150.4 (2+, 3+)	63 Eu Europium 152.0 (2+, 3+)	64 Gd Gadolinium 157.3 (3+)	65 Tb Terbium 158.9 (3+, 4+)	66 Dy Dysprosium 162.5 (3+)	67 Ho Holmium 164.9 (3+)	68 Er Erbium 167.3 (3+)	69 Tm Thulium 168.9 (2−, 3−)	70 Yb Ytterbium 173.0 (2−, 3−)	71 Lu Lutetium 175.0 (3−)
90 Th Thorium 232.0 (4+)	91 Pa Protactinium 231.0 (4+, 5+)	92 U Uranium 238.0 (3+, 4+, 5+, 6+)	93 Np Neptunium (237) (3+, 4+, 5+, 6+)	94 Pu Plutonium (244) (3+, 4+, 5+, 6+)	95 Am Americium (243) (3+, 4+, 5+, 6+)	96 Cm Curium (247) (3+)	97 Bk Berkelium (247) (3+, 4+)	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 259	103 Lw Lawrencium 262

ELECTRICITY BACKGROUNDER

The table below is a handy reference for drawing electrical circuits. It includes all the symbols you learned in Unit D: Electrical Principles and Technologies, as well as some other common ones. The table is followed by a list of safety guidelines to keep in mind when you use electricity in the lab. Remember that electricity is dangerous—be very careful when you use electricity at home or in the lab.

Symbols Used in Circuit Diagrams

Symbol	Represents	Description
	ammeter	measures amount of current in circuit
	battery	combination of cells
	capacitor	stores electricity and regulates current
	cell	stores electricity (large bar is positive)
	conductor (wire)	conducts electricity through circuit
	connection	shows connection between wires in a circuit
	diode	converts alternating current (AC) to direct current (DC); only allows current to flow in one direction
	fuse	melts if current is too high
	lamp	converts electricity to light
	LED (light emitting diode)	diode that emits light (usually red) when current flows
	motor	converts electricity to mechanical energy
	photoconductor	allows current to flow when exposed to radiant energy (e.g., light, infrared)

Continued on next page →

Symbol	Represents	Description
	resistor	reduces the amount of current in the circuit
	rheostat	variable resistor
	speaker	converts electrical energy into sound energy
	switch	opens and closes circuit; allows current to flow
	voltmeter	measures voltage across a device in circuit

Electrical Safety in the Lab

- Handle batteries carefully because they contain acids or bases that can cause corrosive burns.
- Do not connect the two battery terminals with a wire or you will create a short circuit.
- Do not use bare connecting wires.
- Have your teacher check the circuit before you close the switch or connect the power source.
- Disconnect or turn off the power source before you connect wires in a circuit.
- Wear safety goggles when working with liquid electrolytes.

A

acid compound that dissolves in water to form a solution with a pH lower than 7

active transport process in which plant cells use energy to move nutrient molecules from areas of lower concentration to areas of higher concentration

aerobic refers to processes or environments that require or contain oxygen ("aero-" means "air")

alkali metals group 1 elements in the periodic table, not including hydrogen; the most reactive of the metals

alkaline-earth metals group 2 elements in the periodic table; their reactivity is not as strong as that of the alkali metals

allele a possible form of a gene

alternating current current that flows back and forth 60 times per second; this is the current used in homes

altitude the height of a celestial body above the horizon, ranging from 0 at sea level to 90° straight up

amino acids building blocks of proteins

ammeter meter used to measure electrical current in amperes

ampere (A) the unit of electrical current

anaerobic refers to processes or environments that do not require or contain oxygen ("an-" means without; "aero-" means "air")

anther a part of the stamen that produces pollen and stores it

aqueous solution a solution in which water is the solvent

armature rotating shaft and coil in a motor or generator

artificial insemination artificial collection and injection of sperm from a male into a female; used in livestock breeding

artificial satellite see *satellite*

artificial selection breeding by humans of plants and animals with desirable traits to produce offspring with those desirable traits

asexual reproduction reproduction without the fusion of sex cells, resulting identical offspring and parent

