

# SCIENCE in Action 8

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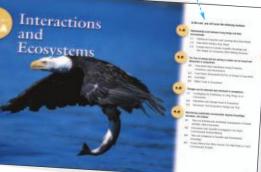
You are about to begin a scientific exploration using Science in Action 8. To assist you in your journey, this book has been designed with the following features to help you.

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.



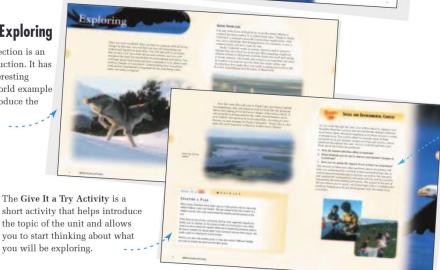
#### 1 Unit Outline

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



### 3 The Sections

Each section heading summarizes what you will learn in this section. These can be very useful to help you organize your thoughts when you have to study.

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 are what you should know and be able to demonstrate your understanding of upon completing the section.

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

The Focus On section has several questions to help you think about what you learn 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 social and environmental situations that involve science and technology.

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



Check out this Web site for relevant links.

Topic subheadings make the text easier to follow.

To begin each subsection, your teacher may choose to use a short Give It a Try Activity. This helps you start thinking about what you will be learning.

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



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

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.

There is also a Focus On activity to help you connect what you have learned in this section to activities in your own life.



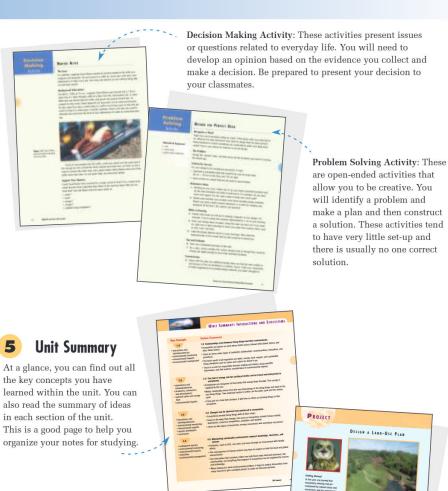


#### **Science Activities**

There are three main types of activities.

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 much more. In these activities, you investigate many different phenomena found in our world.







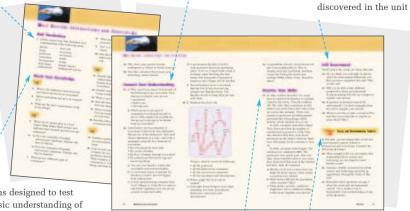
A project at the end of each unit presents a hands-on opportunity for you to demonstrate what you've learned. You'll work both in a group and individually. The project requires you to apply some of the skills and knowledge that you've acquired to a new situation.



#### **Unit Review**

The Unit Review presents:

- a chance to review the important terms in the unit
- questions that require you to use the ideas in more than one section in the unit to answer
- opportunities to express your thoughts about ideas you have discoursed in the unit.



- questions designed to test your basic understanding of the ideas in each section of the unit
- questions that are related to specific skills you have learned in the unit
- questions that relate to the specific emphasis of the unit



#### 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 related to an issue that can have more than one solution or opinion.

#### Careers and Profiles

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



Try This at Home This is an activity you can try at home on your own.



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

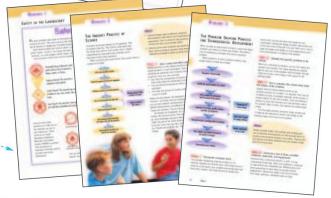
#### Experiment on Your Own

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



#### 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.





#### lcons



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

Now it's time to start. We hope you will enjoy your scientific exploration using *Science in Action 8*!

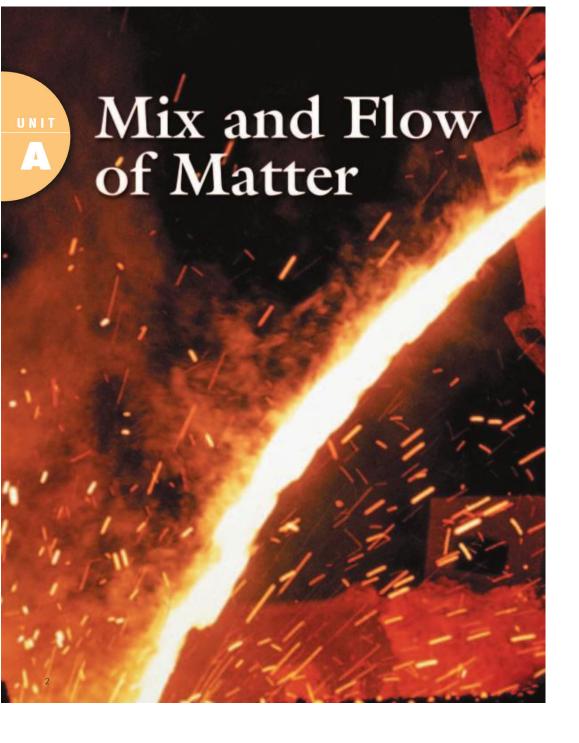


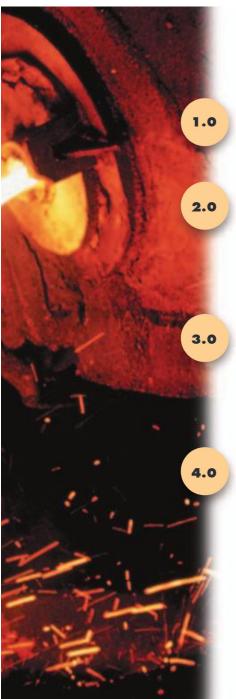
#### Glossary

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



xxi





#### In this unit, you will cover the following sections:

## Fluids are used in technological devices and everyday materials.

- 1.1 WHMIS Symbols and Safety Procedures
- 1.2 The Many Uses of Fluids

# The properties of mixtures and fluids can be explained by the particle model of matter.

- 2.1 Pure Substances and Mixtures
- 2.2 Concentration and Solubility
- 2.3 Factors Affecting Solubility
- 2.4 The Particle Model of Matter and the Behaviour of Mixtures

# The properties of gases and liquids can be explained by the particle model of matter.

- 3.1 Viscosity and the Effects of Temperature
- 3.2 Density of Fluids
- 3.3 Density, Temperature, and Buoyancy
- 3.4 Compression of Fluids
- 3.5 Pressure in Fluids—Pascal's Law

#### Many technologies are based on the properties of fluids.

- 4.1 Technologies Based on Solubility
- 4.2 Technologies Based on Flow Rates and Moving Fluids
- 4.3 Designing a Working Model of a Fluid-Using Device

# **Exploring**

## Canadian Invention Brings Water to African Villages



RESEARCHERS AT THE University of Waterloo in southern Ontario have developed a low-cost, shallow-well pump that can easily be used in developing countries.

Since the early 1980s, many African and Southeast Asian communities have utilized the pump to bring clean drinking water to their villages.

Now, with the help of the International Development Research Centre in Ottawa, these inexpensive pumps are being made all over the developing world.

#### USING SCIENCE AND TECHNOLOGY TO SOLVE PROBLEMS

In 1978, two Canadian scientists, Alan Plumtree and Alfred Rudin, invented a reliable hand-operated water pump suitable for use in developing countries. The new pump had to meet the following criteria:

• It had to be durable enough to work continuously for 18 hours a day.

- It had to be cheap enough for people in poorer countries to afford.
- It had to be simple enough for villagers to maintain and repair themselves.
- It had to be designed so that it could be manufactured within developing countries. This would create jobs and ensure that spare parts would be available.

#### NEW TECHNOLOGY FROM OLD

When the two scientists were researching pump designs, they noticed a pump at a Mennonite community in southern Ontario. It was practical and reliable and had been used for generations. With this pump as a model, they designed a hand pump with a tubing made out of a plastic called polyvinyl chloride (PVC). In the past, pumps were made of iron and steel, materials that are scarce and costly in many developing countries. PVC is inexpensive and available everywhere around the world. Plus, PVC doesn't rust! The new PVC pump was light, sturdy, cheap to build, and easy to install and maintain.

#### ADAPTING THE TECHNOLOGY

Thanks to these Canadian inventors, villagers in developing countries are building and maintaining their own water pumps. Over 11 000 pumps are being used in 13 developing nations.

Of course, the basic pump design can be modified for local conditions. For example, in Sri Lanka, they decided to use a leather washer instead of a plastic one. The advantage of the leather one is that it can be made locally. In Malawi, the spigot on the pump has to be made out of black metal because hyenas ate the original white plastic ones. The hyenas thought the white spigots looked like bones and kept chewing them off the pumps!

Mennonites in southern Ontario have used hand pumps like this one for generations.





The PVC water pump is a good example of the importance of understanding a concept so that you can apply that understanding to different situations. In this case, the inventors knew about the properties of fluids and how a water pump operates. They applied this knowledge to develop a better pump that would work reliably for long hours and be easy to fix. In this unit, you will learn about the properties of fluids and see how they can be used to solve a variety of practical problems.

These villagers in Thailand are being trained to maintain and repair a Canadian-invented hand pump.



ACTIVITY

#### THE NEW DRINK @ 6 0





Now you have an opportunity to use what you already know about fluids and develop your problem-solving skills. You and your product development team have to find a solution to the following problem.



Test a variety of liquids to determine if a piece of fruit floats, sinks, or can be suspended in any of them.

A variety of liquids will be available for you to test. You may use any one of these liquids or a combination of them. Design a procedure that will allow you to collect the necessary data. Have your teacher approve your design before you start.

Prepare a reply to the president of the company that summarizes your results.

Unit A: Mix and Flow of Matter

## Focus On

#### SCIENCE AND TECHNOLOGY

As you work through this unit, you will be reading about mixtures and fluids and doing activities that focus on science and technology. Science attempts to explain the phenomena in our world. The goal of technology is to provide solutions to practical problems.

In this unit, one of your main tasks is to practise your problemsolving skills. The scientific knowledge you gain throughout this unit will help you develop these skills. Remember that many technological problems have many different solutions. There may be no one right way to solve the problem. These three steps can help you in your problem solving:

- clearly define your need
- develop appropriate plans and designs
- test and evaluate these designs

You will be learning about the role of the properties of mixtures and fluids in both scientific research and technological developments. Use the following questions to guide your reading.

- 1. What are the properties of fluids?
- 2. Why are these properties and their interactions important?
- 3. What technologies have been designed to use the interactions between fluids and other materials?



Exploring

7

1.0

# Fluids are used in technological devices and everyday materials.

#### **Key Concepts**

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

- WHMIS symbols
- · properties of fluids

#### **Learning Outcomes**

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

- explain WHMIS and other safety symbols
- describe safety precautions for using substances
- identify examples of fluids in products and devices
- describe examples of fluids used to transport, process, or use materials
- identify important properties of fluids



The ladder on this truck helps firefighters save lives in tall buildings. But without fluids, firefighters wouldn't be able to use it. It would take many people working together to put up a huge, heavy ladder like this one. But with the push of a button, a hydraulic system can raise and lower it easily. A **hydraulic system** uses fluids under pressure to move loads. It is just one of many technologies that use fluids to make our lives easier and safer. Fluids are substances that flow. Both liquids and gases are fluids.

In this section, you'll begin to learn about fluids and how and why they are used in technological devices and everyday materials. The first step in investigating fluids is learning how to work with them safely in the lab.

# 1.1 WHMIS Symbols and Safety Procedures

Before you begin your study of mixtures and fluids, you need to review some safety rules and basic lab skills. Figure 1.1 shows a science class performing a science activity. Unfortunately, some of the students are not following proper safety procedures. Work with a partner to identify and list the problem actions. Then suggest a better, safer way to perform each action. After you have finished, share your observations with the class.



Figure 1.1 What are these students doing wrong? What are they doing right?

#### WHMIS AND OTHER HAZARD SYMBOLS

You will be doing many activities in this unit. Before you do an activity, read through it and watch for "Caution!" notes that will tell you if you need to take extra care. There are two areas of special consideration when working in the lab—understanding warning labels and following safety procedures.

Some of the materials you will use in the lab are hazardous. Always pay attention to the warning labels described on the next page, 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, look on the labels for special storage and disposal advice.





warning



These shapes and their colours indicate how dangerous the substances are.

All hazardous materials have a label showing a hazard symbol. The hazard symbol has a safety warning and a shape to indicate how hazardous the material is. You may have already seen these labels on fluids you find at home, such as bleach or oven cleaner. There are two separate pieces of information for each symbol. The first is the shape of the symbol, shown in the *info*BIT. A yellow triangle means "caution," an orange diamond means "warning," and a red octagon means "danger."

The second piece of information is a picture inside the shape that indicates the type of hazard. There are seven pictures of common hazards shown in Figure 1.2.



Figure 1.2 These pictures tell you what type of hazard to watch out for.

Figure 1.3 shows some of the WHMIS symbols. WHMIS stands for Workplace Hazardous Materials Information System. This is another system of easy-to-see special symbols on hazardous materials. These symbols were designed to help protect people who use potentially harmful materials at work.



Figure 1.3 WHMIS symbols

#### UNDERSTANDING THE RULES

When performing a science investigation, it is very important that you follow the lab safety rules.

#### Lab Safety Rules



- 1. Read all written instructions before doing an activity.
- 2. Listen to all instructions and follow them carefully.
- 3. Wash your hands carefully 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.
- 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.
- Never pour liquids into containers held in your hand.
   Place a test tube in a rack before pouring substances in it.
- 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.
- Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of any 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.



#### WHMIS Symbols at School

Check around your school for WHMIS symbols. Try the art room or a cleaning room. Make a map showing where the different hazardous materials are located in your school.



#### SAFETY BEGINS WITH YOU

Not following one or more of the lab safety rules could result in injury to you or your classmates. Follow the list of 15 safety rules to ensure that you work in a safe manner. Your teacher will also discuss any specific rules that apply to your classroom. After you have read the rules here, you can read more about safety in Toolbox 1 at the end of the book.

Remember that safety in a science class begins with you. Before you start any activity, you should be prepared to

- follow the safety instructions outlined by your teacher and this text
- $\bullet$  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

#### CHECK AND REFLECT

1. What does each hazard warning label mean on the fluids shown in Figure 1.4?



Figure 1.4 Warning labels on hazardous products

- Choose five of the lab safety rules given on page 11. For each one, explain briefly why it's important to follow it. Give an example of what could happen to a student who didn't follow that rule.
- Make your own chart of hazard warning symbols. When you go home, check for each symbol on materials where you live or at your local grocery store. List two or three substances or items to which the symbol applies.

# 1.2 The Many Uses of Fluids

A **fluid** is anything that has no fixed shape and can flow. Usually it is a liquid or a gas. Look at Figure 1.5. How many different examples of fluids being used can you observe? Make a list of the fluids you see there and how they are being used. Include one additional use for each fluid. Remember to note uses by other living things besides humans. After you have made your list, group the examples into four different categories. Label each category with a title that makes sense to you.



Figure 1.5 How are fluids being used?

#### FLUIDS MAKE IT EASIER TO USE MATERIALS

It's easy to think of many fluids you use every day, such as water, soft drinks, and detergents. One of the reasons that fluids are so useful is that they make it easier to transport, process, and use different kinds of materials, even if these materials are solids.

#### infoBIT

#### Agrifoam Cold Crop Protector

Frost damage is a big risk for farmers who grow fruit. To help farmers protect their crops, Canadians Dr. D. Siminovitch and J.W. Butler invented Agrifoam Cold Crop Protector. Agrifoam is a shaving-cream-like material that can be sprayed onto plants to protect them from freezing.



Figure 1.6 Because it's a fluid, the water can carry the sand and other solids away.

#### Slurries

Think about washing off a sidewalk or driveway with a hose. If you had a coating of mud or sand on your driveway, you could turn your hose on it. The water would wash or carry the mud or sand off the driveway. This mixture of water and solids is called a *slurry*. Slurry technology—the transport of solids in water—is important in many applications. One of these is in mining oil sands. Syncrude in Alberta is the world's largest producer of oil from oil sands. Syncrude started out by using conveyor belts to move the oil sands from the mine to the processing plant. But this technology proved to be very expensive. Now Syncrude creates an oil-sand slurry at the mine site and pumps this slurry through pipelines to the processing plant.

#### Fluids Become Solids

Fluids are easy to move, and they take the shape of containers. Because of these properties, many of the things we see and use as solids were originally prepared as fluids. Glass, for example, is manufactured by heating a mixture of substances that includes sand, limestone, and other carbonates. Other materials can be added to give the glass colour or special qualities. The mixture is heated in a furnace at 1000°C until it becomes a fluid. This allows it to be shaped into the form needed for particular uses, such as bottles, windows, or fibre-optic strands.

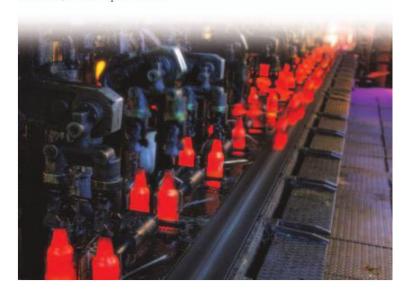


Figure 1.7 Glass bottles being formed

Steel is another example of the use of fluids as a stage in processing materials. Steel consists of a mixture of iron, carbon, and small quantities of other substances. This mixture is heated to 1650°C to melt everything together, and to add more materials. The fluid steel is then shaped into the desired forms and allowed to cool.

#### Fluids Can Hold Other Materials

The ability of fluids to spread or flow and to carry other materials makes them useful in many applications. Toothpaste is an example that you may not have thought of. Most toothpaste contains powdered materials, such as bauxite, to polish your teeth. It also contains a detergent to clean your teeth, and fluoride to keep your teeth strong. Substances called binders, made from wood pulp, keep the paste mixed. Colouring and flavouring are added to make the mixture more agreeable.

#### USEFUL PROPERTIES OF FLUIDS

From the information you have learned so far in this section, you can begin to appreciate the importance of fluids in our world. You've seen some examples of the different ways that fluids are involved in transporting, processing, and using materials. Fluids can be used in all these ways because of their properties.

By understanding the properties of fluids, people can design technological devices that use these properties. Later in this unit, you will be exploring these properties: viscosity, density, buoyancy, and compressibility. Figures 1.8 to 1.12 on the next page show how these properties can be important in choosing and using fluids in different applications.

#### **I'8**SEARCH

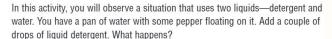
#### Froth Flotation

A common method of processing mineral ore is called froth flotation. How are fluids used in this process?

#### Give it a TRY

#### ACTIVITY

#### ANOTHER PROPERTY OF FLUIDS @ 6 0



Suggest a situation where what you observed could be used in a practical way. Present your ideas to the class either orally or as a short written description.





**Figure 1.8** Your bicycle starts to make grinding noises as you pedal. What do you do? You use oil on your bicycle or in a car to make sure that the parts operate smoothly together. The viscosity of the oil that you use is important. Viscosity describes how easily a fluid flows. You will learn more about viscosity in section 3.0.



Figure 1.9 In making maple syrup, you have to determine when the mixture reaches the right concentration of sugar. A device called a **hydrometer** is used to measure the density of the syrup to find out if there is enough sugar in it. You will learn more about density in section 3.0.



Figure 1.10 This ship floats because of the buoyant force of the water acting on it. You will learn more about buoyancy in section 3.0.



Figure 1.12 The hovercraft operates by directing air downward so it floats on a fluid cushion over the waves.

**Figure 1.11** This jackhammer is pneumatic. Systems that use compressed air are called **pneumatic systems**. **Hydraulic systems** use liquids to lift or move things. You will learn more about pneumatic and hydraulic systems when you learn about the compression of fluids in sections 3.0 and 4.0.

#### CHECK AND REFLECT

- Review the list of fluids and their uses that you made at the beginning of this subsection when you looked at Figure 1.5. Are there any changes you would make based on what you have learned? Add at least three other examples, and make one new category for your list.
- 2. Describe an example where materials are prepared as fluids so they can be moved more easily.
- Explain why it is important for steel to go through a fluid phase as it is being produced.

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. What labels would you expect to find on containers of the following materials?
  - a) oven cleaner in a spray can
  - b) bleach
  - c) paint thinner
  - d) unknown bacteria
- 2. Describe the process for getting rid of broken glass in your class.
- 3. What protective measures must you take when you work around an open flame?
- 4. Describe an example where materials are prepared as fluids to make it easier to use them.
- 5. Describe two technologies that require a specific property of a fluid to function properly.



#### SCIENCE AND TECHNOLOGY

The goal of technology is to provide solutions to practical problems. For example, toothpaste is a technology to solve the problem of tooth decay. It was invented to keep teeth clean and strong. It also freshens your breath. Think back to what you learned in this section.

- 1. What were some practical problems that you read about?
- 2. What technologies were used to solve these problems?
- 3. Did it seem to you there would be more than one way to solve some of these problems?





# 2.0

# The properties of mixtures and fluids can be explained by the particle model of matter.

#### **Key Concepts**

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

- pure substances, mixtures, and solutions
- · solute and solvent
- concentration
- solubility and saturation points
- · particle model of matter

#### **Learning Outcomes**

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

- distinguish between pure
- substances and mixtures

  define concentration and
  solubility
- identify factors that affect solubility and rate of dissolving
- relate the behaviour of mixtures to the particle model of matter



All the objects in the pictures on this page have at least one thing in common. They are all examples of matter. Matter may be hard, soft, rough, smooth, round, square, hot, or cold. It may be smaller than a cell or larger than the sun. Matter may have colour or it may be colourless. Matter is what makes up everything in our universe.

Matter can be organized in different ways. You already know one way: matter can be classified as solid, liquid, or gas. In this section, you will look at another classification system. This system classifies matter as pure substances or mixtures. You will also learn about a model that you can use to describe the nature of matter. This model will help you understand fluids and their properties.

# 2.1 Pure Substances and Mixtures

All matter is either a pure substance or a mixture. A **pure substance**, such as sugar, is made up of only one kind of matter. A **mixture**, such as soil, is made up of a combination of different substances.

#### Give it a TRY

#### ACTIVITY

#### CLASSIFYING PURE SUBSTANCES AND MIXTURES

You can find examples of pure substances and mixtures all around you. Work with a partner to make a list of 20 different things you have used in the last day or two. Try to include at least two solids, two liquids, and two gases.

Classify the items in your list as either pure substances or mixtures. If you are not sure into which grouping an item fits, make a third grouping.

Review your groupings and answer the following questions in your notebook or in a class discussion:

- · Could you tell pure substances and mixtures apart?
- · Which were the hardest items to classify?
- · Did some items seem to be neither a pure substance nor a mixture?



#### **PURE SUBSTANCES**

A pure substance is made up of one type of matter and has a unique set of characteristics or properties. For example, aluminum foil, baking soda, and distilled water are all pure substances. You cannot separate them into different substances.



#### **MIXTURES**

Mixtures are two or more substances combined together. In a mixture, each substance keeps its properties, but it may be difficult to identify these properties. For example, you may not see the sugar in a drink of soda pop, but you can certainly taste it. Sometimes it is easy to identify the different substances in the mixtures. For example, you can see the different vegetables in a package of mixed vegetables.

#### infoBIT

### What Are Pennies Made Of?

Until 1997, pennies were made of a pure substance—copper. Since then, other substances have been added so pennies are now a mixture of metals. Mixtures of metals are called alloys.

#### MECHANICAL MIXTURES AND SOLUTIONS

If you think about pure substances, you might list common examples such as sugar, water, salt, and oxygen gas. Some other examples you might think of may seem to be pure substances, but aren't. For example, how would you classify vinegar—is it a pure substance or a mixture? To be able to classify matter, you need to know more about mixtures.

In a mechanical mixture, you can see the different substances that make up the mixture. Soil and mixed vegetables are both mechanical mixtures. This type of mixture is sometimes called a heterogeneous mixture. In other mixtures, you can't see the different substances that make them up. These mixtures may be solutions, suspensions, or colloids. A solution looks as if it is all one substance. It is called a homogeneous mixture. Sometimes it is difficult to tell the difference between a pure substance and a solution without performing some tests. You can learn more about suspensions and colloids on the next page. The chart in Figure 2.1 summarizes the classification of matter as pure substance, mechanical mixture, solution, suspension, or colloid.