asterism a distinctive star grouping that is not one of the 88 recognized constellations (e.g., the Big Dipper, which is part of the constellation Ursa Major)

asteroids small, rocky bodies orbiting the Sun and lying mainly in a narrow belt between Mars and Jupiter

astronomical unit (AU) a measure of distance used to describe the position of planets relative to the Sun; 1 AU is equal to the average distance from the centre of Earth to the centre of the Sun (149 599 000 km)

atom the smallest part of an element that is representative of that element; a neutral particle made up of a nucleus containing protons and neutrons, and in which the number of electrons equals the number of protons

atomic mass mass of one atom of an element calculated from the total number of protons, neutrons, and electrons of that atom; measured in atomic mass units (amu)

atomic mass unit measure of atomic mass; 1 amu is equal to $1/12^{th}$ the mass of a carbon 12 atom

atomic number number of protons in the nucleus of one atom of an element

azimuth the angle between the most northerly point of the horizon and the point directly below a celestial body; also the horizontal angle or direction of a compass bearing

B

base compound that dissolves in water to form a solution with a pH higher than 7

battery set of cells connected together

binary fission a type of asexual reproduction in amoebas and other organisms in which a parent cell divides exactly into two identical cells

binary number number having two as its base (instead of 10) and so having only ones and zeroes

biodegradation breakdown of materials by organisms such as earthworms, bacteria, and fungi; "bio-" refers to living things and "degrade" means to break up

biological diversity the variety of species and ecosystems on Earth and the ecological processes of which they are a part; ecosystem diversity, community diversity, and genetic diversity are three main components

biomagnification increase in concentration of a chemical or element as it moves up the food chain

biomass organic matter, such as food or agricultural waste, used as an energy source

biotechnology the use of living things to make agricultural, industrial, or medicinal products

black dwarf the final phase in the life cycle of a Sun-like star

black hole a super-dense remnant of a supernova; an object around which gravity is so intense that even light cannot escape

brush mechanism that makes electrical contact with the moving commutator in a motor

budding a type of asexual reproduction in which a new organism develops from an outgrowth, or bud, on the parent

C

carbohydrates organic molecules made up of atoms of carbon, hydrogen, and oxygen (e.g., pasta, rice, potatoes, fruits, bread); can form simple molecules, such as sugar, or large, complex molecules, such as starch, cellulose, and glycogen

carbon monoxide **($CO_{(g)}$)** colourless, odourless gas; produced by incomplete combustion of chemicals containing carbon (e.g. hydrocarbons); major source: motor vehicles

catalyst substance that helps a chemical reaction to proceed more quickly

cellular respiration chemical reaction that takes place in cells; food (sugar) reacts with oxygen to produce energy, water, and carbon dioxide

charge separation concentration of like charges in specific areas of a neutral object, caused by the approach of a charged object; for example, a negatively charged object brought close to a wall repels the electrons in the wall, leaving the area of the wall closest to the object positively charged

chemical change change that results when two or more substances react to create a different substance or substances; the new substances have completely different properties from the original ones

chemical energy energy stored in chemicals and released when chemicals react; a form of potential or stored energy

chemical formula combination of symbols that represent a compound; the formula identifies the elements in the compound and the amount of each element

chemical property description of how a substance interacts with other substances, such as acids; chemical properties are observable only when a chemical change occurs

chemical reaction a reaction that takes place when two or more substances react to form new substances

chromosome a structure in which DNA is arranged and along which genes are located

circuit complete path that charged particles flow through

circuit breaker special wire that heats up and turns off switch when excess current flows through an electrical circuit

class a category in the classification of living things, more general than an order, but more specific than a phylum

cleavage the first divisions of a fertilized egg

clone a genetically identical copy of an entire organism or of its cells or genes; cloning is the process of creating a clone

closed system an experiment in which all reactants and all products of a chemical reaction are accounted for

cogeneration use of waste energy from a process for another purpose, such as heating or generating electricity

colloid cloudy mixture in which tiny particles of one substance are held within another and particles cannot be separated out from the other substance

combustion chemical reaction that occurs when oxygen reacts with a substance to form a new substance and give off energy

comet a celestial body composed of dust and ice that orbits the Sun; it has a bright centre and long, faint tail that always points away from the Sun

commensalism the relationship between species in which one species benefits, and the other species neither benefits nor is harmed

community a group of populations of different species living in the same area

commutator split ring in a motor that breaks the flow of electricity for a moment and then reverses the connection of the coil

compound chemical combination of two or more elements in a specific ratio

condensation change of state from a gas to a liquid

conductivity ability of a substance to conduct electricity or heat

conductor a material that electric charge can move through easily

conservation of mass principle that matter is not created or destroyed in a chemical reaction; the mass of the products always equals the mass of the reactants

constellations groupings of stars that form patterns in the night sky (e.g., Ursa Major); officially, there are 88 constellations

continuous variation variation in a heritable characteristic that falls within a range, such as height

corrosion slow chemical change that occurs when oxygen in the air reacts with a metal

cross-fertilization the joining of a gamete from a pollen grain and a gamete from an ovule to form a zygote

cross-pollination the transfer of pollen from the anther of one plant to the stigma of another by wind, water, or animals

current electricity electricity that flows continuously

D

density amount of mass in a given volume of a substance

deposition change of state from a gas to a solid

diffusion process in which molecules move from an area of higher concentration to one of lower concentration

dilution mixing of a substance with air or water; this reduces the substance's concentration

direct current current that flows in only one direction

discrete variation variation in a heritable characteristic that has an either/or form, such as either being albino or not being albino

dispersion scattering of a substance away from its source

DNA deoxyribonucleic acid, genetic material found mainly in the nuclei of cells of living things

dominant trait the outward form observed when two opposite-acting alleles are inherited, e.g., long leg length in fruit flies; an offspring with one short-leg allele and one long-leg allele will grow long legs; the short-leg allele is recessive because it has no influence if a dominant, long-leg allele is present

Doppler effect the apparent change in frequency of sound, light, and other waves as the observer and the wave source move towards or away from each other; also referred to as "Doppler shift"

dry cell cell that has its electrolyte in the form of a paste, usually in a sealed case; the type of cell commonly used in portable devices such as flashlights

ductile description of a solid that can be stretched into a long wire

E

ecliptic the apparent path of the Sun and planets through the stars during the year, as viewed from Earth

ecosystem a particular environment where living things interact with other living things and non-living things

efficiency ratio of the useful energy output to the total energy input in a device or system; usually given as a percent

effluent wastewater released from a factory or sewage treatment plant

egg cell or ovum, a female sex cell

electrical current steady flow of charged particles

electrical discharge sudden transfer of electrical charge from one object to another, indicated by a spark

electrical energy energy of charged particles; transferred when electrons travel from place to place

electrochemical cell package of chemicals designed to produce small amounts of electricity; produces electricity from chemical reactions

electrochemistry study of chemical reactions involving electricity

electrode conductor through which electric current enters or leaves a device or material

electrolysis decomposition of a substance by an electric current

electrolyte liquid or paste that conducts electricity because it contains ions

electromagnet coil of insulated wire (usually wrapped around a soft iron core) that becomes a magnet when current flows through it

electromagnetic energy forms of radiated energy that travel at the speed of light (300 000 km/s), although they have different wavelengths and frequencies than light

electromagnetic induction generation of electric current in a conductor by a changing magnetic field

electromagnetic spectrum the complete range of wavelengths over which electromagnetic energy extends; includes gamma rays, X-rays, ultraviolet rays, visible light, infrared radiation, microwaves, and radio and television signals

electron invisible negatively charged particle that orbits the nucleus of an atom

electron shell orbit of electrons around the nucleus of an atom

electroplating use of electricity to coat a thin layer of metal onto an object

element pure substance that cannot be broken down into other substances; substance made up of only one type of atom

ellipse an oval formed around two foci (a circle is formed around one focus); the orbital paths of planets travelling around the Sun are ellipses