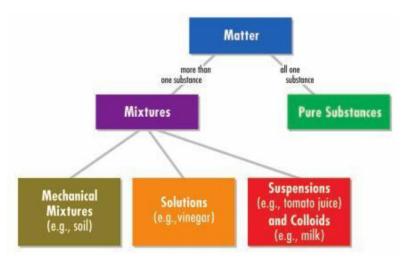


Figure 2.1 Matter classification chart

#### SUSPENSIONS AND COLLOIDS

A suspension is a cloudy mixture in which droplets or tiny pieces of one substance are held within another substance. If you leave a suspension undisturbed, its parts will usually separate out. Muddy water is an example of a suspension. A colloid is also a cloudy mixture but the droplets or tiny pieces are so small that they do not separate out easily. Homogenized milk is a colloid of tiny cream droplets in whey.

#### PURE SUBSTANCE OR SOLUTION?

Look at the list of different fluids in this table. Answer the following questions.

- Are these fluids pure substances or solutions?
- How would you determine if your classification is correct?

Copy the table into your notebook. In your table, mark  ${\boldsymbol \nu}$  in the column to which each fluid belongs.

Fluid Pure Substance Solution

soda pop
hot chocolate
water
apple juice
windshield washer fluid

Figure 2.2 A foam is a colloid of a gas in a liquid. The foam in this photo is used for insulation. It comes out of the can as a fluid, and then hardens in place to seal cracks.

#### PAPER CHROMATOGRAPHY

For some fluids, the *paper chromatography* test can be used to determine if they are pure substances or solutions. A piece of filter paper is placed partly in a solution. If the fluid is a pure substance, it will move up a strip of filter paper to one level. If the fluid is a solution, the different substances in it will move up the paper to different levels. This is a powerful technique for separating several substances mixed together.

# **Inquiry**Activity

#### Materials & Equipment

- · filter paper or coffee filters
- pencil
- · 250-mL beaker
- black, water-soluble marker pen
- · paper towels
- water



Figure 2.3 Step 1. Cut a piece of filter paper slightly larger than the width and height of the beaker.



Figure 2.4 Step 6. Curve the paper so it will stand up by itself in the beaker.

#### PAPER CHROMATOGRAPHY

#### The Question

Is the black ink in a marker pen a pure substance or a solution?

#### The Hypothesis



Write a hypothesis stating whether the marker pen's ink is a pure substance or a solution. (See Toolbox 2 if you need help with this.)

#### **Procedure**

- Cut a piece of filter paper so that it is slightly larger than the width and height of the beaker. This will become your chromatogram.
- 2 Using a pencil, draw a horizontal line 1 cm from one end of the paper.
- 3 Put 2 large dots of black ink on the filter paper along the horizontal line. Make sure that the dots aren't too close to each other.
- 4 Pour water into the beaker to a depth of 0.5 cm.
- 5 Predict what will happen to the ink dots when you put the paper in the water.
- Curve the paper so that it can stand up by itself in the beaker. Be sure the bottom edge is touching the bottom of the beaker. The line of dots should be just above the water. Do NOT allow the water to touch the line of dots.
- The water will move up as it soaks into the paper. When the water almost reaches the top of the paper, take the paper out and place it on a paper towel. Allow it to dry.

#### **Collecting Data**

8 Record your observations. Be sure to include or draw your strip of paper.

#### Analyzing and Interpreting

9 What happened to the original colour of the black dots?

#### Forming Conclusions

10 Is the ink in a marker a pure substance or a solution? Support your answer with your data.

#### **Applying and Connecting**

Chromatography has many uses, including identifying forged cheques. In one recent case, a greedy man changed the dollar amount on a will from \$1000 to \$10 000 simply by adding an extra 0. Using chromatography and comparing the ink from the different digits, investigators determined that the ink from one of the zeros came from a different pen. The man was convicted of forgery.

#### Extending

What would happen if you tested coloured markers? Try it and find out.

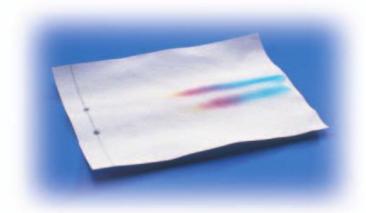


Figure 2.5 You can see from this chromatogram that the ink is not a pure substance. How many substances are mixed together in this kind of ink?

#### **READING CHROMATOGRAMS**

The filter paper used to test the substance is called a *chromatogram*. Figure 2.5 shows a filter paper with two spots of ink from a black marker on it after it was placed in water. The water soaked into the paper and eventually dissolved the ink spots. Notice how the different substances making up the ink separated at different levels on the chromatogram. The distance a substance moves depends on its attraction to the paper. Some substances are more strongly attracted to the paper. Those with the strongest attraction to the paper don't move very far. Those with the weakest attraction move farthest.

#### CHECK AND REFLECT

- 1. What is the difference between a mixture and a pure substance?
- 2. Below is a list of some examples of matter. Classify each example as a heterogeneous mixture, a homogeneous mixture, or a pure substance. Explain your classification in each case.
  - a) chocolate chip cookies
  - b) coffee with cream
  - c) aluminum foil
  - d) potting soil
  - e) gold medal
- 3. Create a flowchart that would help you classify matter into heterogeneous mixtures, homogeneous mixtures, or pure substances. Hint: Review the flowchart on page 20. Test your flowchart using the examples in question 2.
- 4. What practical uses can you think of for chromatography?

#### **I'8**SEARCH

#### **Separating Mixtures**

Methods of separating mixtures can be classified as either destructive or non-destructive. Use print or electronic resources to find examples of methods and what they are used for. Try to find examples other than chromatography.



# 2.2 Concentration and Solubility

Dissolving one substance into another makes a solution. The substance that dissolves is called the **solute**. The substance that does the dissolving is called the **solvent**.

In a concentrated solution, there are large amounts of solute in the solvent. For example, you may have made orange juice from frozen juice concentrate. The concentrate has a large amount of orange solids (solute) in a small amount of water (solvent). You add water to make a diluted solution. A diluted solution has small amounts of solute in the solvent. So the orange juice you drink is actually a diluted solution.

#### MEASURING CONCENTRATION

Concentrated and diluted are not exact terms. They don't tell you the actual amount of solute in the solvent. The concentration of a solution tells you the amount of solute dissolved in a specific amount of solvent. For example, a solution with 50 g of solute dissolved in 100 mL of water has a concentration of 50 g/100 mL of water. This is read as "fifty grams per one hundred millilitres."

Another common way of describing concentration is to state the number of grams of solute per 100 mL of solution. A concentration of 50 g/100 mL of solution means that 100 mL of the solution has 50 g of solute dissolved in it. Sometimes you will see concentrations stated in other ways. For example, the label on a juice box may say "5% real juice." Very low concentrations may be stated in parts per million (ppm).

#### info**BIT**

#### The Smell of Chlorine

A concentration of one part per million of chlorine in a swimming pool can be detected by the human nose.

#### Give it a TRY

#### ACTIVITY

#### COMPARING SOLUTIONS

You have three drinks in front of you. You know how they were made, but are unsure which one has the highest concentration of juice crystals. The first drink has 10 g of juice crystals dissolved in 50 mL of water. The second drink has 15 g of juice crystals dissolved in 100 mL of water. The third drink has 6 g of juice crystals dissolved in 25 mL of water.

Work with a partner to make a plan to figure out the concentration of each drink.

What was the most concentrated drink? How did you determine this since all three drinks had different amounts of solvent?



#### **COMPARING CONCENTRATIONS**

To compare the concentrations of two solutions, you need to know the amount of solute in the same volume of solvent for each solution. For example, you have two solutions. One has 10 g of salt in 50 mL of water (10 g/50 mL). The other has 25 g in 100 mL (25 g/100 mL). Which one is more concentrated?

For a comparison, the volume of solvent must be the same for both solutions. In our example, this means doubling the 10 g/50 mL to 20 g/100 mL. So now you are comparing the amount of salt per 100 mL of water in both solutions. The solution with the most solute in the same amount of water is the most concentrated: the solution with 25 g/100 mL is more concentrated than the one with 20 g/100 mL.

#### SATURATED AND UNSATURATED SOLUTIONS

You have just learned how to state the concentration of a solute in a solvent. You know that you can make a very diluted solution by adding a small amount of juice crystals to water. If you add more juice crystals, the solution becomes more concentrated. As long as the juice crystals keep dissolving, you have an **unsaturated solution**. An unsaturated solution is one in which more solute can dissolve.

What would happen if you kept adding juice crystals until no more would dissolve? You would now have a saturated solution. A saturated solution is a solution in which no more solute can dissolve at a given temperature. Solubility is the maximum amount of solute you can add to a fixed volume of solvent at a given temperature. In our example, the solubility of the juice crystals would be the maximum amount of juice crystals that you could dissolve in water at that temperature. Every solution has a saturation point at a given temperature. This occurs when no more solute can be dissolved in a fixed volume of solvent at that temperature.

Figure 2.6 When you drink juice made from concentrate, you have mixed water with the concentrate to make a diluted solution. The water is the solvent and the part of the concentrate that dissolves is the solute.

#### math Link

A cleaning solution is made of 5.25 g of a chemical called sodium hypochlorite in 100 mL of water. If you had a solution of 21 g of sodium hypochlorite in 100 mL of water, how would you make the cleaning solution?



#### Inquiry Activity

#### SATURATED AND UNSATURATED SOLUTIONS

#### The Question

How can you make saturated solutions?

#### Materials & Equipment

- · graduated cylinder
- beaker
- balance
- paper to hold solutes
- spoon or scoopula
- · water at room temperature
- · powdered drink crystals
- sugar
- salt
- stir sticks



Figure 2.7 Step 2. Accurately measure 5 g of a substance.

#### Procedure 🕲 🗇 🧷





- 1 Use the graduated cylinder to measure 50 mL of water into a beaker.
- 2 Measure 5 g of one substance. Add this to the water.
- 3 Stir the mixture until the substance has dissolved. Record your observations
- 4 Keep adding more of the same substance to the water, 5 g at a time, until no more will dissolve.
- 5 Repeat steps 1 to 4 for each substance.

#### **Collecting Data**

6 Make a table like the one below in your notebook:

Substance	Mass Added	Volume of Water	Concentration in g/100 mL Water	Observations

7 Fill in the table for each substance you use.

#### Analyzing and Interpreting

- 8 Calculate the concentration of each solution in grams per 100 mL. Don't forget you used only 50 mL of water, so you will need to correct the differences in mass and volume.
- 9 How did you know when a solution was saturated?

#### Forming Conclusions

10 Describe how you made saturated solutions and calculated the concentration of each of your solutes.

#### Applying and Connecting

Many industrial processes depend on producing solutions of various concentrations. In some situations, the more concentrated the solution, the more useful the solution can be. An example of this is red dye for food colouring. In the 1970s, synthetic red dye was banned because of its potential carcinogenic effects. Industry needed a safe replacement. Scientists found it in an insect called the

cochineal [kotch-e-neel] that lives in cacti in the Andes Mountains of South America. This bright red natural dye has been approved for use in cosmetics, drugs, and foods. Recently, two chemists from Simon Fraser University, Dr. Cam Oehlschlager and Dr. Eva Czyzewska, developed a method of improving the production process to make a more concentrated dye. The process is being used on the condition that the dye production remain close to the source of the insects. This is important because rural people are employed in collecting the insect.



**Figure 2.8** Cochineal insects live on cacti. They are the source for a bright red dye.

#### reSEARCH

#### Insoluble Substances

Sometimes a substance won't dissolve in a solvent. That substance is insoluble in that solvent. Find out why some substances are insoluble.

#### COMPARING SOLUBILITY OF COMMON SUBSTANCES

The solubility of a solute is the maximum amount of that solute that you can dissolve in a given amount of solvent at a given temperature. If you did the last Inquiry Activity, you noticed that different solutes have different solubilities. Solubility is a unique property for each substance. The table below shows the solubilities of some common substances in water at 0°C. You can see that 35.7 g of salt will dissolve in 100 mL of water at 0°C, and 180 g of sugar will dissolve in 100 mL of water at 0°C.

Solubility in g/100 mL of Water at 0°C		
Compound Solubility (g)		
salt	35.7	
baking soda	6.9	
carbon dioxide	0.35	
sugar	180	
hydrogen	0.00019	
oxygen	0.007	
ammonia	92	

# 1. 2. 3. 4. 5.

#### CHECK AND REFLECT

- 1. What is the difference between a diluted solution and a concentrated solution?
- 2. If a solution has a concentration of 75 g per 100 mL, what does this mean?
- 3. Calculate the concentrations in grams per 100 mL for the following solutions:
  - a) 10 g of chocolate in 50 mL of water
  - b) 3 g of sugar in 300 mL of water
  - c) 5 g of maple syrup in 25 mL of water
- 4. What is the difference between a saturated solution and an unsaturated solution?
- 5. What is the solute in a fruit punch drink?

# 2.3 Factors Affecting Solubility

In the last section, you learned about solubility. It is the maximum amount of solute you can dissolve in a given amount of solvent at a given temperature. Solubility depends on at least three factors: the type of solute, the type of solvent, and the temperature. First, let's consider the type of solute and the type of solvent.

#### Give it a TRY

#### ACTIVITY

#### DISSOLVING SOLUTES IN DIFFERENT SOLVENTS 🕍 🤡 🗇 🥖



Your teacher will give you these solutes: juice drink crystals, petroleum jelly, sugar, and salt. You will have two solvents: water and vegetable oil.

Which solutes will dissolve in water and which solutes will dissolve in vegetable oil?

Create a procedure that will allow you to collect data that will answer the above question. You will have to design a fair test to determine the answer to this question. (See Toolbox 2 for more information on how to design a fair



#### TYPES OF SOLUTES AND SOLVENTS

The most common solvent is water. Water is sometimes referred to as the universal solvent because it can dissolve so many different substances. If you see the term aqueous solution, that means the solvent is water. (Aqua is the Latin word for water.)

It is important to remember that solutions do not have to be made up of only liquids. The table below contains examples of solutes and solvents in other states.

Examples of Common Solutions				
Solute Solvent		Solution		
gas	gas	air (oxygen and other gases in nitrogen)		
gas liquid soda water (carbon dioxide in water)				
liquid	liquid	uid antifreeze (ethylene glycol in water)		
liquid solid rubber cement (benzene in rubber)		rubber cement (benzene in rubber)		
solid liquid seawater (salt and other substances in wa		seawater (salt and other substances in water)		
solid solid brass (zinc and copper)				

#### Inquiry Activity

#### Materials & Equipment

- · 2 beakers
- water
- thermometer
- · hot plate or access to hot water
- · solute and solvent
- · spoon or scoopula
- · graduated cylinder
- · triple beam or electronic balance



Figure 2.9 Carefully measure the mass of solute that you use.

#### TEMPERATURE AND SOLUBILITY

What effect does temperature have on the solubility of a substance? Hint: Recall that solubility is the maximum amount of solute (solid) that you can dissolve in a fixed volume of solvent (liquid) at a given temperature.

#### The Hypothesis

Write a hypothesis about how the temperature of the solvent affects the amount of solute that can dissolve in it.

#### Procedure 🕲 🔘 🥖





- 1 Decide which materials you will need to test the hypothesis.
- 2 Plan your investigation.
- a) What variable(s) will change?
  - b) What variable(s) will stay the same?
- 3 Write a procedure and show it to your teacher. Do not proceed any further until it is approved.
- 4 Carry out your investigation.

#### **Collecting Data**

5 Make sure you have recorded at least the following information: the hypothesis, your procedure, the temperature of the liquids used, and the mass of solute added.

#### Caution!

If you spill liquid on your hands, wash it off with water right away. Wash your hands when you have completed the activity.

#### Caution!

Always heat solvents in a water bath.

#### Analyzing and Interpreting

6 Share and compare your results with your classmates. What variables did each group have to keep the same so that you could compare results?

#### Forming Conclusions

7 In a short paragraph, describe your results and how they compared with the hypothesis.

#### Extending

A supersaturated solution is one that contains more solute than it normally would be able to dissolve at a certain temperature. How do you think you could make a supersaturated solution with the solute and solvent combination you tested here? Find out how to do this and try it.

#### SOLUBILITY CHANGES WITH TEMPERATURE

For most common solid or liquid substances, solubility increases as the temperature of the solvent increases. For example, at  $25^{\circ}$ C, you can dissolve 36.2 g of salt in 100 mL of water, but at  $100^{\circ}$ C, you can dissolve 39.2 g. The reverse is true for a gas. As the temperature increases, the solubility of a gas in a liquid solvent decreases.

#### **Thermal Pollution**

This decrease in the solubility of gases can have a serious effect on the environment. Many industrial plants use water as a coolant in their processes. Usually this water is drawn from a lake or a river. Once the water is used, it is warmer than when it was taken into the plant. Before it can be returned to the lake or river, it must be stored in a cooling pond. What would happen if the warm water were poured directly back into the river or lake? This is commonly called thermal pollution.

All water contains various amounts of different gases, including oxygen. The oxygen is important for supporting life that lives in the water. If the temperature of the water increases, the concentration of oxygen decreases. This occurs because the solubility of a gas in a liquid solvent decreases as the temperature increases. So the solubility of the oxygen is less in the warmer water. What do you think will happen to the living organisms in the lake or river if the amount of oxygen in the water decreases greatly?

#### CHECK AND REFLECT

- 1. Why is water called "the universal solvent"?
- 2. What factors affect the solubility of a solute?
- For the substances in the chart below, answer the following questions.

Solubility in g/100 mL of Water			
Substance	at 0°C	at 100°C	
sodium chloride	35	39	
sodium nitrate	74	182	
sodium carbonate decahydrate	21	421	

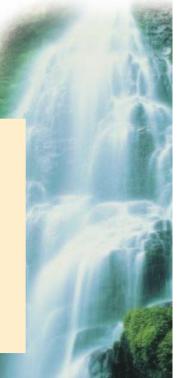
- a) Which substance is the most soluble at 100°C?
- b) Which substance is the most soluble at 0°C?
- c) Which substance shows the most change in solubility as the temperature increases?

The Properties of Mixtures and Fluids Can Be Explained by the Particle Model of Matter

#### infoBIT

#### The Colour of Money

In 1857, Thomas Sterry Hunt, a professor at McGill University in Montreal, produced a green ink called chromium trioxide. This green ink is used to this day to print American money. Dr. Hunt's green ink cannot be dissolved or copied by photography.



# 2.4 The Particle Model of Matter and the Behaviour of Mixtures

As you study the properties of mixtures, you may observe events that seem difficult to explain. For example, how would you explain the following situations involving mixtures?



**Figure 2.10a)** The potassium permanganate has just been added to the water.



**Figure 2.10b)** What happened to the potassium permanganate after 5 min in the water?

## Situation 1. Can something dissolve without stirring?

Figure 2.10a) shows a petri dish three-quarters full of water. A crystal of potassium permanganate was carefully added to the still water. The dish was left for 5 min without disturbing it. Figure 2.10b) shows the potassium permanganate after 5 min. What happened to it? Why do you think this happened?



**Figure 2.11a)** 20 mL of rubbing alcohol and 20 mL of water in separate 25-mL cylinders



**Figure 2.11b)** The two liquids combined in a 50-mL cylinder

#### Situation 2. Can you combine two liquids and have a volume less than the sum of the volumes when you started?

A lab technician carefully measured 20 mL of rubbing alcohol into one graduated cylinder and 20 mL of water into another. He then combined the two liquids. The combined liquid filled the graduated cylinder to a level of 39 mL. Did the technician make a mistake? Can you explain why this measurement resulted?

You may have developed explanations for these two situations, but you may not be completely sure of your answers. A model of matter would help explain these and other observations.

#### THE PARTICLE MODEL OF MATTER

Why did the potassium permanganate start to dissolve without being stirred? Why did the volumes not add up when the water and the rubbing alcohol were added together? The particle model of matter can help to explain these and other situations. The particle model has four main points that describe the structure of matter. Using this model, you will be better able to explain the properties of mechanical mixtures and solutions. As you look through the description of the particle model shown here, think about the situations described on the previous page.

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#### How Big Is a Particle?

There are about 10<sup>18</sup> particles in a snowflake. That's the number 10 with 18 zeros after it.



All matter is made up of tiny particles. Different substances are made up of different particles.

- This means every object in any state is made up of tiny particles too small to see.
- There are more particles in a given volume of solid than there are in the same volume of a liquid or a gas.

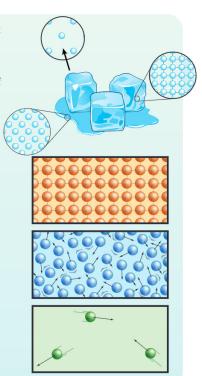
The tiny particles of matter are always moving and vibrating. For solids, this movement is like wiggling in one place. For liquids, the particles are sliding around and over each other. For gases, this movement means moving as far as the space they are in allows.

The particles in matter may be attracted to each other or bonded together.

 Some particles, such as water, have more attraction for other particles, such as salt, than for each other.

The particles have spaces between them.

• Notice the difference in the amount of space between particles of a solid and a gas.



#### USING THE PARTICLE MODEL OF MATTER 😂



You have 50 mL of sand in one container and 250 mL of marbles in another container. When you mix the contents of the two containers, you will be modelling what happens when alcohol and water are mixed together.

What will be the total volume of the sand and marbles when they are mixed

Slowly pour the 50 mL of sand into the container of marbles. Record your observations.

Use the particle model to explain what happened when you mixed the sand and marbles together. Now use it to explain what happened when the technician mixed the alcohol and water earlier in this subsection.





Figure 2.12 The marbles and sand represent two different substances made up of particles of two different sizes. Notice how the sand fills in the spaces between the marbles.

#### HOW THE PARTICLE MODEL EXPLAINS MIXING SUBSTANCES

The alcohol and water that the technician mixed together earlier are two different substances. They are made of different particles, and these particles are different sizes. When the two substances are mixed together, the smaller particles of one substance fill in the spaces between the larger particles of the other. Figure 2.12 shows a model of this situation.

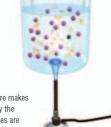
The particle model can also explain why substances dissolve. The particle model states that particles are attracted to each other. However, particles in some substances are more attracted to particles in other substances than to each other. For example, consider the situation in Figure 2.10 at the beginning of this subsection. When potassium permanganate is placed in water, its particles are attracted to the water particles. This is the process called dissolving. In a solution, the particles of the solute (potassium permanganate) are attracted to the particles of the solvent (water). The solute dissolves in the solvent. This is why a solute seems to disappear when mixed with a solvent.

#### FACTORS AFFECTING THE RATE OF DISSOLVING

In the subsection 2.3, you investigated different factors that affected the solubility of a substance. You found out that the kind of solute, the kind of solvent, and the temperature all had roles in solubility.

Another important consideration in dissolving solutes is the rate of dissolving. How fast will a solute dissolve in a solvent? How can you make a solute dissolve more quickly? Look at Figures 2.13a)-c). They show how the particle model can explain the factors that affect the rate at which a solute dissolves.





the particles move faster. Heat energy is transferred by the movement of the particles. Because the solvent particles are

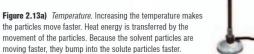






Figure 2.13b) Size of Pieces. Small pieces of solute dissolve more quickly than large pieces. All the smaller pieces together have more surface area among them for the solvent particles to bump into. Think of cooking a potato in water. If you put the whole potato in, it takes a long time to cook. If you cut the potato up into smaller pieces, the cooking time becomes much shorter.





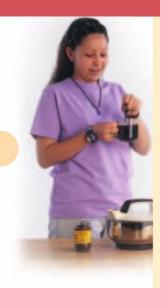
Figure 2.13c) Stirring. Stirring moves all the particles around, so the solvent particles bump into the solute particles.

#### **Atomic Structure**

The particle model is a simple way of describing matter and its behaviour. Atomic structure is another way. You have probably heard about atoms. How are atoms related to particles? Find out about atomic structure.



#### CHECK AND REFLECT



- Make a particle sketch showing how instant coffee dissolves in hot water
- 2. You've been asked to try out a new type of fruit drink flavouring that comes in the form of a cube that dissolves in water. You're in a hurry to try it so you want to dissolve it as quickly as possible. Name three ways of speeding up dissolving. Explain each one using the particle model.
- 3. Figure 2.14 shows a Web page about the particle model that is still under construction. The text hasn't been added yet.
  - a) In your notebook, complete the Web page with information that explains the picture. Include one hyperlink topic in the text of your Web page.
  - b) Write one other Web page that explains your hyperlink. The text on this page should use the words solubility and factors affecting the rate of dissolving.