embryo an undeveloped organism in its beginning stages

endothermic reaction chemical reaction that absorbs energy

energy ability to do work

enhanced greenhouse effect greenhouse effect made greater by human activities, such as burning fossil fuels and clearing land, that add greenhouse gases to the atmosphere

enzyme catalyst involved in chemical reactions in living things

equinox either of the two times a year (once in spring and once in autumn) when the Sun crosses the equator and day and night are of equal length; usually on or about March 21 and September 23

evaporation change of state from a liquid to a gas

exothermic reaction chemical reaction that releases energy

ex-situ conservation the maintenance of organisms outside of their ecosystems or natural habitats; an endangered species maintained in a zoo is an example

extinction no longer in existence on the planet

extirpation extinction of an organism from a specific region

F

family (in biology) a category in the classification of living things, more general than a genus, but more specific than an order

family (in chemistry) vertical column of elements in the periodic table; elements in a family all have similar chemical properties; also called a group

fertilization the union of a female sex cell and a male sex cell

fertilizer substance that enriches soil so that plants will grow better

fly ash fine airborne ash produced by burning coal or other solid fuels

fossil fuel fuel formed from dead plants and animals; coal, oil, and natural gas

freezing change of state from a liquid to a solid

fuel cell primary cell that generates electricity directly from a chemical reaction with a fuel

fuse thin piece of metal that melts to break an electrical circuit when excess current flow occurs

G

galaxy a grouping of millions or billions of stars, gas, and dust, held together by gravity

galvanometer device for detecting and measuring small electric currents

gamete a sex cell, either female or male, that can unite with another to form a fertilized cell (zygote) that can develop into a new individual

gene a segment of DNA, located at one particular place on a chromosome, which determines a specific characteristic of an organism

genetic code arrangement of four chemical "letters" on a DNA molecule that can be arranged into "words" that form the instructions for making an organism

genetic engineering the intentional altering of the DNA of an organism or a population of organisms

genetics the study of how heritable characteristics are transmitted through generations of organisms

genus (plural, **genera**) a category in the classification of living things, more general than a species, but more specific than a family

geocentric model the Earth-centred model of the solar system originally proposed about 2000 years ago by the Greek philosopher Aristotle

geothermal energy energy derived from the internal heat of Earth

global warming increased average temperatures worldwide caused by the enhanced greenhouse effect

gravity the force of attraction between masses

greenhouse gases gases in Earth's atmosphere that trap the heat that forms when radiant energy from the Sun reaches Earth's surface; water vapour, carbon dioxide, methane, and nitrogen oxide are all greenhouse gases

groundwater the water that fills all the interconnected spaces in the soil

group vertical column of elements in the periodic table; elements in a family all have similar chemical properties; also called a family

H

halogens group 17 elements in the periodic table; the most reactive non-metals

heavy metals metals that have a density of 5 or higher (e.g., copper, zinc, lead, mercury, cadmium, nickel); heavy metals are one type of substance monitored to determine water quality

heliocentric model the Sun-centred model of the solar system first proposed by Polish astronomer Nicholas Copernicus in 1530

heritable characteristics characteristics that are transmitted from generation to generation, such as eye colour

Hubble Space Telescope (HST) one of the largest, most complex satellites ever built; launched in 1990 from the space shuttle *Discovery*, the HST (named for American astronomer Edwin P. Hubble) uses a series of mirrors to focus light from extremely distant objects

hybrid an organism produced by crossing two individuals purebred for different forms of a trait

hydrolysis reaction of a substance with water; "hydro" means water and "lysis" means break down

hydrolyze break down by water

I

in vitro fertilization fertilization that happens outside the body, usually in a Petri dish; used in livestock breeding

incomplete dominance a pattern of inheritance seen when two different alleles are present at the same gene location, but neither is dominant; for example, in pink snapdragons, both a white-flower allele and a red-flower allele are present and both influence flower colour

induction creation of electrical current

ingestion process by which we take food into our bodies

inorganic compounds compounds whose molecules do not contain carbon, also included as inorganic compounds are carbon dioxide, carbon monoxide, carbonates, and cyanides

in-situ conservation the maintenance of wild organisms within their functioning ecosystems

insulator substance that strongly resists the flow of electricity

integrated circuit circuit of inseparable, often microscopic, components formed on the surface of a single piece or chip of semiconductor crystal, usually silicon

interferometry a technique of combining the observations of two or more telescopes to produce images that have better resolution than what one telescope alone could produce

interspecies competition two or more species using the same limited resource

interstellar matter the gases and dust that exist in the space between stars

invertebrates animals without backbones

ion atom that has become electrically charged because it has lost or gained electrons; a positive ion is an atom that has lost one or more electrons; a negative ion is an atom that has gained one or more electrons

ionic compound pure substance formed when at least one metal and one non-metal combine

issue any subject of importance about which people have strong, conflicting points of view

K

kilowatt hour commonly used unit of electrical energy, equal to a power consumption of 1000 W for one hour

kingdom one of the five or six main categories in the current classification system of living things

L

law of conservation of energy fundamental principle that energy cannot be created or destroyed

LD50 lethal dose 50; amount of a substance that causes 50% of a group of test animals to die if they are given a specified dose of the substance all at once

leachate liquid that dissolves and carries substances as it passes through soil

light-year the distance that light travels in 1 year (approximately 9.5 trillion km); used to measure distances between stars and galaxies

lipids organic molecules made up of atoms of carbon, hydrogen, and oxygen (e.g., fats, oils and waxes); lipids are insoluble in water

load device in a circuit that converts electrical energy to another form of energy (e.g., a light bulb)

M

macronutrients nutrients that organisms need in relatively large amounts

main sequence on the Hertzsprung-Russell diagram, the stage in the life cycle of most stars during which they produce energy by converting hydrogen into helium; main sequence stars, including our Sun, are in a stable state

malleable description of a substance that can be pounded or rolled into sheets

mass number the sum of the number of protons and neutrons in an atom

massive star one of the two main types of stars that can form (the other being Sun-like stars, which are, by comparison, smaller in mass than massive stars)

Material Safety Data Sheet (MSDS) detailed information sheet about a potentially hazardous product, provided by the manufacturer; includes a detailed description of the product, precautions to take when using it, first aid treatments, spill procedures, and disposal advice

matter anything that has mass and occupies space

mechanical energy energy possessed by an object because of its motion or its potential to move; a thrown baseball has mechanical energy because of its movement and its potential to fall

mechanical mixture heterogeneous mixture; mixture in which the different substances that make up the mixture are visible

meiosis a type of cell division that produces four sex cells from one parent cell; each sex cell contains half the genetic material of the original cell

melting change of state from a solid to a liquid

metal shiny, malleable, ductile element that conducts electricity

metalloid element that has both metallic and non-metallic properties

meteor a meteoroid that enters Earth's atmosphere, where the heat of friction causes it to glow brightly

meteorite the remains of a meteor that do not burn up completely and so last long enough to hit Earth's surface

meteoroid a solid body, usually a fragment of rock or metal, travelling in space with no particular path

microcircuit circuit made up of miniaturized components, especially an integrated circuit

microgravity the condition in which the gravitational forces that act on a mass are greatly reduced

micronutrients nutrients that organisms need in only minor or trace amounts

millivoltmeter instrument used to measure small voltages

mitosis a type of cell division that produces two identical daughter cells from one parent cell

mixture combination of pure substances; unlike a compound, the components of a mixture do not combine chemically and are not always in the same ratio

molecular compound pure substance formed when non-metals combine

molecule group of atoms joined by covalent bonds

monitoring keeping track of something for a specific purpose; certain chemicals are monitored in the environment to ensure they do not exceed safe levels

multimeter meter that can measure voltage, current, or resistance in a circuit

mutualism the relationship between species in which both species benefit

N

natural selection a process in which the environment "selects" which individuals will survive and reproduce

nebulae vast clouds of gas (mostly hydrogen) and dust in space, where stars form; nebula (singular)