Figure 2.14 Question 3. Web page under construction

4. Why did the potassium permanganate crystals start to dissolve in water without being stirred?

#### **Assess Your Learning**

- 1. Give an example of a pure substance. Why is it a pure substance?
- Think about examples of solutions made by combining different states of matter. Make a chart like this one, and fill it in with an example of each combination.

Substance	Substance	Solution Made	Other Examples
solid	liquid	table syrup	
solid	solid	steel	
liquid	liquid	perfume	
liquid	gas	tap water	

- a) Which combination of substances was the most difficult to think of as a solution?
- b) Which combination was the easiest?
- 3. In paper chromatography, is the substance being tested the solute or the solvent? Explain your answer.
- 4. Use the particle model to explain what happens to the rate at which a solute dissolves when the temperature increases.
- 5. A bucket of paint spills on your classroom floor. How could you use your knowledge of dissolving to help clean up the paint?



#### SCIENCE AND TECHNOLOGY

Scientific knowledge may lead to the development of new technologies, and new technologies may lead to scientific discovery. Think back to the information on using paper chromatography to separate substances in a solution.

- 1. What do you need to know about pure substances and solutions in order to use paper chromatography technology?
- 2. Use the library or the Internet to find other applications of chromatography.
- 3. After finishing your research, consider the following statement. Then write a brief response to it. *Understanding the scientific principles of paper chromatography is more important than developing uses for it.*



3.0

# The properties of gases and liquids can be explained by the particle model of matter.

#### **Key Concepts**

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

- · properties of fluids
- · mass, volume, density
- · viscosity and flow rate
- · buoyancy

#### **Learning Outcomes**

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

- define viscosity and describe how temperature affects it
- calculate and compare densities and relate them to the particle model of matter
- describe methods of altering density in fluids
- · explain buoyancy
- describe pressure and examples of its use
- compare the compressibility of liquids and gases

Most people think of liquids when they hear the word "fluids." But gases are also fluids. A fluid is any matter that has no fixed shape—it takes the shape of its container. For example, the air in a bicycle tire takes the shape of the tire and water in a bottle takes the shape of the bottle.

Fluids have many properties that are useful. In this section, you will investigate the fluid properties of viscosity, density, buoyancy, and compressibility. Each of these plays a role in how a fluid may be used. For example, the Canadarm can move heavy objects using only gears while the space shuttle orbits Earth. On Earth's surface, hydraulics provide an advantage that makes it possible for one person to lift and move huge loads. An engineer designing a hydraulic arm must understand how forces are transmitted through a fluid and how fluids behave under pressure. You will have the scientific knowledge to design a hydraulic arm at the end of this section.



# 3.1 Viscosity and the Effects of Temperature

One property of fluids is how they move or flow. Think about the fluids you have used in the last couple of days. What would happen if they didn't flow the way they usually do? For example, what if soda pop was like a thick syrup or ketchup was like water? In both these situations, the properties of the fluids are very different. With your partner, identify three fluids that you have used, and describe what they would be like if they were thicker or thinner. Here is an example:

Thicker	Thinner
- hard to get out of bottle	— would probably use more to wash hair
	- hard to get out

How quickly fluids flow is a property called **viscosity**. It is determined by a fluid's internal resistance or friction that keeps it from flowing. Recall from the particle model that the particles in a liquid slide around and roll over each other. In a gas, the particles move around even more easily. The greater the friction or rubbing between particles in any fluid, the higher the viscosity. Fluids with high viscosity do not flow as easily as fluids with a low viscosity.

Figure 3.1 Juice has a low viscosity. Ketchup has a high viscosity.



#### infoBIT



What grade of motor oil is this?

#### Multi-grade Engine Oil

The Society of Automotive Engineers (SAE) assigns all motor oils a viscosity number between 5 and 50. The higher the number, the higher the viscosity. SAE 30 oil is suitable for summer use, while SAE 10 oil can be used for winter driving. Multi-grade motor oil, such as SAE 10W30, has compounds added to it that allow the oil to flow easily at cold temperatures, but prevent it from thinning out too much when the weather becomes hot.

#### THE EFFECT OF TEMPERATURE ON VISCOSITY

Earlier in this section, you thought about different fluids and what would happen if their viscosity changed. What might cause a fluid's viscosity to change? Temperature is one factor that can have a big effect on viscosity. Look at Figures 3.2a)-d). What will happen to the viscosities of these fluids in the situations shown?



Figure 3.2a) Table syrup poured on hot pancakes



Figure 3.2b) Hot tar spread on a road



Figure 3.2c) Olive oil placed in a refrigerator



Figure 3.2d) Room temperature engine oil poured into a hot engine

#### MEASURING VISCOSITY WITH THE RAMP METHOD

The ramp method of testing viscosity involves pouring a fluid down a ramp and timing how long it takes to get to the bottom. By pouring the same amount of another fluid and timing it, you can compare the viscosities of different fluids. You can also investigate the effect of temperature on viscosity by testing the same fluid at different temperatures. First, you test it at room temperature. Then, you warm it in hot water or cool it in an ice bath, and test it again.

#### Give it a TRY

#### ACTIVITY

#### HOW FAST CAN IT GO? 4 3 0 0



You will use the ramp test to determine the effect of temperature on the viscosity of four fluids.

Design a fair test that will allow you to collect evidence to demonstrate the effect of temperature on viscosity. (See Toolbox 2 for more information on designing a fair test.)

Write a procedure and show it to your teacher for approval. Then carry out your tests.

When you have completed your tests, create a one-page summary poster of your results. Include one graphic illustrating your results.

#### Caution!

Handle hot water carefully. If you spill any on your skin, immediately run cold water over the area.

#### Materials & Equipment

- shampoo
- · pancake or table syrup
- · vegetable oil
- · Teflon-coated cookie sheet
- thermometer
- hot water
- · cold water
- beakers
- · a stopwatch

#### UNDERSTANDING VISCOSITY AND TEMPERATURE

Recall that viscosity is a fluid's internal resistance or friction that keeps it from flowing. A fluid with a high viscosity has a large amount of internal resistance or friction. As the temperature of a liquid increases, its viscosity decreases. The opposite is also true. As the temperature of a liquid decreases, its viscosity increases. If you did the ramp method activity, your data will show that the warmer the fluid, the faster it flows.

The particle model of matter can help you understand why this change in viscosity happens. Recall that in the particle model, a liquid is made of particles that can slide and roll over each other. When energy or heat is added to the liquid, the particles slide and roll more quickly. As a result, the fluid flows more readily—its viscosity decreases. The reverse is also true. As the temperature of the liquid drops, the particles slow down. The result is that the viscosity increases—the fluid flows more slowly.

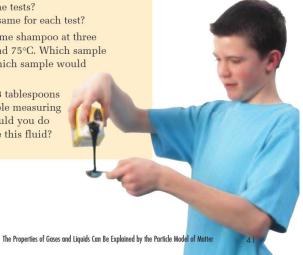
#### **CHECK AND REFLECT**

- Write a short paragraph to describe viscosity. Include at least two examples of fluids, and use the words flow, fluid, particles, and viscosity in your description.
- Describe two substances that are useful because of their viscosity.
- 3. In a fair test, you have to keep all the variables the same except one. That way, you can see the effect of the one variable. If you had to do a ramp test for viscosity:
  - a) What would you change during the tests?
  - b) What things would you keep the same for each test?
- 4. You are given three samples of the same shampoo at three different temperatures: 35°C, 50°C, and 75°C. Which sample would have the highest viscosity? Which sample would have the lowest?
- 5. You are making cookies that call for 3 tablespoons of molasses. But you are having trouble measuring out the thick, syrupy liquid. What could you do to make it easier to pour and measure this fluid?



#### Fluids from the Environment

In Alberta, Aboriginal peoples used to use the thick, viscous bitumen of the oil sands to seal their canoes. Aboriginal peoples all over North America also used tree sap to make a glue for building canoes. Find out how Aboriginal peoples made glue from tree sap. In what other ways did Aboriginal peoples use their knowledge of fluid characteristics?





# 3.2 Density of Fluids

Recall that at the beginning of this unit, you had an opportunity to answer an e-mail from the president of GeeWHIZ Beverage Ltd., asking you to find out if a piece of fruit could be suspended in a fluid. Here is an example of some data that was collected in this activity. One student, Emma, used cranberry juice, tomato sauce, peach juice concentrate, and a grape in her research.

Fluid	Grape Sank	Grape Floated on Top	Grape Floated in Middle
cranberry juice	1		
tomato sauce			1
peach juice concentrate		1	
		~	

Why did the grape sink in some liquids and not in others? The reason for the difference is a property of fluids called density. Density is the amount of matter in a given volume. Think about density as you examine the results of Emma's investigation above.

#### Give it a TRY

#### ACTIVITY

#### DENSE AND DENSER 🤡



You have six identical jars full of different materials in front of you.

Make a list, ranking them in order of highest density to lowest density. You may use any method you like to determine this ranking, but you cannot open the jars.

The list here tells you what is in each jar. If a substance has been changed, your teacher will tell you.

What ranking did you choose? Be prepared to explain your reasons for the order of your ranking. Keep your ranking handy because you will be testing these substances later. You will be able to compare your ranking with your test results.

#### **Contents of Jars**

- 1 water
- 2 sand
- 3 corn syrup
- 4 aquarium stones
- 5 shampoo
- 6 wood chips



#### UNDERSTANDING DENSITY

As you probably realize, not all substances have the same density. Recall that the particle model of matter states that all matter is made of tiny particles. It also states that different substances are made of different particles. So the particles in each fluid are different from the particles in every other fluid. The density of a fluid or any other kind of substance depends on the particles it is made of.

Think about Emma's results again on page 42. If the density of the grape was *greater* than the density of the fluid, the *grape sank*. If the density of the grape was *less* than the density of the fluid, the *grape floated*. Look at the graph of the densities of some common materials in Figure 3.4. You'll notice that some solids are less dense than some liquids. That's why wood floats on water. It's the kind of particles in a substance that are important in determining a substance's density.

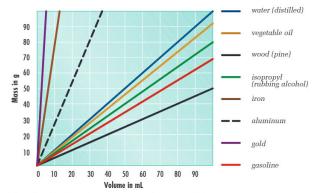


Figure 3.4 Densities of some common substances at 20°

#### CALCULATING DENSITY

Density is the mass per unit of volume, which can be measured in  $\rm mL$  or  $\rm cm^3$ . Density is calculated by dividing the mass of a substance by its volume.

Density (d) = 
$$\frac{\text{Mass } (m)}{\text{Volume } (V)}$$

The units for the density of liquids and gases are usually grams per millilitre (g/mL) or kilograms per litre (kg/L). The units for the density of solids are usually grams per cubic centimetre (g/cm<sup>3</sup>).



#### Now That's Dense!

Mercury, like water, is a liquid at room temperature. Water's density at this temperature is 1.00 g/mL. Mercury's density at this same temperature is 13.55 g/mL!



#### What's the Difference?

A can of diet soda pop will float in water, but a can of regular pop will not. Find out why.

#### Inquiry Activity

#### Materials & Equipment

- · 250-mL beaker
- · graduated cylinder
- · triple beam or electronic balance
- water, sand, corn syrup, aquarium stones, shampoo, wood chips
- · graph paper



Figure 3.5 Step 2. Pour 50 mL of one substance into the beaker and record the volume in the table.

#### CALCULATING MASS/VOLUME RATIO

#### The Question

How can you calculate the density of a variety of solids and liquids?

#### The Hypothesis

Write a hypothesis about how to calculate density of solids and liquids. Hint: Recall that density is the mass of a substance in a given volume.







- 1 Measure the mass of the beaker and record it in your table. (See Toolbox 5 for information on measuring mass.)
- 2 Pour 50 mL of one substance into the beaker and record the volume in the table. (See Toolbox 5 for information on measuring volume.)
- 3 Place the beaker containing the substance on the balance and measure the mass. Record the mass in your table.
- 4 Repeat steps 2 and 3 for the same substance with volumes of 100 mL, 150 mL, 200 mL, and 250 mL.
- 5 Repeat this procedure for each of the other substances.
- 6 Clean and return your equipment to the proper location.

#### **Collecting Data**

7 In your notebook, make a table like the one shown below to record your data. Use a table like this for each substance.

Substance	Volume of	Mass of	Mass of	Mass of	Mass/
	Substance	Beaker	Beaker and	Substance	Volume
	(mL)	(g)	Substance (g)	Only (g)	Ratio
_			_		~

#### Analyzing and Interpreting

- 8 When you have finished taking your measurements, enter your data into a spreadsheet program.
- 9 Find the mass of each substance by subtracting the mass of the beaker from the total mass of the beaker and substance together.

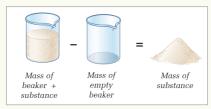


Figure 3.6 How to calculate the mass of the substance

- 10 Set up a line graph with mass on the vertical axis and volume on the horizontal axis. Plot your results for the first substance. Draw a straight line through or close to the points on the graph.
- 11 Plot your results for the other substances on the same graph. Label each line.
- 12 Compare the slopes of the lines. Which slope is the steepest? Which slope is the shallowest?
- 13 Find the ratio of the mass to the volume by dividing the mass of the substance by the volume for each volume measured. What is the average ratio for each substance? This ratio is the density of each substance. For example:
  - 200 mL of a substance has a mass of 400 g
  - the mass to volume ratio is  $\frac{400 \text{ g (mass)}}{200 \text{ mL (volume)}}$
  - Density =  $\frac{400 \text{ g}}{200 \text{ mL}} = \frac{2.00 \text{ g}}{1 \text{ mL}}$
- 14 Can you see any relationship between the average ratio for each substance and the slope of each line on your graph?
- 15 Compare your calculated densities for the substances with the predictions you made when you did the Give It a Try Activity at the beginning of this subsection. Was the order of the densities you predicted the same or was there a difference? Suggest reasons for any differences.
- 16 Use your graph to determine the answers to the following questions:
  - a) What would be the mass in grams of 150 mL of corn syrup?
  - b) What would be the volume in millilitres of 225 g of sand?
  - c) What would be the mass in grams of 300 mL of shampoo?

#### Forming Conclusions

17 Write a summary paragraph that explains how you calculated the density of the substances used in this investigation. Your summary should include the words substance, volume, mass, graph, slope, ratio, and density. Include your graph with your summary.

#### Applying and Connecting

If a boat is heavier than water, why does it float on water? The answer is in the concept of average density. Each of the materials that make up the boat might sink in water, but the average density of the whole boat is less than the average density of the water. The average density of the boat includes the boat's total volume, which not only contains the solid parts of the boat, but also the air in the cabins, the hold, and other spaces.

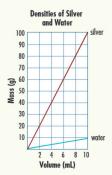


Figure 3.7 Step 10. How will you determine what scale you will use for each axis?

#### CHECK AND REFLECT



1. The table below shows mass and volume data for baby oil. What happens to the mass of the baby oil as the volume changes?

Mass (g)	Volume (mL)		
0.8	1.0		
1.6	2.0		
2.4	3.0		
3.2	4.0		

- 2. a) What is the density of the baby oil?
  - b) What happens to the density as the mass and volume change?
- 3. Suppose you were to graph the baby oil data on a graph with mass on the vertical axis and volume on the horizontal axis. Would the slope of the line for the baby oil be shallower or steeper than one for water? (The density of water is 1.0 g/mL.)
- 4. What is the density of each of the following substances?
  - a) 2.0-mL of mercury has a mass of 27.1 g
  - b) 0.5-mL of silver has a mass of 5.25 g
  - c) 2.5-mL of lead has a mass of 28.5 g
- 5. If you had 100 mL of each substance in question 4, which one would have the greatest mass?



#### SOFT-DRINK MANUFACTURER

To make a soft drink, you need to experiment with different combinations of water, sugar, and flavourings to make a syrup. Flavours come from fruits and berries, as well as from tree bark, herbs, and roots. Once you've got exactly the right taste, this syrup will be your own secret formula!

Next, you'll carefully purify the water for your drink. Then, you'll mix your secret syrup with the right amount of water. Your drink is a solution, since the sugar and flavourings dissolve in water.

The last step is pumping your water and syrup solution into a machine called a carbonator. This machine mixes carbon dioxide gas into your solution

under very high pressure. Now your drink is a mixture of a gas and a liquid! The drink goes straight from the carbonator into the bottle or can, which is then sealed so the gas won't escape.



 What would you need to know about science and technology to develop a soft drink?

## 3.3 Density, Temperature, and Buoyancy

Earlier in this unit, you discovered that viscosity changes with temperature. Does density also change when the temperature changes? The particle model of matter states that for each substance, the number of particles in a given volume remains constant if the temperature is kept constant. Density does not change as long as the temperature stays the same.

#### Give it a TRY

#### ACTIVITY

#### MEASURING DENSITY CHANGES 🔕 🥼



Caution! Handle hot water carefully. If you spill any on your skin, immediately run cold water over the area.

Is there a difference in density between a cup of cold water and a cup of hot water? You can test the question by using a hydrometer. A hydrometer is a device for measuring the density of liquids.

Use a hydrometer to determine if the density of cold water is the same as the density of hot water.

You will need two beakers for the water and a hydrometer.

In a short paragraph, summarize your results. Use the particle model to help explain what you observed.



#### THE PARTICLE MODEL AS AN EXPLANATION FOR DENSITY CHANGES

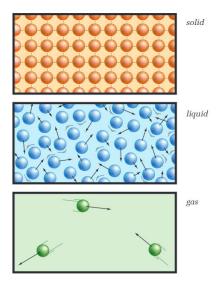
Think about swimming in a lake on a hot summer day. The water on the surface of the lake is noticeably warmer than the water below it. The warm water floats on the cold water because it has a lower density than the cold water has.

According to the particle model, particles in a substance move more quickly when energy is added. As a solid changes to a liquid and eventually to a gas, the particles move faster and faster. This affects the density of the substance. As particles become more active, they move away from each other, and the space between them increases. This causes the volume to increase, but the number of particles stays the same. With the same number of particles in a larger volume, the density decreases. Recall that density is the ratio of mass to volume.

#### **Different Temperature, Different Density**

One substance, then, can have different densities depending on its temperature. What happens to a substance as it is heated? It changes state: at low temperatures, it will be a solid, and at higher temperatures, it will be a liquid, and at even higher temperatures, a gas. A substance (except water) has a greater density in its solid state than in its liquid state and gas state. Figure 3.8 shows how the particle model explains this.

Figure 3.8 The particle model of matter describes particles in a solid and a liquid being packed close together compared with particles in a gas. A gas has more space between particles. This explains why a substance is most dense when it's a solid and least dense when it's a gas.



#### infoBIT

#### Galileo's Thermometer

The thermometer shown here is Galileo Galilei's thermometer (or thermoscope), first invented in the 1590s. Can you determine how it works? Each temperature bulb acts like a hydrometer and floats to the top when the water's density is greater than that of the bulb.





Figure 3.9 Why is this swimmer floating so easily?

#### CHANGING DENSITY BY CHANGING CONCENTRATION

Have you ever tried to float in a lake, a river, or a swimming pool? How easy was it? It probably wasn't as easy as it is for the person in Figure 3.9. This person is floating in the Dead Sea in Israel. The Dead Sea is one of the saltiest bodies of water on Earth. Why do you think it might be easier to float in salt water than in fresh water?

Earlier, you learned that density depends on the number and kind of particles in a given volume. Distilled water has a density of 1 g/mL. What do you think would happen if you added salt to this water? Recall from the particle model of matter that dissolving one substance (salt) in another (water) increases the number of particles in a given volume. By adding more particles, you increase the density of the water solution. Increasing the concentration of salt in the solution increases the density. That means denser objects can float in the solution now than could in the distilled water.

So far, you have learned how density determines if one object will float in another. Less dense objects float in more dense substances. But is density the only factor that affects floating?

#### BUOYANCY

In this unit, you have seen that an object sinks when its density is greater than the density of the fluid it is in. What is the connection between the object's density and the forces that act on it in a liquid? When an object is in a liquid, the force of gravity pulls it down. The liquid, however, exerts an opposite force, called the **buoyant force**, that pushes the object upward.

What happens when the density of the liquid is greater than the density of the object? The buoyant force of the liquid on the object is greater than the force of gravity pulling down on the object. The object floats.

What happens when the density of the object is greater than that of the liquid? The force of gravity acting on the object will be greater than the buoyant force of the liquid. The object sinks. **Buoyancy** is the tendency of an object to float when placed in a fluid. The buoyant force is the force in fluids that acts against gravity.



Figure 3.10a) The diver is able to move downward because of a combination of forces. The force of gravity acting on her, along with the force of her leg movement, is greater than the buoyant force of the water.



Figure 3.10b) The diver can move upward because the buoyant force, combined with the force of her leg movement, is greater than the force of gravity.



Figure 3.10c) The diver can float suspended in the water where the force of gravity equals the buoyant force. This situation is called neutral buoyancy.

#### APPLICATIONS OF BUOYANCY

Buoyancy is an important factor in some transportation technologies. For example, ships are designed to float safely all over the world. But what happens when a ship moves from more dense to less dense water?

#### **Plimsoll Line**

A fully loaded cargo ship sails across the Atlantic Ocean. As it enters the fresh water of the St. Lawrence River, it sinks dangerously low. Why? It sinks because fresh water is less dense than salt water. The ship floats lower in the less dense water. The same thing happens when a ship sails from cold northern water into warm tropical water. Warm water is less dense than cold water.

Because of density variations in the world's oceans and rivers, all cargo ships have what is known as a *Plimsoll line* painted on their hulls. The Plimsoll line shows how heavily a ship can be safely loaded in different water conditions. Look at Figure 3.11. The marks on the left indicate where the waterline should be in fresh water. The marks on the right indicate where it should be in salt water.

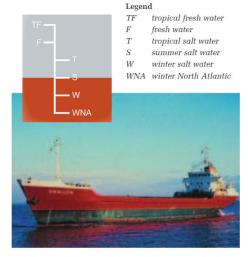


Figure 3.11 The Plimsoll line indicates how heavily loaded a ship can be in different densities of water.

#### **Hot Air Balloons**

Another transportation technology where buoyancy is important is in hot air ballooning. As the air in the balloon is heated, it becomes less dense than the surrounding air. The buoyant force pushes the balloon up into the air. The balloon stops rising when the buoyant force equals the force of gravity. That's the point when the balloonist stops adding heat to the air in the balloon.

#### **PESEARCH**

#### Airships

Early airships looked something like the Goodyear blimp that flies over sports events, but they were much larger. These airships were called *zeppelins*, after their inventor, Count Ferdinand von Zeppelin. The Graf Zeppelin airship was 236 m long and could travel at 129 km/h.

Find out more about early airships. Why did these balloon-like aircraft have to be so large? Why did the Hindenburg, shown here, go up in flames?

The Hindenburg



#### CHECK AND REFLECT



- 1. What units are usually used for measuring the density of solids? of liquids?
- 2. Use the particle model of matter to describe what happens to the density of a substance when it cools.
- 3. Look at Figure 3.12. Can you spot the mistake in the directions for this water-play air mattress? Explain your answer.



This air mattress should not be used by children without adult supervision.

Do not inflate.

Keep away from sharp objects to prevent punctures.

Figure 3.12 Question 3. Air mattress warning tag



#### ACTIVITY

#### SINK OR SWIM

You can make your own model of a diver at home using a plastic pop bottle with a cap, water, and an eyedropper.

- · Fill a plastic pop bottle about three-quarters full of water.
- Float an eyedropper on the surface of the water.
- Use the cap to seal the bottle tightly.
- Squeeze the bottle with your hands so the sides go in.
- Can you explain what happens?
- $\bullet\,$  What would happen if you used a fluid other than water? Try it and see.



# 3.4 Compression of Fluids

Another useful property of some fluids is **compressibility**. When a force pushes on an object, the object is said to be under compression. Objects under compression tend to deform in shape. For example, when you kick a soccer ball, the force of your foot compresses the ball and temporarily deforms it, as shown in

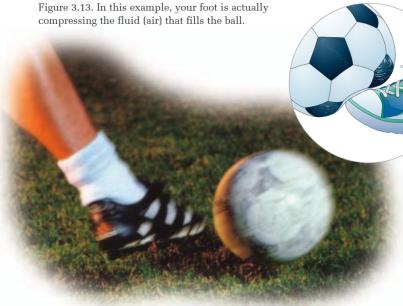


Figure 3.13 Your foot deforms the soccer ball as you kick it.

#### infoBIT

#### **Compressing Solid Objects**

A solid object can be compressed if a great enough force is applied to it. The photo shows that the force exerted by the baseball bat on the baseball compresses and deforms the ball.

The effect of a baseball bat on a baseball



## **Inquiry**Activity

#### Materials & Equipment

#### Part 1

- 50-mL syringe
- . 5 cm of latex tubing
- · bulldog clamp
- water
- · sink or bowl

#### Part 2

- · 2 burette clamps
- modified 50-mL syringe with platform
- . 5 cm of latex tubing
- · bulldog clamp
- · support stand
- 4 1-kg masses
- water
- · empty container



**Figure 3.14** Step 1. The plunger should be three-quarters of the way up the tube.

#### COMPRESSING FLUIDS

#### The Question

What happens to air as it is compressed? Does water react in the same way?

#### Procedure 🕲 🧔



- 1 Attach the latex tubing to the end of the syringe. Place the plunger of the syringe three-quarters of the way up the tube. Seal the tubing at the end of the syringe with the bulldog clamp.
- 2 Before you press the plunger down, predict how far the plunger will go. Record your prediction. Test your prediction.
- 3 Press down the plunger and record the change in volume in the syringe.
- Unclamp the tubing, and place the syringe in a sink or bowl of water. Pull up the plunger to draw in water until the syringe is filled to the same level as in step 1. If you get air in your syringe, turn the syringe upside down so the plunger points downward. Allow the air to rise to the top of the syringe. Then gently push the plunger up until all the air has escaped. Add more water if necessary. Clamp the end of the tubing shut.
- Before you press the plunger down, predict how far you think the plunger will go. Record your prediction. Test your prediction.
- 6 Press down the plunger and record the change in volume in the syringe.

#### Part 2 Compressing Water

- Use the burette clamps to attach a modified syringe (with platform) to a support stand, as shown in Figure 3.15.
- 3 Attach the latex tubing to the end of the syringe. Pull the plunger to the 50-mL mark. Seal the tubing with the bulldog clamp.
- Place a 1-kg mass on the centre of the platform that is attached to the syringe. (This applies a 10-N force.) Measure and record the volume of air in the syringe.
- Repeat step 9 by adding another 1-kg mass so that you have a 2-kg mass (a 20-N force).
- Repeat step 10 for the following masses (forces): 3 kg (30 N) and 4 kg (40 N). Place the masses in the centre of the platform.



Figure 3.15 Step 7. Be sure to follow safe work procedures. Clamp the syringe tightly at right angles to the stand.

- 12 Remove all the masses.
- Remove the syringe from the burette clamps and place it in a sink or bowl of water. Fill the syringe to the 50-mL mark by pulling on the plunger, not the platform. Remove any air bubbles as before. Reattach the syringe with the burette clamps. Place an empty container under the syringe. Repeat steps 9, 10, and 11.
- (1) Clean and return your equipment to the appropriate location.

#### **Collecting Data**

Part 1

- 15 Record your predictions in your notebook.
- 16 Record the volume in the syringe before and after you push down the plunger.

#### Part 2

17 Record your data in a table like the one shown below.

Force Acting on Fluid in Syringe (N)	Volume of Air (mL)	Volume of Water (mL)
0		
10		
	~ ~	

#### Analyzing and Interpreting

- 18 How did your predictions compare with your results?
- 19 Which fluid compressed more? Why do you think this happened?
- 20 How did the force affect the compression of the air and the water?
- 21 Draw a line graph of the compression of the air and water from Part 2 using a different colour for each. Put the volume on the vertical axis, and the force on the horizontal axis.

#### Forming Conclusions

22 Use the particle model to explain what happened when you compressed the air and the water. Focus your explanation on the differences in the amount of space between particles in air and water. Use your observations, and remember to refer to your graph to support your explanation.

#### Applying and Connecting

The property of compressibility in fluids is useful to other living things, besides humans. For example, starfish move by filling their tube feet with water.



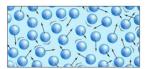
Figure 3.16 Starfish

#### reSEARCH

Engine Compression Find out why compression is important in a car's engine.

#### DIFFERENCES IN COMPRESSIBILITY BETWEEN GASES AND LIQUIDS

One of the properties of fluids is that gases can be compressed much more than liquids can. Think about squeezing a sealed plastic bottle when it's full of juice and then when it's empty. How much more can you compress it when it's empty than when it's full? The particle model can explain this situation. Figure 3.17 shows that there is much more space between particles in the gas than between those in the liquid.



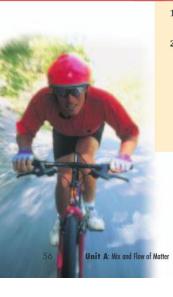


**Figure 3.17** There is much more space between particles in a gas than there is between particles in a liquid.

As a result, when a force is applied to the particles, much more compression takes place in the gas than in the liquid. The gas particles have more space to move. In fact, very little compression occurs in liquids. Materials in a liquid state are said to be incompressible; that is, they cannot be compressed easily. This property of liquids is very useful. Can you think of any situations where it would be used?

#### CHECK AND REFLECT

- Use the particle model to explain the differences in compressibility between liquids and gases.
- Use your explanation in question 1 to identify which material in each pair below would compress more than the other. Provide a brief reason for each answer.
  - a) a helium balloon or a water balloon
  - b) a solid rubber bicycle tire and an inflated mountain bike tire
  - c) plastic bubble-wrap or a liquid-filled baby's teething ring
  - d) a golf ball or a soccer ball



## 3.5 Pressure in Fluids — Pascal's Law

Fluids can be very useful in helping us perform tasks because of the way they transmit pressure. For example, you may already know something about hydraulics and pneumatics, where fluids are used in devices. In this subsection, you'll learn why this property makes fluids so useful.

An important part of understanding how to use fluids in devices is knowing the relationship between force, area, and pressure. **Pressure** is the amount of force applied to a given area. It is measured in pascals (Pa). A pascal equals the force of 1 N (newton) over an area of 1 m² (1 Pa =  $\frac{1 \text{ N}}{1 \text{ m}^2}$ ). The more force you can apply to a given area, the greater the pressure. You can write this relationship as an equation: p = F/A, where p is pressure, F is force, and A is area.

Here is an example of how to calculate pressure. You have a force of 10 N on an area of 2  $\rm m^2$ . What would the pressure be?

$$\text{Pressure } (p) = \frac{\text{Force } (F)}{\text{Area } (A)} = \frac{10 \text{ N}}{2 \text{ m}^2} = \frac{5 \text{ N}}{\text{m}^2} = 5 \text{ Pa}$$

Look at the examples of pressure measurements in the infoBIT on this page. They are all in kilopascals (1 kPa = 1000 Pa). Scientists use kilopascals because 1 Pa is a very small amount of pressure. It's about the amount of pressure exerted on your desk by a small sheet of paper lying on it. Note that pressure can also be measured in newtons per square centimetre (N/cm²).

#### **Blaise Pascal Investigates**

In the mid-1600s, the French mathematician Blaise Pascal was curious about how pressure is exerted in a fluid. In one of his first experiments, he investigated the relationship between water pressure and depth. Look at Figure 3.18, showing water flowing out of two holes at the same level in a can. Working with a partner, develop an explanation for what you observe. Use the following words in your explanation: pressure, sides of the can, force, equal, and depth. Be prepared to share your explanation with your class.

#### infoBIT

#### **Examples of Pressure**

- The average air pressure at sea level is 101.3 kPa (kilopascals).
- The jaws of an ant exert a pressure of 0.005 kPa.
- A ballet dancer standing on the toes of one foot exerts a pressure of 2500 kPa on the floor.

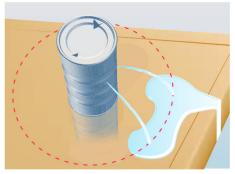


Figure 3.18 Why does the water flow out of the can in this way?



Figure 3.19 The water exerts pressure in all directions in the container.

#### PRESSURE AND DEPTH

From Figure 3.18, you and your class may have determined that the pressure of the water on the sides of the can was equal at the same depth. You could infer this because the water that came out of the holes travelled the same distance outward before hitting the ground. This observation leads to another question: How does pressure change as the depth of the water changes? What do you think would happen if you put holes in the can at different depths?

#### THE GREATER THE DEPTH, THE GREATER THE PRESSURE

In the introduction to this subsection, you saw that pressure forced water out of holes in a container. The water was exerting pressure on the walls of the container. The weight of water in the upper part of the container also pressed down on the water in the lower part of the container. The more water above a hole, the greater the pressure, and the farther water will flow out of the container. So, the greater the depth of water, the greater the pressure at that point.

#### PASCAL'S LAW

Pascal continued his investigations into pressure by studying enclosed fluids. He wondered what would happen if a force was applied to a fluid in a closed system. Through experimentation, he found that the force created pressure that was transmitted equally in all directions throughout the fluid. He developed a law to describe his observations. Pascal's law states that an enclosed fluid transmits pressure equally in all directions. The examples of applications of Pascal's law below will help to explain it further.

#### HYDRAULIC DEVICES

Pascal's discovery of this law led to the invention of many different types of hydraulic and pneumatic devices. **Hydraulic systems** use a liquid as the enclosed fluid. **Pneumatic systems** use air. Figure 3.20 shows a hydraulic device that is used for lifting cars. You may have noticed these in car repair garages. Such a device uses two pistons of different sizes to create pressure and to lift the car. A piston is a disk that moves inside a cylinder. The small piston is the input piston, which pushes down on the liquid to create pressure. This pressure is then transmitted through the liquid where it pushes up on the large piston, which is the output piston.

Recall that pressure equals force divided by area (p=F/A), and look at Figure 3.20. You can see that the output piston has a much larger area than the input piston does, but the pressure is the same everywhere in the system. So, because p=F/A, the force of the larger piston is greater than the force of the smaller piston.

The area of the output piston in this example is 16 times larger than the area of the input piston. The result is an output force 16 times greater than the input force—a force strong enough to lift a car! One of the benefits of a hydraulic system is that it can multiply force. However, to move the large piston, the small piston must move much farther that the large piston does. You will learn more about hydraulic systems in Unit D: Mechanical Systems.

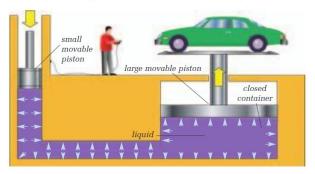
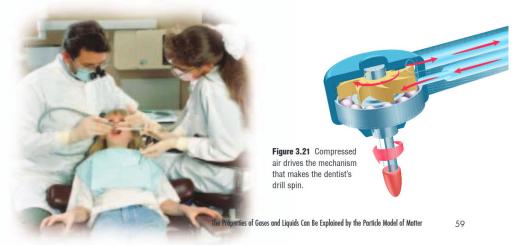


Figure 3.20 A car lift or hoist. The arrows in the liquid indicate the pressure transmitted throughout the system. Hoists are used in repair garages so that mechanics can work under cars more easily.

#### PNEUMATIC DEVICES

Pneumatic devices use compressed air to do tasks. Dentists' drills, jack hammers, paint sprayers, and air brakes on trucks are all examples of pneumatic devices.

Reasonable cost and safety are two advantages of pneumatic systems. Compressed air is cheap and safe, as the devices do not create sparks within the system. This can be important if you are working in a mine where a spark could cause an explosion. Pneumatic devices are also free of electrical hazards, which is one reason that dentists' drills are pneumatic.



#### TESEARCH

#### Ultrahigh-Pressure Water Systems

An ultrahigh-pressure water system forces water out of a hose at 275 000 kPa of pressure. This water jet can be used for cleaning, blasting, cutting, and processing materials. Using the library or the Internet, research applications of ultrahigh-pressure water systems.

Figure 3.22 Pneumatic systems are used for bus doors and for brakes in large vehicles like buses and trucks.

#### MAINTAINING THE PRESSURE

For a pneumatic or hydraulic system to function properly, the entire system must be completely sealed. Even the smallest hole or leak can cause the system to fail. For example, cars have hydraulic brakes. If there is a leak in the hydraulic line, the brakes can fail. Pneumatic bus doors also depend on a sealed system, so that the door can open and close. A leak in the system allows air to escape. This loss of pressure means that the system can't generate enough force to close the door if it's already open, or to open the door if it's already closed!



#### CHECK AND REFLECT

- 1. Describe how pressure is transferred in a fluid.
- 2. If 10 N of force is applied to an area of 1  $\mathrm{m}^2$ , what is the pressure?
- 3. What is the difference between a hydraulic and a pneumatic system?
- 4. A hydraulic lift has 1000 N applied to an input piston that has an area of 30  $\rm cm^2.$ 
  - a) What is the pressure exerted on the liquid by the input piston?
  - b) If the force were doubled, what would be the pressure?
  - c) If the area were reduced to  $15~\mathrm{cm^2}$ , what would be the pressure?

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. What is viscosity? Why is it an important property?
- Use the particle model to describe why ketchup is more viscous than liquid dish soap.
- 3. How does temperature affect the viscosity of a fluid?
- 4. What does density measure?
- 5. Describe how you find the density of an object.
- 6. a) What is the density of a shampoo if 13.2 g of the shampoo fills a 5-mL container?
  - b) What is the density of vegetable oil if 50 g of the oil has a volume of 8 mL?
  - c) What is the density of gasoline if 90 mL of it has a mass of  $62~\mathrm{g}$ ?
  - d) If you had  $50~\mathrm{mL}$  of each of these substances, which one would have the least mass?
- 7. How does the particle model of matter help you explain why cold water is denser than hot water?
- 8. Why does a liquid compress much less than a gas does?
- 9. Describe Pascal's law and give one example of its application.
- 10. A full juice can has a hole at the top and another hole near the bottom. How will the juice flow out of the two holes? Why is there a difference?
- 11. How does a car lift work? What problems does a car lift solve?



### SCIENCE AND TECHNOLOGY

Any scientific investigation or technological development leads to new questions and problems. Think back to the information you learned and the activities you did in this section.

- 1. After learning about viscosity, what two new questions do you have about this property of fluids?
- Identify one problem you encountered in this section and describe how you solved it.
- 3. At the end of the unit, you will do a project to design a soft drink with a grape floating in it. What did you learn about density that would help you float the grape?



## 4.0

## Many technologies are based on the properties of fluids.

#### **Key Concepts**

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

- · properties of fluids
- · fluid technology applications

#### **Learning Outcomes**

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

- describe examples of technologies based on solubility
- describe examples of technologies based on flow rates and moving fluids
- explain how to design and construct a working model of a fluid-using device



In this unit, you have had an opportunity to learn about the properties of fluids. Now it is time to look at some applications of this knowledge. Applied scientific knowledge results in new technologies. Technology includes devices, systems, and processes that meet people's needs or wants. In this section, you will explore technologies that meet needs to keep things clean, cure "the bends," move fluids, and explore uncharted waters where humans have never gone before.

## 4.1 Technologies Based on Solubility

While you are eating a hamburger, a glob of mustard falls on your favourite jeans. This could be a disaster but you're sure that the laundry detergent will get the stain out. What is it about detergents that give them their special cleaning power?

A detergent is a substance that can remove dirt from fabric. Most detergents are liquids or powders that can dissolve in water. Detergents contain a cleaning agent called a *surfactant*. Surfactants are particles that attach themselves to dirt and oil particles, separating them from fabric or other material. Figure 4.1 illustrates this process.

#### **How Detergent Works**

Dirt and grease on fabric

The mixture of water, detergent, and clothes is agitated in the washing machine. Dirt breaks off from the clothes.

Surfactants in the detergent surround the dirt particles so they can't re-attach to clothes.

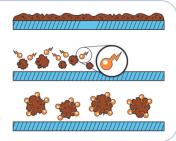


Figure 4.1 Detergents use surfactants to carry away dirt.

In the past, manufacturers added chemicals called *phosphates* to detergents. Phosphates made detergents work better in hard water. However, the phosphates damaged the environment by polluting the water. Today, most detergents do not include phosphates.

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#### Ingredients in a Typical Laundry Detergent

Ingredient	What It Does	Ingredient	What It Does
surfactant	cleans clothes	builder	softens water to help surfactant clean
filler	stops detergent from clumping	corrosion inhibitor	prevents washer from rusting
suspension agent	stops dirt from re-attaching to material	enzyme	removes protein stains
bleach	removes stains	optical whitener	adds brightness
fragrance	adds scent	colouring agent	gives detergent colour

## Inquiry

### Activity

#### Materials & Equipment

- · 3 250-mL beakers
- · water (at room temperature)
- · rubbing alcohol (at room temperature)
- · vinegar (at room temperature)
- · graduated cylinder
- · 3 identical pieces of fabric
- mud
- linstick
- · chocolate
- · laundry detergent
- · pair of forceps or tweezers



Figure 4.2 Step 4. Swirl the fabric around in each solution using the forceps.

#### CLEANING SOLVENTS

#### The Question

Which solvent is best for removing stains from clothing?

#### The Hypothesis

Write a hypothesis that predicts which solvent in this inquiry activity works best at removing stains.

#### Procedure 🕲 🔘 🥖





- 1 Pour 50 mL of water into one beaker, 50 mL of rubbing alcohol into another beaker, and 50 mL of vinegar into a third beaker. Label the beakers.
- 2 Predict which solvent will be best for removing stains.
- 3 Mark each piece of fabric with mud, lipstick, and chocolate.
- 4 Place one piece of soiled fabric into each beaker. Swirl the fabric around in each solution using the forceps. Leave for at least 10 min. Look at the stains.
- **5** Add some laundry detergent to the beaker containing water. Use the forceps to swirl the fabric around in the solution. Leave for at least 10 min. Look at the stains.

#### **Collecting Data**

6 Make a chart of your observations.

#### Analyzing and Interpreting

- 7 Did the mud dissolve in each solvent? Explain.
- 8 Did the lipstick dissolve in each solvent? Explain.
- 9 Did the chocolate dissolve in each solvent? Explain.
- 10 Did the detergent help the water dissolve the stains?

#### Forming Conclusions

11 Describe the results from your investigation. Conclude which solvent did the best cleaning job for each type of stain and which did the worst job. Support your conclusions with your data. Also, include one new thing you learned in this activity that you didn't know before.

#### Applying and Connecting

Canadian researchers have been at the forefront of developing environmentally friendly inventions. Ragui Ghali of Ontario invented Spil-Kleen. Made from old phone books, Spil-Kleen soaks up water, and cleans up oil spills.

Make a cleaner by mixing 50 mL of baking soda in 4 L of water and adding 125 mL of vinegar. Create a fair test to compare the cleaning ability of your home-made cleaner with that of store-bought brands.

#### **DIVING AND DECOMPRESSION**

People are able to dive deep below the surface of oceans and lakes because of an invention that uses fluids. SCUBA stands for Self-Contained Underwater Breathing Apparatus. It consists of air tanks and regulators to maintain the flow of air. Another fluid-based technology helps us deal with the stress on our bodies of deep dives.

At greater water pressures, nitrogen gas dissolves in our blood and tissues at a much higher concentration than normal. If a diver ascends slowly to the surface, the extra gas leaves the body gradually as the water pressure decreases.

A problem arises when the diver ascends too quickly, so that the pressure decreases rapidly. Decompression sickness, called "the bends," can result. The sudden change in pressure causes nitrogen gas to bubble out of the blood and tissues. These bubbles can collect in other body parts and cause considerable pain. Death can occur if the condition is left untreated.

One treatment for "the bends" is to place the affected diver in a special chamber. This chamber increases the pressure surrounding the diver's body. The greater pressure forces the gas bubbles to redissolve back into the blood and tissues. By very slowly decreasing the pressure back to normal, the gas slowly leaves the body.



Figure 4.3 This person is in a hyperbaric chamber to cure a case of "the bends." Hyperbaric means high pressure.

#### CHECK AND REFLECT

- 1. Describe one new thing you learned about cleaners.
- 2. How does a detergent remove a stain?
- 3. The following statements were taken from an advertisement for laundry detergents. What ingredients are being emphasized?
  - a) "Now brighter and whiter than ever."
  - b) "Cleans your washing machine as it cleans your clothes."
  - c) "Removes the toughest stains."
  - d) "Now in new ocean mist scent."
- 4. What do divers need to know about solubility?

#### **PESEARCH**

#### **Dry Cleaning**

What is dry cleaning? Find out how clothes are dry-cleaned and what happens to the chemicals after they are used.

## 4.2 Technologies Based on Flow Rates and Moving Fluids

Imagine having to move a fluid from one place to another. Maybe you are putting air in a basketball. Or maybe you want to filter the water in your aquarium. What would you use?

For both examples, you probably thought that a pump would be the solution. What exactly is a pump and how does it work? A pump is a device that moves a fluid through or into something. To fill up your basketball, you use a pump to force air into the ball. Your aquarium pump moves water through a filter to clean it and add air. Pumps also exist in nature. The most important one to you is your heart—it pumps blood through your body.

#### Two Types of Pumps — Diaphragm and Archimedes Screw

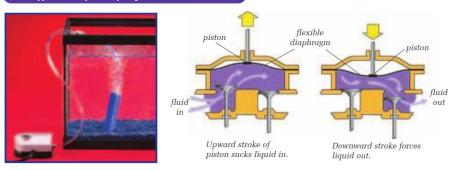
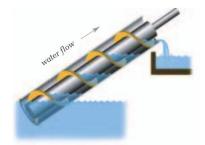


Figure 4.4 Diaphragm pumps are used for both liquids and gases, such as the air pumped into this aquarium.





**Figure 4.5** The Archimedes screw is a pump supposedly invented by Archimedes to remove water from the hold of a ship. Here it is used as a sand washer on a construction site.

Unit A: Mix and Flow of Matter

66

#### THE BICYCLE PUMP

There are many different kinds of pumps, but one of the most common is the bicycle pump. This kind of pump has a piston that moves up and down in a cylinder. When you pull up the piston, air fills the cylinder. By pushing down on the piston, you apply a force to the air in the cylinder. This compresses the air. The pressure of the air in the pump therefore increases. If the opening at the bottom of the cylinder is connected to an area of lower pressure, the air will move to that area. For example, the area of lower pressure could be a flat bicycle tire or an uninflated soccer ball.

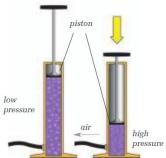


Figure 4.6 When force is applied to the air in the cylinder, the pressure increases

#### PIPELINE PIGS

The oil and natural gas that we depend on for heat and transportation move across the country in bulk through pipelines. Pumps push these fluids along at a steady rate. In large natural gas pipelines, the pressure of this flow is used to help keep the pipeline clean to ensure a clean fuel supply. A computerized unit called a "pig" is placed in the pipeline and pushed through it by the moving gas. The "pig" cleans the pipe with brushes as it moves through. At the same time, the "pig's" sensors check the pipe and record its condition so any necessary repairs can be made.



#### **Oil Sands Production**

The oil in the oil sands is a thick, viscous substance called bitumen. One method of extracting bitumen uses two wells. Steam is pumped down one well to heat the bitumen in place. The heated bitumen now has a lower viscosity, so it flows into the other well. It is pumped out of there and sent for processing.

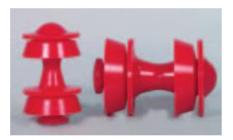


Figure 4.7 A pipeline "pig" relies on the flow of the fluid to move it through the pipeline.

#### TESEARCH

#### **Artificial Hearts**

Doctors and engineers have been working for many years to develop artificial hearts that will help save lives. Find out how valves and pumps are being used in this technology.

#### VALVES

Valves are an important part of any system for moving fluids. They are devices to control or regulate the amount of flow, like the valves in your bathroom taps. Turning your tap one way allows water to flow out. Turning it the other way closes off the flow of water. Valves can also be used to control the level of fluid in a container, like the valve in the toilet tank. The float in the toilet tank is connected to a valve that closes off the flow of water when the water reaches the right level. That's why your toilet tank doesn't overflow when you flush the toilet. Two other kinds of valves are shown in Figures 4.8 and 4.9.

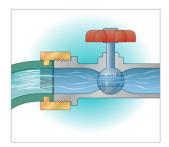


Figure 4.8 A ball valve works by turning. In one direction, it allows water to flow through. If you turn it in another direction, it stops the flow. This ball valve is in a hose.