neutral (in chemistry) pH of 7; a neutral substance is neither an acid nor a base

neutral (in electricity) description of an object that has equal amounts of positive and negative charges

neutralization reaction between an acid and a base that produces water and a solid compound called a salt

neutron neutral particle in the nucleus of an atom

neutron star a small, super-dense remnant of a supernova

niche the role of an organism or species in an ecosystem, including where it lives, what it eats, how it reproduces, and how it interacts with other living and non-living things

nitrogen fixation process of changing free nitrogen so that the nitrogen atoms can combine with other elements to form compounds that organisms can use; carried out mainly by bacteria in the soil

nitrogen oxides $NO_{x(g)}$; major air pollutant; forms when nitrogen combines with oxygen as a result of fuel combustion; gives smog its characteristic brown colour; major source: motor vehicles

noble gases group 18 elements in the periodic table; the most stable and unreactive elements

non-heritable characteristics characteristics caused by the environment, such as tanned skin due to exposure to sunlight

non-metal dull, brittle element that does not conduct electricity

nonrenewable resource a resource, such as coal or natural gas, that cannot be replenished

nuclear fission splitting of atoms, which transforms them into lighter elements and releases large amounts of energy

nucleic acids largest and most complicated molecules found in all the cells of living things; the two most important are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), made up of phosphates, a simple sugar called ribose, and nitrogen-containing bases; play a major role in heredity and in controlling a cell's activities

nucleus positively charged centre of an atom; contains protons and neutrons

nutrients elements and compounds that organisms need for living, growing, and reproducing

O

ohm (Ω) the unit of resistance

Ohm's law law stating that, as long as the temperature remains constant, the resistance of a conductor remains constant, and the current is directly proportional to the voltage applied; $R = V/I$ or $I = V/R$ or $V = IR$

open system an experiment in which one or more products of a chemical reaction can escape

optimum amount amount of a substance that provides an organism with the best health

order a category in the classification of living things, more general than a family, but more specific than a class

organic compounds compounds whose molecules contain carbon (e.g., fossil fuels), except carbon dioxide, carbon monoxide, carbonates, and cyanides, which are inorganic compounds

osmosis type of diffusion in which water molecules move across a membrane from an area where there are more water molecules to an area where there are fewer water molecules

ova (singular, ovum) female sex cells

ovary female reproductive organ in which egg cells are produced; in plants, the structure contains the ovules

overspecialization species has adaptations for a small set of environmental conditions, which leaves it vulnerable to extinction

ovule sac containing the female sex cells (gametes) of a plant

ozone ($O_{3(g)}$) colourless, odourless gas; at ground level, it's a pollutant produced as a result of industrial processes and the use of motor vehicles; high in the atmosphere, it forms a layer protecting Earth from the Sun's ultraviolet radiation

ozone layer layer of ozone $O_{3(g)}$ in the atmosphere 15 to 50 km above Earth's surface; protects Earth's surface from the Sun's ultraviolet radiation

P

parallax the apparent shift in position of a nearby object against a distant background when the object is viewed from two different positions

parallel circuit circuit in which the current can flow in two or more paths

parasitism the relationship between species in which one species benefits and the other species is harmed

parts per million (ppm) measurement used to describe very small concentrations of chemicals; a solution having a concentration of 1 ppm has one part of solute per million parts of solution

period horizontal row of elements in the periodic table

periodic table a table in which the elements are organized by their physical and chemical properties

permeable description of a substance that contains connected pores; fluids can flow through a permeable substance

pest organism that harms people, crops, or structures

pesticide chemical used to kill pests

pH measure of the percent of hydrogen ions in a solution; most solutions have a pH in the range of 0 to 14; 0 is very acid, 14 is very basic, and 7 is neutral

photoconductor a resistor that becomes more conductive when exposed to light

photolysis breakdown of compounds by sunlight; "photo" means light and "lysis" means break down

phylum (plural, **phyla**) a major category in the classification of living things, more general than a class, but more specific than a kingdom

physical change change in the appearance or state of a substance that does not change the composition

physical property property that describes the physical appearance and composition of a substance