Figure 4.9 This type of valve allows you to inflate a ball, but also keeps air from leaking out. To open the valve, you insert a hollow pin. You inflate the ball by pumping air through the pin. You deflate the ball by allowing air to escape through the pin.

#### CHECK AND REFLECT

- List and describe the different types of pumps you have read about.
- 2. Look at the drawing of the hand pump in Figure 4.10. How does the particle model help to explain how a hand pump operates?
- Identify the different functions of valves. Give one example of a valve application that has not already been mentioned.



Figure 4.10 Question 2. A hand pump

## 4.3 Designing a Working Model of a Fluid-Using Device

How could an understanding of the properties of fluids help you go to the deepest spot on the planet? This spot is about 11 000 m below sea level in the Marianas Trench in the Pacific Ocean, about 330 km south of Guam. Humans cannot dive this deep by themselves because the pressure is too great. To go this deep, you need an underwater ship called a *bathyscaph*. The name comes from the Greek words *bathos* for "deep" and *scaphos* for "ship." The Swiss scientist Auguste Piccard invented the bathyscaph and called his vessel the *Trieste*.

Since the *Trieste*, many different types of submersible exploration ships have been designed and built. One example is the Canadian submersible called the Remotely Operated Platform for Ocean Science (ROPOS) shown in Figure 4.12.

#### infoBIT

#### Changing Buoyancy Naturally

Most fish use a swim bladder to change their buoyancy. This is a gas-filled sac found just under the backbone. Dissolved gases in the fish's blood move into the sac to give it greater buoyancy. The swim bladder empties when the fish wants to dive deeper.



Figure 4.11 The bathyscaph Trieste made it to the bottom of the Marianas Trench in 1960. A bathyscaph consists of a large float with a metal sphere underneath. The sphere is where the people sit.

**Figure 4.12** This submersible robot ROPOS is equipped with two robotic arms and can dive to 5000 m.



#### DIVING DEEPLY

#### Recognize a Need

At the cottage, your cousin drops a precious gold necklace into the lake. It disappears into about 5 m of murky water.

Create a model of a bathyscaph that could carry a battery-operated video camera to the bottom of the lake to search for the necklace.

#### Criteria for Success

For your model to be successful, it must meet the following criteria:

- solve the problem described above
- be designed first on paper
- · be built and tested as a prototype
- be made of common materials
- be controlled from the surface so it can travel to the bottom and back to the surface by a transfer of fluid from or to it
- · be usable more than once

#### Brainstorm Ideas

1 You will be working in teams. As a team, brainstorm possible solutions to the problem. Once you have several solutions, choose the one you think will work the best to meet the above criteria.

teacher for approval.



- Build a Prototype 🔞 2 Create a plan for how you will build your bathyscaph. Include a diagram of the bathyscaph and a list of materials you require. Show your plan to your
- 3 Assemble your materials and build your prototype. Remember that you may need to modify or change your design as you build your prototype. Make sure to note any changes you make to your original design.

4 Once you have built your prototype, test it to see if it meets the criteria. After your test, you may need to make some modifications or changes to the bathyscaph and retest it.

#### Communicate

- 5 What do you have to do to make the bathyscaph go up and down in the
- 6 Would this model work in the lake or would you have to make further modifications? What would they be?



your materials and build your prototype.

#### HOW A SUBMARINE WORKS

How does a submarine move up and down in the water? A submarine moves through three stages in the water: floating on the surface, diving, and re-surfacing. Figure 4.14 shows how a submarine operates. Notice that the submarine has air tanks called ballast tanks between the inner and outer hulls of the submarine. The submarine also carries compressed air in tanks to help it re-surface.

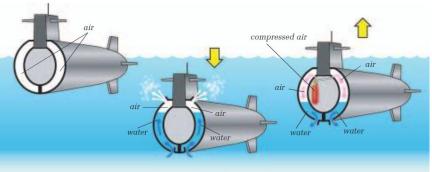


Figure 4.14a) On the Surface. When the submarine is on the surface, its ballast tanks are full of air. The average density of the submarine is less dense than the density of the water, and it floats.

Figure 4.14b) Diving. To dive, the submarine releases air from the ballast tanks through valves on the top of the tanks. Other valves at the bottom of the tanks open and allow seawater to enter. The density of the submarine with seawater in the tanks becomes greater than the density of water outside, so the submarine begins to sink.

Figure 4.14c) Re-surfacing. To surface, compressed air is forced into the ballast tanks through the valves at the top. This forces the seawater out of the bottom valves. The density of the submarine with air in the tanks becomes less than the density of the water, so the submarine rises to the surface.

#### CHECK AND REFLECT

- 1. What is a bathyscaph?
- 2. What is the difference between a bathyscaph and a submarine? Hint: Read the caption for Figure 4.11.
- 3. Describe how a submarine can stay underwater and then move up to the surface.



## Experiment .....

## Design and Build a Hydraulic or PNeumatic Elevator

#### Before You Start ...

One of the most common ways to move people or things up and down is an elevator. Primitive elevators existed as early as the 3rd century B.C., but elevators were put into buildings only in the 1800s. These early devices were powered by steam engines or operated with a hydraulic system. Their use was limited because of safety concerns. The main concern was that the rope or cable lifting the elevator could snap. This changed when an inventor named Elisha Graves Otis developed a "safety elevator" in 1852.

By the late 1800s, motors began to replace hydraulic systems in elevators. Today, the limitations of an elevator are more human than technological. Some people feel sick if an elevator moves too fast.

Other types of elevators or lifts include hydraulic ladders, such as those on firetrucks, which you saw

earlier in this unit, and hydraulic cherry pickers on repair vehicles.

Now you'll have an opportunity to design your own hydraulic or pneumatic elevator.

#### The Question

What would you have to do to design and build a hydraulic or pneumatic elevator that could lift a golf ball 30 cm?

#### **Design and Conduct Your Experiment**

- Working by yourself or in a small group, generate possible ideas on how you could design your device.
- 2 Create a plan for how you will build your device. Include a detailed sketch of your device and a list of equipment you will need. Show your plan to your teacher for approval.
- 3 Build your device. Be prepared to demonstrate how your device works to your class.
- 4 Compare your device with others in the class. How successful were the other devices?



Figure 4.15 Elisha Graves Otis and his "safety elevator"



Figure 4.16
A cherry picker
makes it easier for
workers to do tasks
in high places where
they need to be able
to use both hands.

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. How can a detergent clean grease off clothes?
- If you had a beaker of water, a beaker of rubbing alcohol, and a beaker of vinegar, describe how you would construct a fair test to determine which liquid was the best cleaner.
- 3. What is a pipeline "pig," and how does it move?
- Describe a technology that uses pressure to change the solubility of gas.
- 5. Describe three uses of pumps.
- 6. What are two major uses of valves?
- 7. How does a bathyscaph work?
- 8. Identify one industry that uses the properties of fluids.



### SCIENCE AND TECHNOLOGY

Technological problems often lend themselves to more than one solution. These solutions may involve different designs, materials, and processes. Think back to what you learned in this section.

- 1. What examples did you encounter of multiple solutions to a problem?
- 2. Was one solution better than the others?
- 3. How did you know when you had a solution that would work in your own activities?





## The Alberta Oil Sands Deposits

#### The Issue

The oil sands have important benefits and potential costs to everyone living in Alberta. What do you think these benefits and costs are? Read the background information below and use the "Go Further" suggestions in the next column to find out more.

Petroleum was once called "black gold" because of both its dark colour and its high value. It made its finders rich because of its importance as a source of energy. Today, petroleum products flow into homes as heating oil, into cars and trucks as gasoline and diesel fuel, and onto roads as asphalt. Petroleum is also used to make plastics.

The first commercial oil wells were developed in the 1850s. Since then, people have been looking for and finding this valuable fluid all over the world. Alberta has been a petroleum producer since the 1940s. It is also home to the largest oil sands deposits in the world.



Oil sands deposits in Alberta. The largest deposits are in the Athabasca region.

The oil sands deposits are unique because they are a mechanical mixture. The sand particles are coated with a thick, tar-like substance called *bitumen* and small amounts of water. Unfortunately for the oil industry, bitumen isn't useful for anything except paving roads. In the early 1900s, some Edmonton streets were paved with oil sands.

The oil sands contain an estimated 1.7 trillion barrels of oil—more oil than all the world's known oil reserves combined. However, getting the oil out of the ground and refining it have not been easy.



Only about 18% of the oil sands within 50 m of the surface can be recovered with today's technology. Even so, almost 20% of Canada's oil supply now comes from these sands.

#### Go Further

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

- Look on the Web: Check out oil sands or synthetic oil on the Internet.
- Ask the Experts: Try to find an expert, such as a petrochemical engineer or an environmental impact officer.
- Look It Up in Newspapers and Magazines: Look for articles about the Alberta oil sands, synthetic oil, or the environmental impact of the oil sands.

#### **In Your Opinion**

- What are the benefits of developing the oil sands?
- Based on the information you have, what do you think should be done with the oil sands?
- Which do you think is more important—the benefits or the costs?

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## UNIT SUMMARY: MIX AND FLOW OF MATTER

#### **Key Concepts**

#### 1.0

- WHMIS symbols
- · properties of fluids

#### Section Summaries

#### 1.0 Fluids are used in technological devices and everyday materials.

- An understanding of the WHMIS symbols and safety procedures in your science class is very important. Unsafe behaviour is dangerous to both you and your classmates.
- Fluids make it easier to transport, process, and use different kinds of materials. Slurry
  technology is an example of how fluids can be used to transport other materials. Glass
  and steel are examples of the use of fluids as a stage in the production process of
  materials. Toothpaste is an example of the use of fluids to make using other materials
  easier.
- Fluids have properties such as viscosity, density, buoyancy, and compressibility that make them useful for meeting human needs.

#### 2.0

- pure substances, mixtures, and solutions
- · solute and solvent
- concentration
- solubility and saturation points
- · particle model of matter

### 2.0 The properties of mixtures and fluids can be explained by the particle model of matter.

- Matter can be divided into pure substances and mixtures. Mixtures can further be divided into mechanical mixtures and solutions.
- Solutions are made with a solute and a solvent. The more solute in the solvent, the
  more concentrated the solution. Concentration can be calculated in grams per millilitre
  (g/mL). The solubility of a solute in a solvent depends on the temperature of the
  solution, the type of solute, and the type of solvent.
- The particle model of matter provides a model for describing how particles behave in the three states of matter and in mixtures.

#### 3.0

- · properties of fluids
- mass, volume, density
- viscosity and flow rate
- buoyancy

### 3.0 The properties of gases and liquids can be explained by the particle model of matter.

- Viscosity is a fluid's internal resistance or friction that keeps it from flowing. As the temperature increases in a liquid, the viscosity decreases.
- Density is the amount of mass in a given volume. It is calculated by dividing the mass
  of a substance by its volume. The density of a substance increases as its temperature
  decreases. Most substances have a greater density in their solid state than in their
  liquid and gas states. The particle model of matter describes particles in a solid and
  liquid being packed closer together than those in a gas. A gas has more space between
  particles.
- Less dense objects float on more dense substances. An object floats because the buoyant force of the fluid acting on it is greater than the force of gravity acting on it.
- Gases are compressible, but liquids are almost incompressible. Pressure is calculated
  by dividing the force exerted by the area over which the force is applied. Pascal's law
  states that when a force is applied to a fluid, the pressure is transmitted equally
  throughout the fluid.

#### 4.0

- properties of fluids
- fluid technology applications

#### 4.0 Many technologies are based on the properties of fluids.

Many different technologies are based on the properties of fluids. Cleaners and
cleaning solvents work because of the different solubilities of substances. Pumps move
fluids from one place to another. Valves control the flow of fluids. Hydraulic and
pneumatic systems use fluids to move objects and devices such as submarines.



## CREATING DRINKIT

#### **Getting Started**

In this unit, you have developed a variety of skills and an understanding of the properties of mixtures and fluids. You learned how to make solutions, calculate density, and describe buoyancy. You will now use these skills and this knowledge to design a new drink. The e-mail to the right contains the information you need to get started on your project.

#### Your Goal

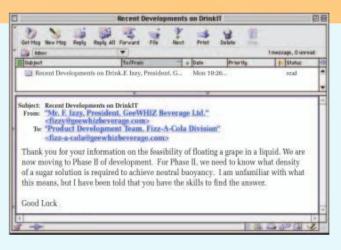
Your goal is to design and carry out a procedure that will allow you to determine the density of a sugar solution that can suspend a grape.

#### What You Need to Know

You will prepare a report to the president, F. Izzy, about your procedure and what you discovered. Your report should include the following:

- an outline of the procedure you developed and any modifications you made
- the data you collected during your investigation
- the results of your investigation
- recommendations for further work

Caution!
Remember
not to taste
anything in
the lab.



#### Steps to Success

- 1 Work with your group to design a procedure for completing your assigned task. After you design your procedure, show it to your teacher for approval.
- 2 Collect the equipment you need and carry out your plan.
- 3 Make modifications to your plan as necessary. Write down any changes to your plan as you work through it.
- 4 Record the tests you made and your observations of the results.
- 5 Verify your results by making a fresh solution based on the results you recorded.

#### How Did It Go?

- 6 Describe the procedure you used when you were trying to determine the best sugar solution to use. Did you follow a specific procedure or did you just keep trying until you found the answer?
- 7 How did you determine the point where you had the appropriate solution concentration?
- 8 Could you have improved on your method of finding the appropriate solution concentration? Suggest changes you would make if you were to repeat this activity.
- In any investigation, errors result. For example, after you determined the mass of sugar to add, some of the sugar may have spilled out before it was added to the beaker. What possible sources of error could have occurred in this activity? Why is it important to identify these sources of error when reporting your results?

### UNIT REVIEW: MIX AND FLOW OF MATTER

#### **Unit Vocabulary**

 Create a mind map that illustrates your understanding of the following terms.
 Use the word fluid as your starting word.

Use the word fluid a
pure substance
mechanical mixture
solution
solute
solvent
concentration
solubility
viscosity
density
pressure
hydraulic
pneumatic

#### **Check Your Knowledge**

1.0

Identify the WHMIS symbols listed below and explain what each one means.







- 3. What should you do if a corrosive chemical spills on you?
- Describe an example of a material being prepared as a fluid to make it easier to transport or use.
- What are some important properties of fluids? Give an example of a technology that uses each property.

2.0

- 6. What is the difference between a pure substance, a mechanical mixture, and a solution? Give an example of each.
- 7. a) What is meant by the concentration of a solution?
  - b) What units are usually used to measure concentration?
- 8. What is the difference between a solute and a solvent?
- 9. What factors affect the rate of dissolving?
- 10. How does the particle model of matter explain the following statement? If you combine 25 mL of water with 25 mL of rubbing alcohol, the total volume is only 49 mL.

3.0

- 11. How does the particle model explain viscosity?
- **12.** What is the density of the following substances?

Substance	Mass (g)	Volume (mL)	Density
vegetable oil	92	100	
iron	39	5	
gold	326	20	

- 13. Why is hot water less dense than cold water?
- Describe Pascal's law, and give one example of a device that uses this law to function.

Unit Review

#### UNIT REVIEW: MIX AND FLOW OF MATTER

15. What is the pressure exerted on the inside of a can if the surface area of the can is  $0.2 \text{ m}^2$  and the force is 10 N?

#### 4.0

- Describe a technology that is based on the solubility of substances.
- 17. Describe one example of how a pump moves a fluid from one place to another.
- **18.** How can a hydraulic system be used to transfer a force or control a motion?

#### **Connect Your Understanding**

- 19. When you open a can of cold soda pop, you hear a small noise. When you open a can of warm soda pop, the noise is much louder. What does this tell you about the relationship between the amount of carbon dioxide dissolved in the soda pop and the temperature of the soda pop?
- 20. Which solution is more concentrated: Solution A with 50 g of substance in 200 mL of water or Solution B with 12 g of the same substance in 40 mL of water? Explain your answer. Calculate the concentration of each solution in g/100 mL.
- 21. The solubility of a substance at 20°C is 40 g/100 mL of water. A solution has 30 g of this substance dissolved in 100 mL of water at 20°C. Is this solution saturated or unsaturated?

- 22. You have two samples of the same liquid. One is at 50°C and one is at 30°C.
  - a) What will happen if you pour the same amount of each liquid down a ramp? Which flow rate would be faster? Use the particle model to explain your answer.
  - b) If you poured the same amount of this liquid at 70°C down the ramp, what would happen?
- 23. Some medicines are more effective if they dissolve slowly. How would you design a pill that would take longer to dissolve?
- 24. On the coast of British Columbia, a fishing boat loaded with fish sank when it entered the Fraser River from the Strait of Georgia. The strait is part of the Pacific Ocean. Why do you think this happened?
- **25.** How can a 2000-kg vehicle be lifted with a small force?

#### **Practise Your Skills**

- 26. Plan an experiment that would test the compressibility of three different fluids.
  - a) What materials would you need?
  - b) What procedure would you use?
  - c) What variables would you need to control?

27. A student dropped pennies one at a time into a known volume of water and measured the volume displaced. The table below shows the results.

Mass (g)	Volume (mL)		
17	2		
35	4		
52	6		
70	8		
88	10		

- a) What is the density of a copper penny?
- b) Graph this data with mass on the vertical axis and volume on the horizontal axis. Find the slope of the line. How does this slope compare with the density of pure copper at 8.96?

#### **Self Assessment**

Think back to the work you did during this unit.

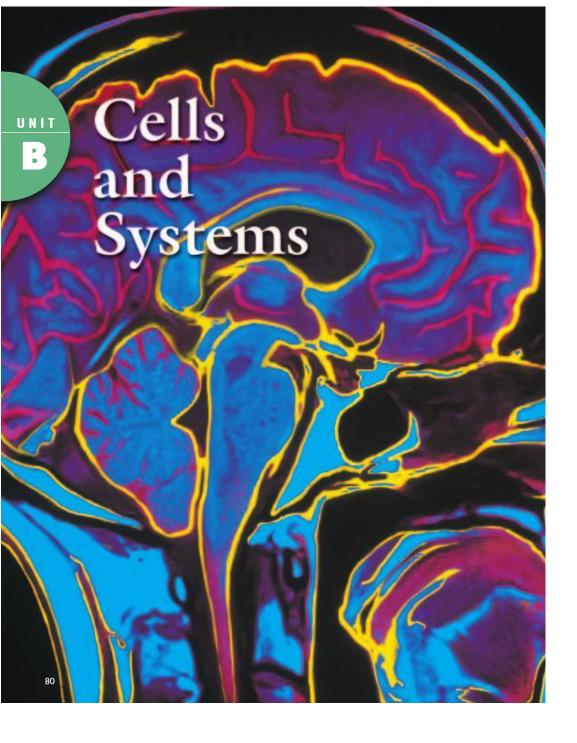
- 28. Describe one situation where you observed the contributions of science and technology to the understanding of mixtures and fluids.
- 29. Give an example of one person's contribution to the science and technology of fluids and mixtures that you found interesting.
- 30. What is one idea or issue covered in this unit that you would like to explore in more detail?

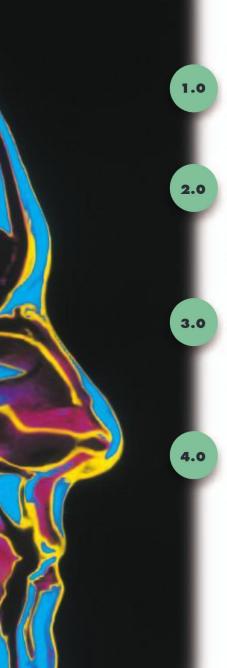
**31.** Why do you think the environment should be considered when people use fluid technologies?

### Focus Science and Technology

In this unit, you have investigated science and technology related to fluids and mixtures. Consider the following questions.

- 32. Reread the three questions on page 7 about the role of the properties of fluids in science and technology. Use a creative way to demonstrate your understanding of one of these questions.
- 33. What examples demonstrated how fluid technology could provide solutions to a practical problem?
- 34. Describe a situation where a technological development involved trial and error and the use of knowledge from other scientific fields.
- 35. Describe the process involved in designing a device to perform a specific task. Was this a set step-by-step process or did it require changes as you developed the device?
- 36. Sometimes technology developers want to design a technology that works well in certain locations. Describe a situation where an understanding of local conditions made this possible.





In this unit, you will cover the following sections:

Living things share certain characteristics and have structures to perform functions.

- 1.1 The Characteristics of Living Things
- 1.2 Structure and Function
- 1.3 Organs and Organ Systems

#### Cells play a vital role in living things.

- 2.1 The Microscope Extends the Sense of Sight
- 2.2 The Cell Is the Basic Unit of Life
- 2.3 Organisms Can Be Single-Celled or Multicelled
- 2.4 How Substances Move Into and Out of Cells
- 2.5 Cells in Multicellular Organisms Combine to Form Tissues and Organs

## Healthy human function depends on a variety of interacting and reacting systems.

- 3.1 Digestive System
- 3.2 Respiratory System
- 3.3 Circulatory System
- 3.4 Excretory System
- 3.5 Nervous System

## Scientific investigation leads to new knowledge about body systems and new medical applications.

- 4.1 Developing a Theory for Disease
- **4.2** Factors That Affect the Healthy Function of Body Systems

# Exploring



Galen lived from A.D. 129 to 216. He eventually became the emperor's doctor.

#### **BLOOD AND GUTS**

One of the first people to observe internal body structures and devise a scheme of how they worked was a Roman called Galen. He was a keen observer, which is an important quality for someone interested in studying the natural world.

Galen wanted to find out how the human body worked, but at the time, there were strict laws against opening up dead human bodies. Luckily, Galen's job allowed him to view the inner workings of the human body. He was the doctor to the gladiators! Roman gladiators had to fight each other to the death. As a result of these combats, the survivors were often injured badly. While he was trying to heal their gaping wounds, he could observe their internal organs. And because these wounds bled so much, he was able to observe how blood flowed in the body.

Through his observations and experiments, he did make some important discoveries. But his ideas about how body parts worked seem quite bizarre today. He mapped the major nerves of the body, but he thought they were hollow tubes through which flowed a "life force." He also thought that the liver was the most important structure in the body because it was so big and had lots of tubes coming out of it. He decided that its purpose was to heat the body.



Though these ideas might seem odd today, doctors accepted Galen's theories on how the body worked right up until the sixteenth century.

#### Give it a TRY

#### ACTIVITY

#### PIECING TOGETHER THE BODY

You may think Galen's theories were absurd, but what do you know about the body's internal and external parts and how they work together? In this activity, you will have a chance to put your knowledge to the test.

Work with one or two of your classmates. Make a list of all the body parts that you can think of, both internal and external. Write each one on a small piece of paper. Try to figure out how they work together to keep you alive. Once your group has decided that there is a pattern, create a concept map showing how these body parts are linked.

- · How many body parts could you name?
- · Did you know the functions of the parts you named?
- · Did you know how each part related to another?



### Focus On

### THE NATURE OF SCIENCE

As you work through this unit, you will be reading and doing activities about cells and systems. You will encounter three major themes that are important to the study of life science: systems, cells, and structures and functions. You will need an understanding of these themes to do the project about investigating single-celled organisms.

Use the following questions to guide your reading as you learn about cells and systems.  $\,$ 

- 1. What do all living things have in common?
- 2. What types of systems do living things have, and how are they organized?
- 3. What are the functions of various structures found in living things?

1.0

# Living things share certain characteristics and have structures to perform functions.

#### **Key Concepts**

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

- organisms
- cells
- organs
- structure and function
- systems
- response to stimuli

#### **Learning Outcomes**

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

- describe the characteristics of living things
- analyze the general structure and function of living things
- explain how living things have different structures for similar functions
- show how the body is organized into systems



Giant Sequoi

Amoeb

There are about 1.75 million different types of living things on Earth. They come in many different forms—from a single-celled bacteria that can be seen only with a microscope to a giant blue whale over 30 m long, to a giant sequoia tree that's over 100 m tall. Despite the differences among all the different life forms on this planet, there are similarities between them. All living things have features in common that distinguish them from non-living things.

Living things have an amazing variety of functioning parts. For example, some have leaves, some have wings. One way of making sense of this variety is to think about the function of the parts, or what they are used for. What do cats use their claws for? What does a tree use its roots for? Does the structure of these parts tell you something about how they work?

Any single living thing is made up of different structures. These structures work together to keep you, or any other plant or animal, alive. These parts work together as a single unit to keep a plant or animal running smoothly.

## 1.1 The Characteristics of Living Things

Before you can make sense of the millions of different living things on Earth, you have to be able to know what is alive and what is not. When trying to decide what is living and what is non-living, you have to find common characteristics for all forms of life. Although they are still debating, most scientists agree on these six characteristics of living things:

- are made of cells
- · need energy
- grow and develop
- respond to the environment
- reproduce
- have adaptations for their environment

All living things, or **organisms**, have all of these characteristics. Non-living things may have some of these characteristics (for example, clouds may grow in size), but they will not have all of them.



Figure 1.1 What is the energy source for the animal? What is the energy source for the plant?

#### Give it a TRY

#### ACTIVITY

#### DEAD OR ALIVE?

Draw a table with two columns, one headed *Living*, the other *Non-living*. Place each of the following items under the appropriate heading: radio, tree, mushroom, hair, fish, rain, bicycle, moss, skirt, soil, television, carrot, baseball, rock, seeds, air.

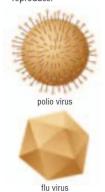
- Do all the things that you placed in the Living category meet the six characteristics of living things?
- · Were there any items that you had trouble placing in either category?



#### infoBIT

#### Viruses

Have you ever had a cold? Colds (and many other diseases) are caused by viruses. Viruses are extremely small and come in many different shapes. There is an entire branch of biology devoted to the study of viruses, even though most scientists don't consider them to be alive. This is because viruses can't reproduce by themselves. They depend on living cells of other living things to reproduce.



#### **CELLS**

The cell is the basic unit of life. A cell can perform all the processes that life depends on. All organisms are made up of at least one cell, and every cell comes from another cell.

Cells are usually microscopic in size, so a single-celled organism is almost always tiny. A large organism, such as a tree, can be made of trillions of microscopic cells.

Non-living things are not made of cells. However, there are exceptions.
Cells are found in non-living material if that material was alive at one time. For example, if you looked at a piece of wood under a microscope, you would see evidence of cells. This is because the wood came from a tree that was once alive.

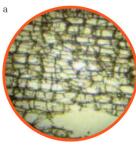


Figure 1.2 Cells from a cork

#### **ENERGY**

Everything an organism does requires energy. Think of all the things you did in the last few hours: you slept, had breakfast, walked to school or ran to catch the bus, and started school. All of these things required energy. Energy is the ability to make things move or change.

Organisms get energy from the environment. Plants and animals differ in how they get their energy. Plants use the energy from the sun to make their own food. Animals get their food from the environment around them. Plants and animals both obtain nutrients from their food and the environment. **Nutrients** are substances that provide the energy and materials that organisms need to grow, develop, and reproduce.

Many different chemical processes happen inside cells. Some of these processes create energy, and some of them use energy. For an organism to stay alive, there has to be a balance between these energy-using processes and the energy-creating processes. The sum of all the different processes that happen in an organism is called the organism's metabolism.

#### RESPONDING TO THE ENVIRONMENT

You step out onto the street and suddenly you see a moving car barrelling toward you. What do you do? You jump out of the way. The sight of the moving car is actually a stimulus. A **stimulus** is anything that causes a response in an organism. Jumping out of the way of the car is a reaction, or **response**, to a stimulus.

#### GROWTH AND DEVELOPMENT

You may have grown a few centimetres taller in the past year. But growth is not just about getting bigger. It may also involve a change in structure. When you plant a seed, it grows roots and produces a stem and leaves. Once the plant gets to a certain size, it may not get any bigger, just as you will not grow beyond a certain height. But growth doesn't end there. Parts of any living thing wear out or get damaged. Every year, trees produce new leaves. Your skin keeps replacing itself as it gets worn away.

As some organisms grow, they change their body shape quite drastically. This is called development. Think of a frog. Adult frogs release eggs in the water. As each egg develops, it turns into a tadpole with a tail and gills. As the tadpole grows, it loses its gills and tail and develops lungs and limbs. Finally, it moves from the water onto the land.

#### REPRODUCTION

All living things come from other living things. This process is called reproduction. Reproduction is not actually necessary for an organism to survive. But since all individual organisms die, reproduction is necessary for the survival of each type of organism.

#### Give it a TRY ACTIVITY MISINTERPRETING THE EVIDENCE It seems pretty clear to us that living things come from living things, but this wasn't always so obvious. People noticed that mice often appeared from stacks of straw, and that flies and maggots appeared from rotting meat. People then assumed that the piles of straw and the rotting meat could create mice and flies. The idea that living things could come from non-living things was called spontaneous generation. But people had misinterpreted the evidence. However, in the 1600s, an Italian doctor called Francisco Redi performed an experiment to test the idea of spontaneous generation. He put some meat into three jars. One he left open, another he sealed shut with a lid, and a third he covered with a mesh screen. He thought that if spontaneous generation actually happened, maggots would appear on the spoiled meat in all the jars. Figure 1.3 shows the results of the experiment. Observe the results of the experiment. How did the experiment disprove spontaneous generation?

#### reSEARCH

#### **Monarch Development**

Monarch butterflies go through an amazing development in their life cycle. What are the stages of development of the butterfly? What happens at each stage?



#### **A**DAPTATIONS

In the winter, snowshoe hares grow a white coat of fur. This allows them to blend in with their snowy surroundings and avoid being noticed by predators. This coloration is an example of an adaptation. An adaptation is a characteristic that allows an organism to live in its environment. Animals and plants have many adaptations. A cactus has spines to stop animals from eating it. A mountain goat has tiny feet to allow it to perch on steep cliffs.



Figure 1.4 Snowshoe hare in winter

#### CHECK AND REFLECT

- List the characteristics of living things. Give an example of each characteristic.
- 2. What adaptations does a fish have for living in water?
- 3. Is skin a living thing?
- Is the following statement true or false? Explain your answer and provide an example. Each individual organism must reproduce in order to survive.



Unit B: Cells and Systems

## 1.2 Structure and Function

As well as having certain characteristics, living things have to do certain things to keep themselves alive. Some of the things animals do are to exchange gases, move, and gather food. Plants don't move like animals do, but they do exchange gases and gather nutrients. Organisms have developed many different ways of doing these tasks and have developed different body parts, or **structures**, to do them. Each structure is used for a specific **function**, which means it carries out a specific task.

#### Give it a TRY

#### ACTIVITY

#### WHICH STRUCTURE FOR WHAT FUNCTION?

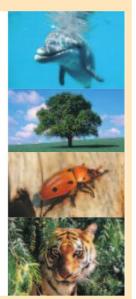
List a number of functions an organism must perform in order to survive. Your list might include movement, food gathering, breathing, and so on. Make a table and place these functions in the first column, and place the organisms pictured in Figure 1.5 in the top row, as illustrated below.

Look at the organisms in Figure 1.5 and decide what structure each organism uses to perform each function. Then, fill in the table. When you are finished, compare your table with those of your classmates.

- · Did they list important functions that you did not?
- · Which function was listed by the most people?
- Did all the organisms have structures for all the functions you listed?

	Dolphin	Tree	Beetle	Tiger
movement				
food gathering			_	

Figure 1.5



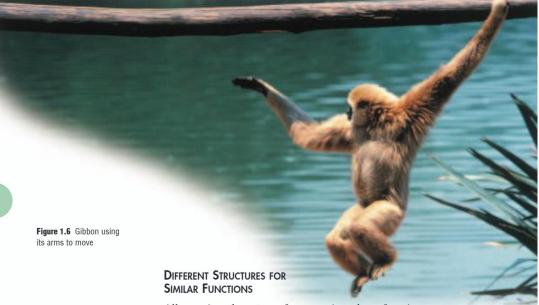
#### infoBIT

#### **Spiracles**

Some animals have unusual ways of breathing! Insects have small holes in the sides of their abdomens called spiracles. Insects adjust the amount of air that enters their bodies by adjusting the size of their spiracles.



Spiracles are the dark spots on the side of the abdomen.



All organisms have to perform certain tasks or functions to stay alive, but different plants and animals have developed different structures for doing similar functions. For example, most animals have to move about in order to find food. But animals have very different structures for performing this function. Birds have wings to fly through the air, and whales have tail flukes and flippers to swim through the water. We humans mostly use our legs to move around, but gibbons mostly use their arms. Can you think of other structures animals have for moving around?

Organisms have an amazing variety of food-gathering structures. Barnacles have tentacles that rake the seawater for tiny bits of food. Birds have bills. Insects have very complicated mouth parts. Mammals have different types of teeth to help them chew the food they eat. Teeth can vary from the sharp teeth of a lion to no teeth at all. An anteater has no teeth, just a long, sticky tongue that allows it to gather ants.





**Figure 1.7** Feeding structures of barnacles and an anteater

Gills, lungs, spiracles, skin—all of these are breathing structures used by different animals. Plants use their leaves to exchange gases with the surrounding air. Leaves can vary widely in shape, from the tiny needles of spruce trees to enormous flat leaves up to 2 m wide! Conifers, like the spruce, have tiny needles to reduce the amount of water lost in their dry environment.



Figure 1.8 Leaves come in many shapes and sizes.

### VARIATIONS IN STRUCTURE

As you have seen, structures used for a certain function can be very different. But they aren't always wildly different. Similar organisms often have slight variations in their structures. These variations are often very easy to see in animals living on islands.

The Galapagos islands are located off the west coast of South America. On the islands, there are 13 closely related species of birds, commonly known as finches. They were discovered by the famous biologist Charles Darwin over 100 years ago. These finches, known as Darwin's finches, as well as many other birds, have different bill structures to perform the function of food gathering.

### T & SEARCH

### Marine Iguanas

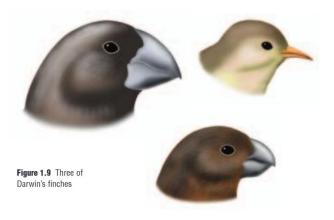
There are other species living on the Galapagos islands that have unique features. What structures does the marine iguana have to help it gather food? How is it different from other species of iguana?



### VARIATIONS IN BILL SHAPE

Three of Darwin's 13 species of finches are pictured in Figure 1.9. Finches are usually seed-eating birds with large bills adapted for crushing hard seeds. However, typical of island organisms, Darwin's finches have different structures for the function of feeding.

Study the different bird bills in Figure 1.9 and decide what kind of food-gathering functions each bill structure would be best suited for. One bird is a warbler-like finch that eats insects hiding within the bark of trees. Another is a ground-dwelling finch that eats seeds and nuts. The third type is a parrot-like finch that eats tree fruit.



### CHECK AND REFLECT

- Name as many functions as you can think of that an organism must carry out in order to survive.
- 2. Identify at least one type of structure that an organism would need to perform each of the above functions.
- 3. Why might similar organisms, such as birds, have different structures to perform the same function such as feeding?
- 4. What is the function of flowers? Why do you think they come in so many bright colours?

## 1.3 Organs and Organ Systems

So far, you have seen that you and other organisms have structures that allow you to survive and interact with your surroundings. But you have many other body structures that are constantly in use for other functions. These include your heart, lungs, brain, and kidneys. What other body parts can you think of? None of these body parts functions on its own. Each part is an **organ**. The organs that make up each **organ system** work together to perform a certain task or function. For example, the organs of your digestive system work together to break down food to supply your body with the energy and nutrients you need to survive. The following charts describe some of your body's organ systems.

### Give it a TRY

### ACTIVITY

### DRAWING SYSTEMS

Notice that some of the organ systems mentioned in the text to follow do not have illustrations. That's your job. On a piece of paper, draw a rough outline of the body. Study the list of structures of the circulatory system. Imagine what they look like and where in the body they are located. Draw these structures in your body outline. Repeat the process for the other organ systems.



### **CIRCULATORY SYSTEM** (see subsection 3.3)

Structure	Function of System	
neart irteries veins apillaries olood	transport oxygen, food, and other substances throughout the body     transport some wastes to other organs for elimination     defend the body against diseases     connect all other organ systems	
	Figure 1.10 Red blood cells	20050

### info**BIT**

**Only Skin Deep** The largest organ in the human body is the skin! It has a surface area of almost 2 m² and it weighs almost 3 kg.

### **RESPIRATORY SYSTEM** (see subsection 3.2)

Structure	Function of System
nose mouth trachea diaphragm bronchi lungs	transport oxygen from the outside air to the blood     transport carbon dioxide from the blood to the outside air

### **DIGESTIVE SYSTEM** (see subsection 3.1)

Structure	Function of System	
salivary glands mouth esophagus stomach liver pancreas gall bladder small intestine large intestine	break down food pieces into much smaller pieces (particles) so they can be absorbed and transported throughout the body	



Figure 1.11 The digestion of food begins in your mouth.



### NERVOUS SYSTEM (see subsection 3.5)

Structure	Function of System
brain spinal cord nerves eyes, ears, and other sensing organs (hands, nose, etc.)	coordinate and control the actions of all organs and organ systems     detect, process, and respond to changes in external and internal environments

Figure 1.12 The brain controls your nervous system.

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### **EXCRETORY SYSTEM** (see subsection 3.4)

Structure	Function of System
kidneys bladder lungs skin liver	remove chemical and gaseous wastes from the blood

### SKELETAL SYSTEM

Structure	Function of System
bones cartilage	provide a movable support frame for the body     protect soft-tissue organs such
	as the heart and lungs

### MUSCULAR SYSTEM

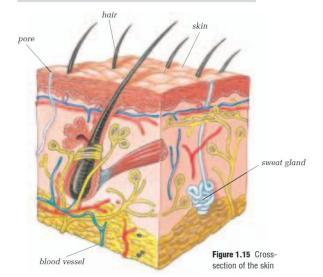
Structure	Function of System
muscles tendons	move bones     move organs that contain     muscle tissue (such as the heart     and stomach)
	N



Living Things Share Certain Characteristics and Have Structures to Perform Functions  $\label{eq:continuous}$ 

### INTEGUMENTARY SYSTEM

Structure
skin



### reSEARCH

### Glands

An organ system that has not been mentioned is the endocrine system. Find out what the endocrine system does. What is the role of each of its organs?

### CHECK AND REFLECT

- 1. Why are organs grouped together into organ systems?
- 2. Could you do without any of your organ systems? Why or why not?
- 3. How do you think the systems studied in this subsection might work together to provide the requirements for a living organism?

### SECTION REVIEW

### **Assess Your Learning**

- 1. How are living things different from non-living things?
- 2. As you dive into a pool, you hold your breath. What characteristic of living things are you showing and why?
- Choose two organisms found in your area and compare the structures each one uses for the same function (e.g., food gathering, breathing).
- 4. Define structure and function.
- 5. Make a labelled sketch of the organs of the digestive system.
- A doctor has a patient complaining of shortness of breath when climbing stairs. Describe what body systems may be causing this problem and why.





## THE NATURE OF SCIENCE

Scientific knowledge develops through observation, experimentation, and the discovery of patterns and relationships. Think back over what you've learned in this section.

- 1. What observations have people made about living things? What new information was developed from these observations?
- 2. What relationship did Redi's experiment establish?
- 3. Describe one relationship between human body systems that you discovered.



## Cells play a vital role in living things.

### **Key Concepts**

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

- cells
- tissues
- organs
- structure and function

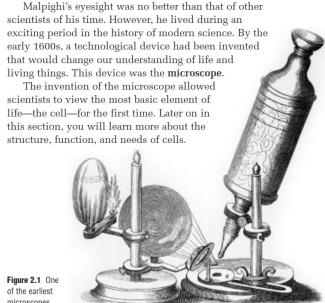
### **Learning Outcomes**

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

- · use a microscope and prepare your own slides
- · explain the role of cells as a basic unit of life
- · identify plant and animal cells
- · identify the differences between one-celled and multicelled organisms
- · explain osmosis and diffusion
- · recognize the roles of cells. tissues, and organs

For a long time, the circulatory system presented an unsolvable puzzle. People could easily observe the arteries and the veins. They could see that these blood vessels branched out into smaller and thinner vessels. Some observers suspected that blood from the arteries returned to the heart through the veins. However, they could not observe any linking structures between them. They had reached the limits of human sight.

In 1660, an Italian scientist named Marcello Malpighi solved the puzzle. He looked at an intricate network of thin, hair-like vessels connecting arteries and veins in the lung tissues of frogs. These blood vessels were later called capillaries, from the Latin



Mitrollay mit flinitlicher Betrachtung bes Chiefifatiffees burch auffallenbes Sich

microscopes

# 2.1 The Microscope Extends the Sense of Sight



Figure 2.2 How close can your eyes come to an object and still see it clearly? Try it with a ruler and a coin.

### Give it a TRY

### ACTIVITY

### HOW SMALL CAN IT BE?

How small an object can you see with just your eyes? In your notebook, draw a line 1 mm long (or try making a circle that has a diameter of 1 mm). Have you ever seen an organism this small? Can you think of any organisms that are this small? Can you draw a line half a millimetre long?



Look closely at the dot pictures in Figure 2.3. All the dots in picture A are 1 mm in diameter. They are also 1 mm apart. (Use your ruler to verify this.) You can probably see each dot clearly. Can you see the dots in picture B clearly? What about in pictures C and D?

You probably can't see individual dots in picture D. This is normal. Most people with good eyesight can see only clear, defined images of things that are 0.1 mm or larger. This is a limitation of the human eye. To overcome this limitation and extend our sense of sight, we need the help of technology. We need a microscope.

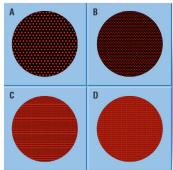


Figure 2.3 Dot pictures

### infoBIT

### A Closer Look

Look at this image close up. What do you see? Now look at it from a distance. What do you see?

Photographs in books, magazines, and newspapers are made up of tiny dots of colour and shade. This example has been exaggerated. The dots on a printed page are usually too small to see without magnification.



### INTRODUCING THE COMPOUND LIGHT MICROSCOPE

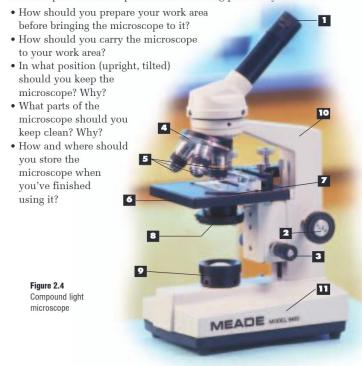
A microscope magnifies (enlarges) the images of small objects. This magnification gives a clear, defined image that the human eye can see. The microscope you'll be using in class probably looks like the one shown in Figure 2.4. Take some time to study its parts and how they function. Then you'll be ready to take a closer look for yourself.

### MICROSCOPE PARTS AND THEIR FUNCTIONS

Any microscope that has two or more lenses is a *compound* microscope.

When you view an object with a microscope, you are looking through a thin slice of the object. You will see a lamp or other light source under the microscope's stage. That's why the full name for your microscope is **compound light microscope**. The light must travel through the thin object for you to see the object properly.

Microscopes are valuable precision instruments. Like all scientific equipment, they must be handled with care. As a class, develop a chart to summarize the proper care and handling of your microscopes. Use these questions as a starting point for your ideas.



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Compound Light Microscope			
Part	Function	Handling Hints	
1 eyepiece	contains the lens that magnifies	Try keeping both of your eyes open.	
2 coarse adjustment knob	moves the stage up or down to focus on the object to produce a clear, sharp image	Use this only when you're using the lowest-power objective lens.	
3 fine adjustment knob	brings the object into sharper focus	Use this with any objective lens, but mainly with the medium-power and high-power objective lenses.	
4 revolving nosepiece	holds the three objective lenses	When you change any objective lenses, you'll feel or hear a "click" when the lens is in the right position.	
5 objective lenses	provide different strengths (power) of magnification	Avoid getting fingerprints or dirt on the lenses. They should be cleaned with proper lens-cleaning paper only.	
6 stage	supports the slide that holds the object you want to view	Keep the stage dry.	
7 stage clips	hold the slide firmly on the stage		
8 diaphragm	has different-sized holes that let different amounts of light pass through the object you're viewing		
9 lamp	supplies the light that passes through the object you're viewing	If your microscope uses a mirror instead of a lamp, be careful <u>not</u> to reflect direct sunlight into the microscope. You could damage your eyes.	
<b>10</b> arm	allows you to carry the microscope securely	When you carry your microscope from one place to another, hold the arm with one hand. Support the microscope with your other hand under the base.	
11 base	serves as a foundation for the rest of the microscope	When you carry your microscope from one place to another, support it with one hand under the base. Use your other hand to hold the arm.	

### TRYING OUT A MICROSCOPE



Now it's your turn to try out a microscope. For information on using a microscope, refer to Toolbox 11.

- · Select a slide and place it on the microscope stage. Make sure that the lens is switched to the lowest power.
- · Look through the microscope and focus the image using the coarse adjustment knob.
- · When it's in focus, make a sketch of what you see.



### reSEARCH

### How Big Is It?

When you view something through a microscope, you can determine the actual size of the image. Ask your teacher how this is done.

### PEEKING INSIDE

Microscopes come in many shapes and sizes. Fibre optics is a technology that allows light to travel down a flexible tube. Medical researchers have used fibre

optics to create microscopes that can be used inside and outside the body. Some have parts that are tiny enough to be passed through a person's arteries. Other devices are used to help surgeons operate.



Figure 2.5 The image you see on the screen is actually the patient's eye!

### CHECK AND REFLECT

- 1. a) Which of the following could you see without a microscope? Why would you need one to see the others?
  - a liver cell (about 0.02 mm)
  - the head of a pin (about 1 mm)
  - a red blood cell (about 0.007 mm)
  - b) Did any of these sizes surprise you? Which one, and why?
- 2. In your notebook, make a labelled sketch of a microscope. Briefly explain how you would use a microscope to look at a
- 3. When using a microscope, why should you start with the lens in the lowest position and then move up? What would happen if you didn't?

## 2.2 The Cell Is the Basic Unit of Life

Cells are the smallest known functioning units of life. All organisms must be made of at least one cell. In most organisms, cells rarely work alone: cells with a similar structure and function are organized into tissues. Tissues that work together for a common purpose form organs, and an organ system is a group of organs that work together for a common purpose in order to keep you alive.

### LOOKING AT CELLS

When you look at cells using a microscope, even at low power you will probably see more than one cell. So it helps to be able to identify where one cell stops and another starts.

## CELL STRUCTURES YOU CAN USUALLY SEE WITH A CLASSROOM LIGHT MICROSCOPE

Many things can affect your ability to see details of the internal parts of cells. These factors include:

- the type of microscope
- the power of the lenses
- the quality of the prepared slides

You are likely to find all of the cell structures listed in the table below if you look at slides of plant material as well as animal material. Not all of these structures will be found in any one cell.

Cell Structure	Feature That Can Help You Identify It	
cell membrane	looks like a thin line that surrounds the whole cell	
cell wall	a rigid, frame-like covering that surrounds the cell membrane	
cytoplasm	a liquid inside the cell, which has grainy-looking bits in it	
nucleus	a fairly large, dark, spherical structure that's usually near the centre of the cell	
vacuoles	clear, liquid-filled spaces in various places within the cytoplasm	



Figure 2.6 How cells, tissues, and organs are related

# **Inquiry**Activity

### Materials & Equipment

- · compound microscope
- one or more prepared slides of plant cells (for example, cells from a lily leaf or hibiscus stem)
- one or more prepared slides of animal cells (for example, skin cells)



Figure 2.8 Using the fine adjustment knob

### COMPARING PLANT AND ANIMAL CELLS

### The Question

How are cells from different living things alike and how are they different?

### Procedure 4

- 1 Set up your microscope.
- 2 Get a prepared slide of plant cells, and put the slide on the stage. Position it so that your specimen is above the hole in the stage. Use the stage clips to hold the slide firmly in place.
- When your glass slide is in place, look at the stage from the side. Make sure the low-power objective lens is above the slide.



Figure 2.7
Using the coarse adjustment knob

- 4 Use the coarse adjustment knob shown in Figure 2.7 to bring the low-power objective lens as close as you can to the slide without touching it.
- 5 Look through the eyepiece. Use the coarse adjustment knob to bring your specimen into focus.
- Suse the fine adjustment knob, shown in Figure 2.8, to get a clear, sharp image.
- Keep looking through the eyepiece. Gently move the glass slide in different directions—a bit to the left, to the right, up, down. See what effect this has on the image.
- 3 Move the specimen back to the centre of your view. Refocus using the coarse adjustment knob. Turn the revolving nosepiece to switch to the mediumpower objective lens. (A "click" will tell you the lens is in place.) Focus the image with the fine adjustment knob.