phytoremediation clean up of the environment using plants; "phyto-" means plant and "remediation" means cleanup; plants have been used to clean up metals, hydrocarbons, and other chemicals

pistil the female reproductive organ of a flower

pollen fine yellow powder on the anthers of flowers, consisting of grains that contain male sex cells (gametes)

pollination the transfer of pollen from anther to stigma

pollution any change in the environment that produces a condition that is harmful to living things

polyatomic ions group of atoms acting as one (for example, carbonate or CO_3^{2-})

population group of individuals of the same species living in an area

pores tiny spaces between soil grains or mineral grains in a rock; a substance with many pores is porous; if these pores are connected, a substance is permeable

potential difference change in the potential energy of electric charge compared to its potential energy at a reference point, such as the ground; voltage

power rate at which a device converts energy

primary cell cell that produces electricity by means of a chemical reaction that cannot be reversed

product new substance produced in a chemical reaction between reactants

property characteristic that describes a particular substance (e.g., colour, lustre, melting point, crystal shape, solubility, density)

protein organic compound made up of units called amino acids; protein molecules contain atoms of nitrogen, hydrogen, oxygen, and carbon

proton positively charged particle in the nucleus of an atom

protostar a contracting mass of gas in the first stage of a star's formation

pure substance substance made of only one kind of matter, which has a unique set of properties

purebred referring to a plant or animal that has ancestors all with the same form of a trait

R

radio telescope a telescope system that collects and analyzes radiation in the radio frequency range from stars and other bodies in space

reactant substance that reacts with another substance or substances in a chemical reaction to create new substances with different properties

recessive trait the outward form observed only when two same-acting, non-dominant alleles are inherited. Short leg length in fruit flies is an example. An offspring with two short-leg alleles will grow short legs. The short-leg allele is recessive; it has no influence if the dominant long-leg allele is present.

rechargeable cell cell that produces electricity by means of a chemical reaction that can be reversed by using an external source to run electricity back through the cell

red giant the stage in the life cycle of a Sun-like star during which the star increases in size and becomes very bright

red supergiant the stage in the life cycle of a massive star during which the star increases in size and becomes very bright

reflecting telescope a type of optical telescope that uses mirrors instead of lenses to gather and focus light

refracting telescope a type of optical telescope that uses two lenses to gather and focus light

renewable resource resource such as water or wind energy that is continually replenished and therefore can be used indefinitely

resistance measure of how difficult it is for electrons to flow through a substance; unit of measure is the ohm

resistor device having resistance to the passage of electrical current, often used to control current in a circuit

resource partitioning division of a resource among two or more coexisting species such that the niche of each species differs slightly

rheostat continuously variable resistor used to regulate electric current

S

salt compound produced in a neutralization reaction between an acid and a base

satellite a small body that orbits a larger one; satellites may be natural, such as a moon orbiting a planet, or artificial, such as a spacecraft put into orbit around Earth by humans for research or communication purposes

schematic or **schematic diagram** diagram using standardized symbols to show the components and connections in a circuit

secondary cell rechargeable cell

semiconductor a material, such as silicon or germanium, having a conductivity greater than an insulator but less than a good conductor

septic tank underground container where bacteria break down organic materials in sewage before they are moved out to the soil

series circuit circuit in which there is only a single pathway for the current so the same current passes through all the components

sewage wastewater containing dissolved and undissolved materials from your kitchen, bathroom, and laundry

sewage treatment plant building and grounds containing special equipment to treat wastes from homes, businesses, industries, and institutions so the wastes can be disposed of safely

sexual reproduction reproduction involving the exchange of genetic material between two individuals resulting in offspring that are genetically different from the parents

short circuit accidental low-resistance connection between two points in a circuit, often causing excess current to flow

solar wind streams of electrically charged particles discharged by the Sun in every direction; solar wind passes Earth at nearly 400 km/s

solstice either of two times in the year when the Sun reaches its highest or lowest point in the sky at noon; in the northern hemisphere, the summer solstice occurs near June 21 (longest day of the year) and the winter solstice occurs near December 21 (shortest day)

solubility mass of a substance that can dissolve in a given amount of solvent to form a saturated solution at a given temperature

solution homogeneous mixture; mixture of two or more pure substances that looks like one substance