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Unit B: Cells and Systems

- Move the specimen to the centre. Refocus with the fine adjustment knob. Switch to the high-power objective lens.
- 10 Use the fine adjustment knob to focus the image.
- Take your time to get familiar with what you can see at low, medium, and high power. In each case:
  - a) Count or estimate the number of cells you observe in the field of view. The field of view is the entire area you can see when you look through the microscope.
  - b) Notice the shapes of cells and how they're arranged.
  - c) In your notebook, draw the view you see.
- Remove the slide. Replace it with a prepared slide of animal cells. Again, observe at low, medium, and high power. Repeat step 11.

### Collecting Data

13 Look over all your cell drawings. Choose one plant cell and one animal cell. Then use the information about typical cell structures in the text to help you label your drawings.

### Analyzing and Interpreting

- 14 What do you think are the differences between plant and animal cells? Give examples from what you observed.
- 15 What are the similarities you can identify between plant and animal cells?

### Forming Conclusions

16 Write a summary paragraph that answers the question: "How are cells from different living things alike and how are they different?" Include diagrams in your explanation.

### Applying and Connecting

In this activity, you looked at slides that were prepared by taking extremely thin slices of samples. When you look at them through the microscope, you are seeing two-dimensional views of the samples. Another method of preparing samples is called freeze-etching, which gives three-dimensional views of the parts of cells, as seen in Figure 2.9.

### Caution!

Whenever you use the medium-power and the high-power objective lenses, focus your image using only the fine adjustment knob.

### Hint!

When your specimen is in focus, try keeping both eyes open. If you concentrate on what you're looking at, all you'll see is your specimen. This method lets you relax your face muscles so you feel more comfortable. As a result, you can observe much longer.

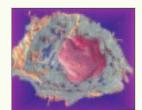
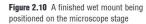


Figure 2.9 Freeze-etching shows parts of this cell in three dimensions.

### PREPARING SLIDES

So far, you have looked at slides that have been prepared for you. In order to learn more about organisms, scientists have to be able to view living specimens. To do this, they must prepare their own slides. This is how it's done.





### Preparing a Wet Mount

Follow these steps to make a wet mount of a lowercase letter "e."

- Gather the following: a clean glass slide and cover slip, an eyedropper, tweezers (or a toothpick), a small cup of water, and your specimen—a letter "e" taken from a newspaper page.
- 2. Pick up the glass slide by the edges and place it in front of you.
- Using an eyedropper, place one drop of water in the centre of the slide. Then use tweezers or a toothpick to lay your specimen—right side up—on the drop of water.
- 4. Pick up the cover slip the same way you picked up the glass slide. Slowly lower it over your specimen as shown in Figure 2.11. Try not to trap air bubbles under the cover slip.

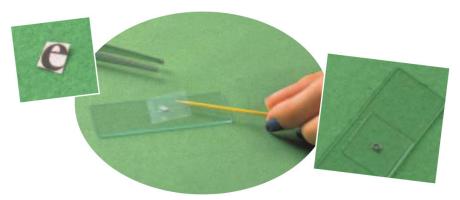


Figure 2.11 Placing a cover slip on a specimen

### Preparing and Viewing a Cell Specimen

If you've ever looked closely at an onion, you may have noticed a thin, semi-transparent skin between the thicker layers. This skin is only one cell thick in most places, which makes it ideal for observing cells.

- 1. Remove this layer from a section of onion as shown in Figure 2.12 and carefully pick it up using tweezers or a toothpick. Hold the slide at a 45° angle and drape the specimen onto the middle of the slide. Try to avoid trapping air bubbles between the specimen and the slide.
- Continue to prepare the wet mount as you did above.



### Give it a TRY

### TESTING YOUR WET MOUNT

Prepare a wet mount of an "e" following the directions on the previous page. Pick up your wet mount slide by the edges and place it on the microscope stage. Before you view anything, make the following predictions. Then, make sketches to record your predictions.

- · How will your specimen appear when you observe it with low power?
- · How will it change when you move the slide to the left? to the right? up? down?
- · How will it change when you view it with medium power? with high power?

View your slide under the microscope to test your predictions. Record your observations in your notebook.

Now, prepare a specimen of onion skin following the directions above. View your specimen under the microscope. Make a sketch of your observations.





Figure 2.13 Part of a liver cell magnified 11 300× using an electron microscope. The circles are mitochondria.

### VIEWING PLANT AND ANIMAL CELLS

Look at Figure 2.14. It is probably very difficult to see all the structures mentioned in the chart on page 103. Even the best light microscopes do not show all the structures found in a cell. For about 300 years, this was a major drawback to scientists studying cells. The electron microscope solved the problem. These microscopes use electrons instead of light. They allowed the discovery of new, smaller cell structures as shown in Figure 2.13.





Figure 2.14 Plant and animal cells viewed through a light microscope. Which is which?

### THE VITAL ROLES THAT CELL STRUCTURES PLAY

Within each cell there are a number of specialized structures called **organelles** that carry out specific functions. One way to think about cells' organization is to think of them as living factories, making all the things necessary for them to live. These factories have the following specialized areas.

Structure	Function
nucleus	a "command centre" that directs all cellular activities such as movement, growth, and other life functions $\frac{1}{2}$
mitochondria	the "powerhouses" of the cell where chemical reactions occur that convert the energy the cell receives into a form it can use
cell membrane	a "controllable gateway" that lets needed materials in and waste materials out
vacuoles	the "storage rooms" where nutrients, water, or other substances can be stored by the cell. Plant cells tend to have just one big vacuole, and animal cells have many small vacuoles.
cytoplasm	the "kitchen" of the cell. It contains the nutrients required by the cell to maintain its life processes.
cell wall	the "frame" of the cell. Found in plant cells but not in animal cells, it provides strength and support to plants.
chloroplasts	the "solar panels" of the cell. They are found in the cells of the green parts of plants. They carry out photosynthesis, converting the sun's energy into food for the cell.

Most cells have these special structures. Because of this, scientists have constructed cell models like the ones shown in Figures 2.15–2.16. How does the function of each cell structure contribute to the overall health of the cell?

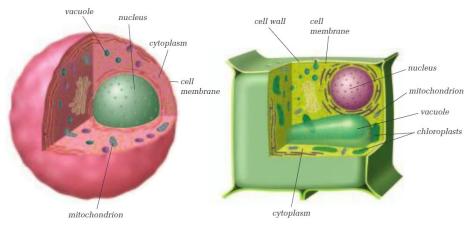


Figure 2.15 Model of an animal cell

Figure 2.16 Model of a plant cell

### CHECK AND REFLECT

- 1. Design a chart to record the following information:
  - a) cell structures that you can see with a compound light microscope
  - b) the functions of these cell structures
  - c) whether these structures appear in animal cells, plant cells, or both
- 2. Scientists build generalized cell models based on organisms made of many cells. Do you think there's such a thing as a generalized single-celled organism? Make a sketch to record your ideas of what one might look like. Include labels to describe the functions of all the structures you include.
- 3. How would the health of a cell be affected if one or more of its organelles were damaged? Give reasons to support your opinion.

### **I'8SEARCH**

### **More Organelles**

You have observed cell structures using a compound light microscope. Using the higher power of an electron microscope, scientists have discovered many more cell structures. Use print or electronic resources to find out about the following cell structures and their functions:

- endoplasmic reticulum
- · Golgi bodies
- · lysosomes
- ribosomes



Figure 2.17 Mycoplasma

2.3 Organisms Can Be Single-Celled or Multicelled

Figure 2.17 shows the smallest kind of organism scientists have discovered so far. It belongs to a group of organisms known as mycoplasma. These are so small that they had to be magnified over 18  $000 \times$  to make this photo.

The organism in Figure 2.18 is the world's largest kind of animal, the blue whale. The whale is about 30 m in length. It's hard to believe that blue whales and mycoplasma have much in common. But they do. They have something in common with you, too, and with every other organism. They are made up of cells.

Cells are the individual, living units that make up all living organisms. Some organisms are multicellular. This means that they are made up of two or more cells. Plants and animals are examples of multicellular (many-celled) organisms.

Other organisms are unicellular. They are made up of only a single cell. Most microscopic organisms, or micro-organisms, such as mycoplasma, are examples of unicellular (single-celled) organisms.

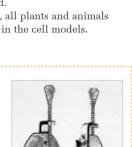
### UNICELLULAR VS. MULTICELLULAR

The little glass pill-boxes in Figure 2.19 are alive! They are called diatoms, and they are single-celled plants. They have chloroplasts just like the plants you see every day. They live in lakes, oceans, and moist soil, and are an important part of the food chain.

Although there is a tendency to consider unicellular organisms as simple because they lack the tissues and organs of more advanced Figure 2.19 Diatoms creatures—they are not. A single-celled organism can do most things that we need trillions of cells to do: eat, move, react to stimuli, get rid of waste products, and reproduce. Unicellular organisms often develop specialized structures to help them perform these functions.

Instead of relying on a single cell to meet all of their needs, multicellular organisms rely on many very specialized cells to perform functions such as feeding, moving, and so on. As a result, all the cells within multicelled organisms react to one another (or interact). For example, in a multicelled animal such as a deer, there are cells specialized for the function of feeding. However, these cells are dependent on other specialized cells, such as muscle cells, to move the deer to new supplies of food.

Whether single-celled or multicelled, all plants and animals have most of the organelles you studied in the cell models.





### **I'ESEARCH**

### The World's First Microscope

The person who first observed unicellular organisms was a Dutch amateur scientist named Antony van Leeuwenhoek [pronounced LAY-ven-hook].

Find out about Leeuwenhoek and his microscopic investigations.

- · What kinds of organisms did he discover?
- · How did he communicate his findings?



### Colossal Cell

One of the world's largest unicellular organisms is so big that you can see it with the unaided eye. It's called acetabularia, and it's a member of the plantlike algae family. Acetabularia measures from 5 cm to 7 cm!



# **Inquiry**Activity

### Materials & Equipment

- · microscope
- glass slide
- cover slip
- eyedropper
- live, unicellular organisms (supplied by your teacher)
- small jar to carry the organisms to your viewing
- · methyl cellulose

### Caution!

Be careful when handling microscopic organisms. Wash your hands thoroughly when you have finished this activity.

### OBSERVING UNICELLULAR ORGANISMS

### The Question

What cell structures can be seen using a simple light microscope?

### Procedure 🕛

 Prepare a wet mount of the live organisms. Set up your slide on the microscope stage and position the low-power objective

lens over your specimen. Observe your organisms.

Tip: Some organisms are fast! Take your time and concentrate on getting familiar with what you're observing, and on keeping your specimen in focus. After a little while, switch to medium power and observe. If you wish, try high power. Was this an impro



Figure 2.20 A common unicellular organism

you wish, try high power. Was this an improvement? Why or why not?

Observe your specimens. Record any features and actions you find interesting. With a partner, brainstorm some questions you would like answered about your specimens.



Figure 2.21 Use a piece of paper towel to "pull" the methyl cellulose under the cover slip.

To slow down fast-moving specimens: If you are viewing fast-moving organisms such as paramecia, slow them down by adding a tiny amount—less than a drop—of methyl cellulose. This is a syrupy liquid that thickens the water so it is harder for the paramecia to move rapidly. Figure 2.21 shows how to add methyl cellulose to your wet mount.

4 Observe your slowed-down specimen. Follow the instructions in step 5 for recording your observations.

### **Collecting Data**

- 5 Make an accurate drawing of one organism. Try to draw what you really see, not what you think or imagine might be there. Include labels to identify or describe the following details:
  - · shape
  - colour
  - · size (how much of your field of view it occupies)
  - · all the cell structures and organelles that you recognize
  - · any cell structures and organelles that you don't recognize
  - · the power of the objective lens you're using

### Analyzing and Interpreting

- 6 Describe how your organisms move. Use an analogy to help you describe their movement.
- 7 a) If you observed paramecia, how did the methyl cellulose slow the paramecia's movements?
  - b) Suppose you didn't have any methyl cellulose available. Suggest another method you could use to slow the paramecia without harming them. Explain why you think it will work.

### Forming Conclusions

8 Write a short story or draw a cartoon strip about a day in the life of your organism. Use your observations to help you include informative details such as how it moves, where it goes, what you think it eats, and what might eat it! Include as many cell structures and organelles as you can to support the details you include.

### Applying and Connecting

Imagine Antony van Leeuwenhoek or the other microscope pioneers examining their drinking water and seeing unicellular organisms like those you have just observed. What do you think their reaction would be? What would yours be? While many micro-organisms are harmless, some cause disease. Do you know what steps have been taken to ensure your drinking water is safe from micro-organism contamination? Find out, if you don't know.



Figure 2.22 Antony van Leeuwenhoek

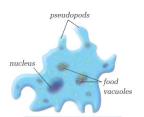




Figure 2.23 An amoeba keeps changing shape as it creates new pseudopods. Here, an amoeba extends pseudopods around a food particle.

### COMMON UNICELLULAR ORGANISMS

### Amoeba

Amoebas are common unicellular organisms that live in water. They move around using foot-like projections called **pseudopods**. They extend a pseudopod and the cytoplasm streams into it. Amoebas also use these pseudopods to capture food. Figure 2.23 shows an amoeba engulfing food between two pseudopods. The ends of the pseudopods fuse together and create a vacuole around the food particle. The food in the vacuole is digested and absorbed into the cytoplasm.

### Paramecium

Unlike amoebas, paramecia (plural form of paramecium) move swiftly through the fresh water where they live. They are covered in hair-like structures called cilia, which move back and forth like oars to move them through the water. Cilia also help them gather food. On one side of the cell is a channel called an oral groove. It's lined with cilia, which sweep food to the bottom of the groove. There, the food enters a food vacuole, which moves into the cytoplasm, and the food inside is digested.

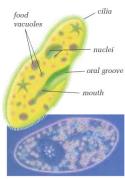


Figure 2.24 In the picture, the tiny circles with dark centres are food vacuoles. Can you see the cilia?

### CHECK AND REFLECT

- Unicellular organisms are simple. Agree or disagree with this statement and fully explain your answer.
- Why can't the individual cells of a multicellular organism live on their own? Explain your answer.
- Describe the steps you would follow to prepare amoeba specimens for observation.
- 4. Identify an amoeba's food-gathering structures and describe how they function.
- 5. Make up three questions about the behaviours of paramecia. Pick one of your questions and write a hypothesis that answers the question. (Remember: A hypothesis is a possible answer to a question. You usually phrase it so that it implies a way you could test it.)



## 2.4 How Substances Move Into and **Out of Cells**

Right now, every cell in your body is bringing in water, gases, and food inside itself. At the same time, each is removing waste products from inside itself. This bringing in and removal of substances is important to your survival. But it isn't unique to humans. These processes are also happening in the cells of every organism. The cell has a structure that permits this vital exchange of substances. It is the cell membrane. Many substances move through the cell membrane by a process called diffusion.

### Give it a TRY

### ACTIVITY

### DIFFUSION IN ACTION



In this activity, you will observe the process of diffusion in action. Place a drop of food colouring into a beaker of room-temperature water. Make sketches in your notebook to show what the drop looks like

- a) as soon as it is dropped in the water
- b) about 20 s later
- c) about 60 s later
- d) about 10 min later

What happened to the drop of food colouring over time? How did it look after 10 min? Can you think of a sentence to explain diffusion?



### THE CELL MEMBRANE AND DIFFUSION

Diffusion is the movement of particles from an area where there are more of them to an area where there are fewer of them. In other words, diffusion moves particles from a more concentrated area to a less concentrated area. It's a "balancing out" or "evening out" process that continues until the concentration of particles is the same everywhere.

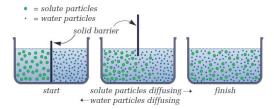


Figure 2.25 The process of diffusion



Figure 2.26 The tiny openings in this tea bag are large enough to allow water to pass through, along with the substances that make the flavour of the tea, but they are small enough to keep in the tea leaves themselves. How is a tea bag similar to a cell? How is it different?

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### **Vultures Find the Spot**

Engineers once used diffusion to find a leak in a gas pipeline. They put a chemical that smells like rotting flesh into the pipeline, and then watched and waited. Turkey vultures can smell even tiny amounts of this gas. The circling vultures led the engineers to the location of the leak in the pipeline.

Particles of many substances move in and out of cells by diffusion. The cell membrane acts like a filter with extremely tiny openings that allow some particles to pass through.

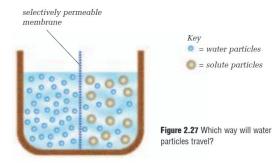
These openings are small enough to keep the cell's cytoplasm and organelles inside. They are also small enough to keep particles of most substances in the cell's external environment out. However, particles of some substances are able to pass from the outside in and from the inside out. So the cell membrane allows the particles of some substances to pass through it, but not others. Because of this fact, scientists say that the cell membrane is **selectively permeable**.

To do their jobs, mitochondria in cells need oxygen. Oxygen particles are small enough to pass through the cell's selectively permeable membrane into the cell. This movement of oxygen happens by diffusion. That's because the concentration of oxygen is usually higher outside the cell membrane than it is inside. As a result, oxygen simply diffuses into the cell. The cell doesn't have to do anything to make it happen.

### THE CELL MEMBRANE AND OSMOSIS

Water is another substance that has particles small enough to diffuse through the cell membrane. The amount of water inside a cell must stay fairly constant. If the water concentration inside the cell gets too low, water from outside the cell diffuses in. If the concentration gets too high, water diffuses out of the cell.

The diffusion of water is vital to the survival and health of cells. For this reason, scientists give it a special name: osmosis. Osmosis, then, is the diffusion of water particles through a selectively permeable membrane. The water particles move from an area of higher concentration (where there are more water particles) to an area of lower concentration (where there are fewer water particles).



## Inquiry Activity

### Materials & Equipment

- · thin slice of onion
- · compound microscope
- · glass slide
- cover slip
- · saltwater solution
- eyedropper
- · paper towelling
- · distilled (pure) water

### EFFECTS OF DIFFERENT SOLUTIONS ON CELLS

### The Question

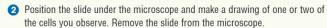
How will a saltwater solution and pure water affect the appearance of a cell?

### The Hypothesis

Form a hypothesis for this investigation describing the effect a saltwater solution will have on an onion cell. (See Toolbox 2 if you need help with this.)



- 1 Prepare a wet mount of a small piece of onion skin. Lay the skin as flat as possible on the slide.
  - Figure 2.28 Onion cells



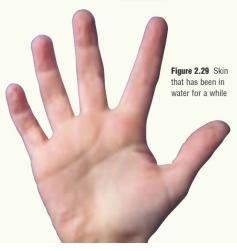
- 3 Place several drops of saltwater solution on one side of the cover slip. Use a piece of paper towel to "pull" the saltwater solution under the cover slip (as shown in Figure 2.21 on page 112). Wait 30 to 60 s.
- 4 Position the slide under the microscope and make another drawing of one or two of the cells you observe. Remove the slide from the microscope.
- 5 Repeat steps 3 and 4, but this time use distilled water on your specimen.

### **Collecting Data**

6 Assemble the three drawings you made in steps 2 to 5.

### Analyzing and Interpreting

7 How did the saltwater solution and the pure water affect the appearance of onion cells?



### Forming Conclusions

8 Explain what happened in this activity.

### Applying and Connecting

Have you ever noticed that when you've been in the water for a long time, your skin wrinkles, as in Figure 2.29? Why do you think this happens?

Cells Play a Vital Role in Living Things

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# Experiment .....

### HOW TO STOP THE WILT

### Before You Start ...

Have you ever given or received flowers from someone? How did they look at first? How did they change over time? Why did this happen?

Selling fresh, vibrant cut flowers, as in Figure 2.30, is big business. Flower shops use a variety of methods to keep plants fresh looking for as long as possible. What's the science behind these methods? Use your understanding of plant cells and tissues to help you solve the following problem.

### The Question

Which substance, technique, or both, will keep flowers from wilting for as long as possible?

### Design and Conduct Your Experiment

- 1 Make a hypothesis.
- 2 Decide what materials and equipment you'll need to test your hypothesis. For example:
  - a) What kind of plant will you use, and how many will you need?
  - b) What substances do you need to test your hypothesis?
  - c) Where can you find what you need, and what substitutions could you make, if necessary?
  - d) How will you troubleshoot for safety?
- 3 Plan your procedure. For example:
  - a) What evidence are you looking for to support your hypothesis?
  - b) How long will you run your experiment?
  - c) How will you collect your data?
  - d) What variables are you working with, and how would you define them?
  - e) How can you make sure that your test is fair?
  - f) How will you record your results?

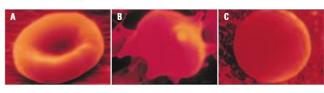


Figure 2.30 Fresh cut flowers

- Write up your procedure and show it to your teacher.
- 5 Carry out your experiment.
- 6 Compare your results with your hypothesis. Did your results support your hypothesis? If not, what possible reasons might there be?
- 7 How did you keep water moving through the plant's roots, stems, and leaves? Can you explain your results in terms of water moving through the plant?
- 8 Share and compare your experimental design and findings with your classmates. How do your results compare with theirs?

### THE EFFECT OF OSMOSIS ON CELLS

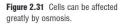
In Figure 2.31, photo A shows a normal red blood cell. It has been in a solution in which the concentration of water was the same inside and outside the cell. In photo B, the cell was in a saltwater solution. The concentration of water was higher inside the cell than outside, so the water moved out of the cell by osmosis. This cell now has a shrunken appearance. In photo C, the cell was placed in almost pure water. The inside of the cell contains far less water than the outside of the cell, so the water moves into the cell by osmosis, causing the cell to swell.





### **Reverse Osmosis**

A process called reverse osmosis can be used to purify water. It is often used on ships to purify drinking water. Find out how it works.



### CHECK AND REFLECT

- a) Use the term selectively permeable in a sentence that clearly demonstrates its meaning.
  - b) What is the function of a cell's selectively permeable membrane?
  - c) How does this function contribute to the health of the cell?
- The terms diffusion and osmosis seem to have similar meanings. Explain how they are similar. Then give a reason why scientists use two separate terms.
- 3. Martin volunteered to carry drinks to the class hosting a surprise party for a retiring teacher. He isn't sure which classroom is the right one, but he does know the students plan to serve pizza and popcorn. Explain how Martin could use the smell of popcorn and pizza as a clue.
- 4. Alex accidentally left a bag of carrots in the warm car. When he found them, they had wilted and were soft. He decides to place them in a container of water and check on them every half-hour or so for several hours. Predict what will happen to the carrots and why.
- 5. Fish species that live in fresh water have to remove excess water as waste from their bodies. Fish species that live in salt water have bodies that keep as much water as possible. Using what you know about osmosis, explain these observations.

Cells in Multicellular Organisms
Combine to Form Tissues and
Organs



**Figure 2.32** Have you wondered why unicellular organisms are so small? Does it surprise you that there aren't any single-celled creatures the size of a dog or elephant?

Unicellular organisms are tiny because there are limits to how large they can grow. One of the reasons involves diffusion and osmosis. These vital processes work well only over very short distances. For example, it takes an oxygen particle a fraction of a second to diffuse over a distance of 10  $\mu m$  (0.01 mm). To diffuse over a distance of 1 mm takes several minutes! Do you see how unicellular organisms benefit by being microscopic?

### CELLS REPRODUCE

Like all organisms, unicellular organisms grow and develop. When they reach the limits of their size, like the amoeba shown here, they reproduce. Amoeba do this by dividing into two, which results in two smaller, identical copies of each organism.

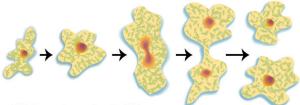


Figure 2.33 An amoeba reproduces by dividing.

Your cells reproduce this way, too. That's how, for example, your body replaces the 50 000 000 or so skin cells that it naturally loses each day! Your body cells also reproduce to repair tissues that get damaged. For example, if you scrape your elbow, your skin cells reproduce to form new skin tissue.