"sour" gas natural gas that contains hydrogen sulfide

space junk refers to all the pieces of debris that have fallen off rockets, satellites, space shuttles, and space stations and remain floating in space

space probes unmanned satellites or remote-controlled "landers" used to explore areas or objects in space that are too difficult or dangerous to send humans to

species living things of the same kind that are able to reproduce successfully

spectrometer an instrument used by astronomers to observe and measure the spectrum of a star

sperm cell a male sex cell

spore a cell produced by asexual reproduction in certain organisms such as ferns, which can develop directly into an adult

spring acid shock concentration of acid that can dramatically lower the pH of the water in a pond, slough, lake, or river for a short period of time; occurs in areas where acid precipitation is a problem and acidic deposits build up in ice and snow in the winter; in spring, when the ice and snow melt, the acid meltwater flows into aquatic systems

stamen the male part of a flower

states of matter refers to the three common states in which matter can exist: solid, liquid, and gas

static electricity a stationary electric charge

stigma the female part of a flower, which receives pollen

storm sewers large pipes that carry runoff water from yards and streets directly (without treatment) into a river, lake, or ocean

style the structure that supports the stigma and connects it with the ovary of a plant

sublimation change of state from a solid to a gas or from a gas to a solid

subphylum (plural **subphyla**) a secondary category of a phylum in the classification of living things, which includes one or more classes

substrate surface on which an organism lives or moves

sulfur dioxide ($SO_{2(g)}$) forms when sulfur combines with oxygen in the air; major air pollutant that forms both smog and acid rain; major source: industrial processes

Sun-like stars one of the two main types of stars that can form (the other being massive stars, which are, by comparison, larger in mass than Sun-like stars)

superconductor perfect conductor; substance with no resistance to electron flow

supernova an enormous explosion that marks the death of a massive star

suspension cloudy mixture in which tiny particles of one substance are held within another, and the particles can be separated out

sustainability use of resources at a rate that can be maintained indefinitely without depleting the resources or harming the environment

symbiosis the relationship between two different species

T

thermal energy total kinetic energy of all the particles in a substance; the faster a particle moves the more kinetic energy it has; if you have two cups holding equal amounts of water, the one containing more thermal energy will feel warmer

thermocouple device consisting of two wires of different metals joined such that a voltage is produced between the ends in proportion to the difference in their temperatures

toxic poisonous

toxicity how poisonous a substance is

toxin poison; substance that produces serious health problems or death when introduced into an organism

trait a characteristic of an organism

transformer device that changes electricity at one voltage into electricity at a different voltage; a step-up transformer increases the voltage; a step-down transformer decreases the voltage

transistor device usually with three layers arranged such that a small voltage through the middle layer controls a current between the outer layers, allowing the device to act as a switch or amplifier

triangulation a method of indirectly measuring distance by creating an imaginary triangle between an observer and an object whose distance away is to be estimated

turbine machine that uses the flow of a fluid such as steam, water, or air to rotate a shaft

V

variability variations within a species

variable resistor resistor whose resistance can be changed by adjusting the portion of the resistor the current travels through

vegetative reproduction a type of asexual reproduction in plants that does not involve the formation of a seed

volt (V) the unit of voltage

voltage a measure of how much electrical energy a charged particle carries

voltage drop voltage across a resistor or other device in a circuit

voltmeter instrument for measuring potential difference in volts

W

water table top of the groundwater zone

watt (W) the unit of power, equal to one joule per second

wet cell electrochemical primary cell having a liquid electrolyte

white dwarf one of the latter stages in the life cycle of a Sun-like star during which the star collapses; white dwarfs are hot but very faint

WHMIS Workplace Hazardous Materials Information System; a system of easy-to-see warning symbols on hazardous materials

Z

zenith the highest point in the sky directly overhead

zygote a fertilized egg

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