### MULTICELLULAR ORGANISMS HAVE SPECIALIZED CELLS

Your skin cell can do this because it's specialized for this function. You and most other multicellular organisms are made up of specialized cells. This means that there are various kinds of cells, and each kind carries out a specific function or functions needed to support life. Each kind of cell has specific structures that enable it to carry out its function. For example, the function of your red blood cells is to carry oxygen to all cells of your body. To do this, the red blood cells often must travel through extremely small blood vessels. Their thin, pliable disc shape enables them to do this.

Red blood cells do not reproduce in the same way as skin cells. When red blood cells mature into the shape shown here, they lose their nucleus. Since the nucleus controls cell division (among other functions), red blood cells can't reproduce by simply dividing to make more of themselves. The only way your body can make more red blood cells is by relying on specialized tissues in another body system. Most bones of the skeletal system contain a type of connective tissue called **marrow**, with specialized cells that make red blood cells.

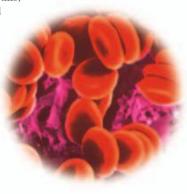
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### The Body's Nerve Centre



This strange-looking tree is actually a nerve cell. It's called a purkinje cell, and it is a very specialized cell from a part of your brain called the cerebellum. Your brain and nervous system are made of billions of nerve cells. These cells are what let you think, touch, taste, move, and see.

Figure 2.34 Red blood cells

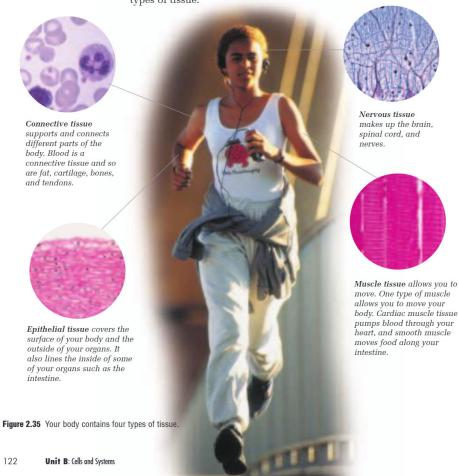


Specialization means that the cells of a multicellular organism must work together to support their own lives, as well as the life of the whole individual. For example, the cells that make up the tissue of your liver rely on other organ systems to provide them with oxygen and nutrients by diffusion.

### SIMILAR CELLS COMBINE TO FORM TISSUE

In humans, as well as in many other animals, the cells are organized into four different tissue types: connective, epithelial, nervous, and muscle tissues.

As you may recall, organs are made of tissues. Almost all of your organs are made up of different combinations of these four types of tissue.



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### TISSUES IN PLANTS

Plant cells are also organized into tissues, but plants have three tissue types: photosynthetic/storage, protective, and transport. These tissues are organized into the three organs that make up plants: the leaves, the roots, and the stems. Unlike animals, though, the organs of a plant are not organized into organ systems. However, the organs of a plant still interact—one organ, such as the leaf, cannot live without the substances provided by the other two

As you look at Figures 2.37, 2.38, and 2.39, observe how each of the tissues are organized in each of the organs.

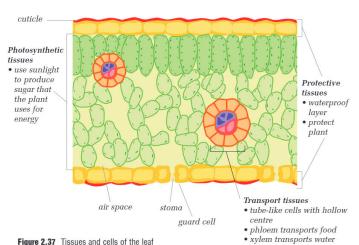


Figure 2.37 Tissues and cells of the leaf

Figure 2.36 Cross-sections of a leaf, stem, and root seen through a microscope





stem



### *re***SEARCH**

### **Water Bears**

Not all multicellular animals are large. For example, the members of one group of microscopic animals fondly referred to as "water bears" are multicellular. They range in size from 0.05 mm to 1.2 mm. (So the largest water bears are just in the range of your unaided sight.) These animals are amazing survivors. Find out more about water bears. How do they withstand extreme conditions?



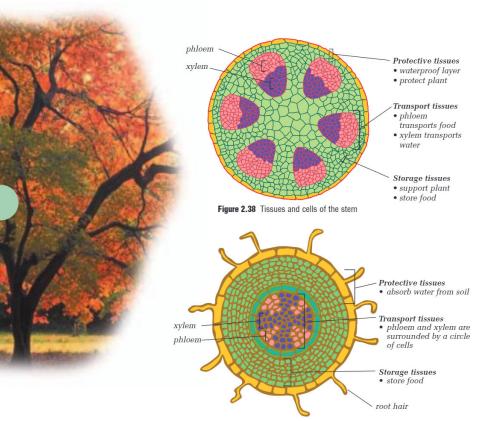


Figure 2.39 Tissues and cells of the root

### CHECK AND REFLECT

- 1. For what reasons do the cells that make up multicellular organisms need to reproduce?
- 2. Is a red blood cell more specialized than an amoeba, or is it the other way round?
- 3. What are the advantages of having specialized cells? Are there any disadvantages? Explain your answer.
- 4. a) Name a plant organ.
  - b) Identify the tissues that make up this organ.
  - c) Describe the cells that make up each of the tissues in these organs.

### SECTION REVIEW

### **Assess Your Learning**

 Identify the organisms in Figure 2.40 as unicellular or multicellular. Give reasons for your answers in each case.











Figure 2.40

- a) Sketch a plant cell and identify, using labels, the organelles and other cell structures.
  - b) Do the same for an animal cell.
  - Describe the key differences between plant cells and animal cells.
- 3. What is the function of a compound light microscope?
- 4. In your opinion, which structure or organelle is the most important to the health of a cell? Give reasons for your answer.
- 5. Choose one of the items below. Using words, pictures, or both, explain how you would prepare it to view with a microscope. Also, make a sketch showing what you think it would look like under low, medium, and high power. (Ask your teacher if you can set up a microscope to verify, and, if necessary, modify your sketches.)
  - a) a hair from your hand
  - b) a fleck of dandruff
  - c) a grain of pepper
  - d) a grain of salt
- 6. Imagine that an amoeba is placed in a solution of salty water. The concentration of salt in the solution is greater than the salt concentration of the amoeba's watery cytoplasm. What will happen, and why? Be sure to use the proper science terms to communicate your understanding.



## THE NATURE OF SCIENCE

A goal of science is to provide knowledge of the natural world. Think back on what you have learned about cells.

- 1. Why do you think it's important to know how cells work?
- 2. How has the microscope helped us to improve our understanding of the natural world?
- 3. What do plants and animals have in common?





3.0

# Healthy human function depends on a variety of interacting and reacting systems.

# **Key Concepts**

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

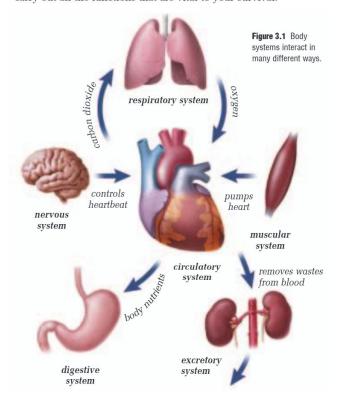
- cells
- organs
- tissues
- structure and function
- · response to stimuli
- systems

#### **Learning Outcomes**

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

- describe how various body systems work
- recognize the roles of organs and tissues in body systems
- describe how various cells help the body to function
- show how the body responds to changing conditions

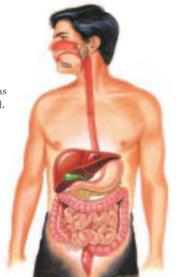
Although each organ system must have the ability to **react** to changes both within and outside your body to maintain life, your body's organ systems actually depend strongly on one another. This means they work together, or **interact**, as a single unit to carry out all the functions that are vital to your survival.



# 3.1 Digestive System

Living organisms require energy to survive. Like other animals, you obtain energy from different sources such as carbohydrates (sugars and starches), lipids (fats and oils), and proteins. But before your cells can use any of these energy sources for fuel, they must be processed by your digestive system. Your digestive system is in charge of breaking down the food you eat into parts small enough to be used by your cells. Each of the different energy sources: carbohydrates, lipids, and proteins must be broken down into small usable particles as they travel through your digestive system.

Figure 3.2 Organs of the digestive system



# Give it a TRY

#### ACTIVITY

# A TASTE OF DIGESTION

Your teacher will give you some unsalted soda crackers. Chew the soda crackers up thoroughly, and then hold them in your mouth for about 5 min without swallowing. (This can be a bit difficult to do, but do your best.) Swallow the crackers once you have finished the activity. At the end of 5 min, you will assess any changes in the taste of the crackers.

- · How did the crackers taste as you first chewed them?
- · Describe how the taste changed as you neared the 5-min mark of the test.
- · Compare your taste experience with that of your classmates.
- · What do you think caused any changes you experienced?



# TYPES OF DIGESTION

There are two types of digestion. Mechanical digestion involves the physical breakdown of food into very small pieces. Chemical digestion involves the breakdown of large particles into smaller particles by substances called enzymes. Mechanical and chemical digestion happen in several different places in our digestive systems.

#### FOOD'S PATH THROUGH THE DIGESTIVE SYSTEM

The digestive system is actually a long tube, with a few attachments along its length. It starts at your mouth and finishes at the rectum. To help you see how the digestive system works, imagine that you've just taken a big bite of your favourite snack. Of course, this snack is well balanced and nutritious, so it contains starch, lipids, protein, minerals, and vitamins.

# THE MOUTH AND ESOPHAGUS

Before the food you've eaten reaches the stomach, it comes into contact with many organs. Digestion begins at the entrance to the tube, the mouth, with the mechanical breakdown of your food. The teeth mechanically digest the food by grinding it and mixing it with saliva. Three pairs of salivary glands located in the tissues surrounding your mouth produce saliva. Saliva contains water to

moisten the food, making the food easier to swallow. It also contains an enzyme known as salivary amylase. This enzyme chemically digests large starch molecules into smaller sugar molecules.

tass contains
as salivary
me
large
atto
cules.

teeth
mouth
tongue
salivary glands
epiglottis
esophagus

**Figure 3.3** Saliva from salivary glands moistens food in the mouth.

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#### **Accident Advances Science!**

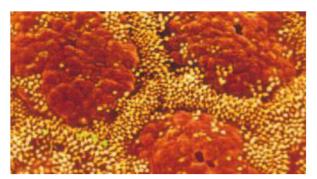
Much of what we know about the stomach can be attributed to Alexis St. Martin, a French-Canadian voyageur and his American doctor, William Beaumont. St. Martin was almost killed by an accidental gunshot wound to his left side. Because of the size of the wound, Beaumont was forced to leave a permanent opening through St. Martin's skin into his stomach. Beaumont used this access to the stomach to study digestion. Beaumont would dangle different food types on a string into St. Martin's stomach. Despite his unusual injury, St. Martin lived into his 80s.



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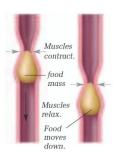
Once you are ready to swallow your thoroughly chewed bite of food, your tongue pushes it to the back of your throat. As you swallow, a flap of skin called the epiglottis moves across your windpipe, and food is funnelled into the esophagus. The food moves down toward your stomach by a wave-like movement known as peristalsis. Peristalsis is caused by contractions of muscle tissue that lines the esophagus. Bands of muscle tissue line the remainder of the digestive system to push the food along toward the end. If you've ever taken a big bite of food and not chewed it properly, you might have felt pain or discomfort as the muscles contract around the food to push it toward your stomach.

# THE STOMACH

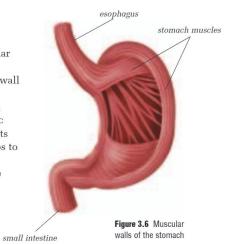


**Figure 3.5** The yellow dots are droplets of mucus produced by the stomach wall.

The stomach responds to the stimulus of the arrival of food in a couple of ways. The muscular wall of the stomach churns the food back and forth, while mixing it with secretions from the wall of the stomach, known as gastric juice. Gastric juice is composed of mucus, hydrochloric acid, water, and digestive enzymes. The hydrochloric acid, along with the enzymes, chemically digests proteins into smaller particles. The mucus helps to prevent the gastric juice from digesting the stomach itself. The stomach slowly releases the food, which is now a liquid, into the small intestine.



**Figure 3.4** Peristalsis in the esophagus



# THE SMALL INTESTINE, PANCREAS, LIVER, AND GALL BLADDER



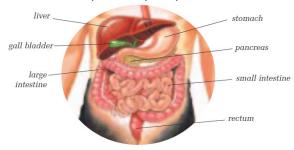




Figure 3.8 A crosssection of the small intestine showing villi on the inner surface

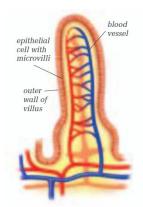


Figure 3.9 The inner structure of a villus

As food moves into the small intestine, chemical digestion continues. Here, the pancreas sends digestive enzymes into the small intestine. These enzymes, along with enzymes produced by the wall of the small intestine, complete the breakdown of starches and proteins into very small particles. The liver produces a substance called bile, which is stored in the gall bladder. The gall bladder sends bile into the small intestine where it breaks up large globules of lipids into much smaller droplets.

Once the food has been broken up into small particles, the small intestine absorbs these particles. The inner surface of the small intestine forms into villi—small, finger-like projections. These increase the surface area of the intestine to aid in absorbing nutrients. Each villus (the singular term for villi) is covered with epithelial tissue. The food molecules get absorbed by this tissue. Blood vessels lie just below the epithelial tissue, and the nutrients are transferred to the bloodstream.

The small intestine is 6 m long; if your small intestine was stretched so that the villi unfolded, it would cover the whole floor of your classroom!

The cells of the epithelial tissue have modified cell membranes that form more finger-like projections called **microvilli**. Microvilli further increase the surface area of the small intestine to help absorb nutrients.

#### THE LARGE INTESTINE

By the time the food reaches the large intestine, mechanical and chemical digestion are complete. In humans, the large intestine is about 1.5 m long. The large intestine absorbs water, along with some vitamins and minerals. Any parts of the food that have not been digested are formed into feces, which is collected in the rectum.

# CHECK AND REFLECT

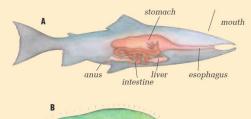
 Make a chart like the one below and use information you have learned to fill it in.

Organ	Mechanical Digestion	Chemical Digestion

- Imagine that you have just eaten a cheeseburger. Describe the path of the cheeseburger through your digestive system and the mechanical and chemical digestion that occurs to the food as it is broken down.
- 3. For each of the terms below, explain the relationship that exists.
  - a) digestion, enzymes
  - b) nutrients, villi
  - c) enzymes, nutrients
  - d) digestion, peristalsis
- Explain how the small intestine, which fits into a fairly small space in the body, manages to have such a large area of foodabsorbing surface.
- 5. Describe the role tissues and cells play in digestion.

food vacuole

- 6. You know that different organisms have slightly different structures to perform the same functions.
  - a) Examine the digestive systems of the animals shown in Figure 3.10. In what ways are the structures of these systems similar and different?
  - b) Describe how the functions of these structures may be similar and different.



oral groove

Figure 3.10



#### Bacteria Breakdown

Many bacteria live in your large intestine, and they help break down certain foods and provide you with nutrients you would not get otherwise. Find out more about these bacteria, such as the nutrients they supply you with and the effect that taking antibiotics has on them.



# 3.2 Respiratory System

Your respiratory system is responsible for supplying your blood with oxygen and removing the carbon dioxide from your blood and returning it to the air outside your body.

# Give it a TRY

### ACTIVITY

# WHAT'S IN YOUR BREATH? @ 6 4





Your body needs oxygen in order to survive, and it must also rid itself of the waste carbon dioxide. Both of these are accomplished by breathing. While it is difficult to prove that the air we inhale contains oxygen, it is easy to prove that your exhaled breath contains carbon dioxide. Follow the procedure below to find

- Add 10 mL of water and a few drops of bromothymol blue to each of 2 test
- Label the first test tube "A" and the second test tube "B."
- Use a straw to gently blow 5 big breaths into the liquid of test tube A, and note any changes you observe.

Bromothymol blue changes colour when it is mixed with carbon dioxide. Did a colour change occur in one of the test tubes? What does this colour change prove? Why was it important to include test tube B in this experiment? What compound is present in your exhaled breath?



# infoBIT

#### How's the Air Up There?

Mountain climbing is a dangerous sport, especially when you want to climb the tallest mountain in the world. However, the danger is not just due to avalanches, crevasses, and blinding snowstorms. Much of it is due to the lack of oxygen in the air at such high altitudes. Your respiratory system tries to compensate for the thin air by acclimatizing and deep breathing. But the brain's function and coordination are affected. According to Calgary educator, speaker, and mountain climber David Rodney (who reached the peak of Mt. Everest in May 1999), everyone is functioning at a lower thinking level because the air has only one-third of the oxygen that sea-level air has.



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#### **B**REATHING

Breathing is the process your respiratory system uses to move air in and out of your lungs. Breathing occurs because of your rib and diaphragm muscles. When you inhale, these muscles contract, pulling your ribs up, and your diaphragm down. This increases the size of your chest and lungs, pulling air into your lungs. When you exhale, these muscles relax: your ribs go down and your diaphragm goes up. This decreases the size of your chest and lungs, forcing air out.



You breathe about 20 times a minute. How many breaths would you take in a day? in a year?

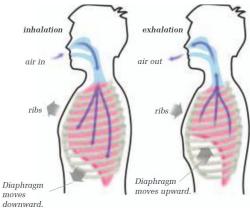


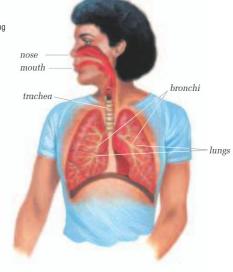
Figure 3.11 Movement of the ribs and diaphragm during breathing

 $\label{eq:Air enters your respiratory system} Air enters your respiratory system through the structures shown in Figure 3.12.$ 

# THE GAS EXCHANGE PROCESS

Your cells need oxygen to release energy from nutrients such as glucose. They also need to rid themselves of the carbon dioxide waste gas produced at the same time. Two body systems work together so that cells can exchange these two gases.

Figure 3.12 The pathway of air into the lungs



The respiratory system draws oxygen-rich air into the lungs through a series of tube-like passageways called **bronchi**. Bronchi are lined with tough connective tissue to keep the walls from collapsing. These bronchi narrow to **bronchioles** that end in about 600 000 000 tiny, air-filled sacs called **alveoli**. The alveoli, like the capillaries that surround them, are made of specialized epithelial tissue. This tissue is only one cell layer thick. This means that the distance between the air inside the alveoli and the blood inside the capillary is very short. If you think back to what you learned about diffusion, you probably have a good idea why this is so.

The air in the alveoli has a high concentration of oxygen and a low concentration of carbon dioxide. The blood in the capillaries surrounding the alveoli has a low concentration of oxygen and a high concentration of carbon dioxide. So oxygen naturally diffuses from the alveoli into the capillaries, and carbon dioxide naturally diffuses in the other direction.

It takes only one second for blood to travel through your lungs, picking up as much oxygen as it can hold and releasing its carbon dioxide waste.

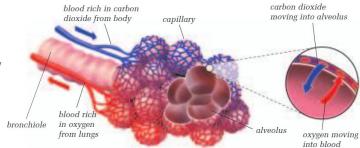


Figure 3.13 Alveoli are hollow sacs surrounded by capillaries. Gas exchange happens in the alveoli.

# CHECK AND REFLECT

- Draw a flowchart showing the process of respiration including the major organs and tissues involved and their functions.
- List the structures that air particles pass through on their way to the alveoli.
- 3. Draw a diagram and label the structure of an alveolus.
- 4. What might be the effect of the following imaginary situations?a) The covering tissue of your capillaries is much thicker.
  - b) Air-sac tissue is much thicker.
- 5. Why is it important to breathe deeply when exercising?

# 3.3 Circulatory System

One of the circulatory system's jobs is to deliver the nutrients absorbed by your digestive system to each cell in your body. The circulatory system, then, is your body's transportation network. Besides nutrients, your circulatory system must also transport oxygen to your cells and remove waste products.

Figure 3.14 How is your circulatory system similar to this highway interchange?

# Give it a TRY

#### ACTIVITY

# WHAT DO YOU KNOW?

What do you already know about the circulatory system? Write down the answers to these questions in your notebook.

- · Where is the blood located? How does it move around your body?
- · Why is some blood bright red and some blood dark red?

Discuss your ideas about the circulatory system with your classmates. As you work through this subsection, you will be able to compare your ideas against what you've learned.



Figure 3.15 Arteries are in red; veins are in blue.

#### THE HEART

Your heart is an important part of your circulatory system. You probably know that the heart is a pump, but did you know it is actually two pumps? The right and left sides of your heart each act as a separate pump, and although they work together, each has its own job to do. The right side of the heart pumps blood to your lungs (where it receives fresh oxygen and gives off carbon dioxide). The left side of your heart receives this oxygen-rich blood from your lungs and pumps it to all the other parts of your body. The blood then returns to the right side of your heart to begin the cycle again. Each side of the heart is divided into two chambers. The top two chambers on each side are called **atria** (atrium is the singular form), and the bottom two chambers are called **ventricles**. Study the diagram below to learn more about the flow of blood through the heart.

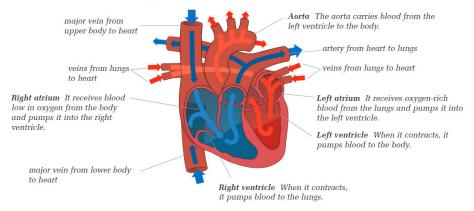


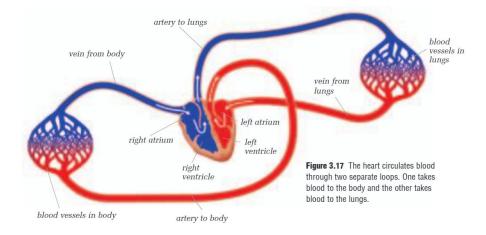
Figure 3.16 Blood flow through the heart. Blue arrows show the path of blood low in oxygen; red arrows show the path of blood high in oxygen.

# infoBIT

### They've Got the Beat

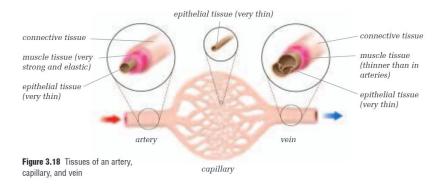
The animal with the fastest heart rate is the hummingbird. Its heart beats about 1000 times a minute. A human's heart beats about 70 times a minute. An elephant's heart beats the slowest at about 25 beats per minute.





# ARTERIES, VEINS, AND CAPILLARIES

Your heart is used to pump blood throughout your body. In fact, it has to pump blood through 100 000 km of blood vessels. The vessels that carry blood away from your heart to all the parts of your body are called **arteries**. Blood is returned from your body to the heart in **veins**. Blood vessels are made up of three of the four types of tissue: connective on the outside, muscle in the middle, and epithelial on the inside. Arteries, in particular, have a thick, muscular layer in the middle that expands and contracts to help push blood along. You feel this expansion of your arteries as a pulse. Veins are thinner and have valves that stop the blood from flowing backward.



# Inquiry Activity



Figure 3.19 Two ways to measure your pulse

# Materials & Equipment

For each pair of students:

- stopwatch, wristwatch, or clock with a second hand
- · graph paper

#### Caution!

Do not complete this procedure if you cannot exercise for medical reasons.

# CHANGES IN HEART RATE

#### The Question

Does your heart rate return to normal immediately after exercising?

#### The Hypothesis

Form a hypothesis based on the question.

#### Procedure

- 1 Your teacher will show you two ways to measure your pulse, as shown in Figure 3.19.
- Work with a partner. One of you will do the experiment, and the other will be the timer and recorder. After you finish the procedure, switch roles and use the other way to measure your pulse. Begin by taking your pulse for 1 min while you sit quietly in a chair. Record your heart rate in a table.
- Exercise vigorously (run in place or do jumping jacks) for 5 min while your partner times you. After 5 min are up, take your pulse for 1 min. Record this in your table.
- 4 After 1 min, take your pulse again for 1 min.
- Sepeat step 4 another two times, or until your heart rate returns to the resting heart rate.

#### Recording Data

6 Record your partner's heart rate immediately after exercising and then at

#### Analyzing and Interpreting

7 Prepare a graph of your experimental data. Which would be the best kind of graph to use and why?

#### Forming Conclusions

- 8 What was your resting heart rate?
- 9 What was your maximum heart rate? When did this occur?
- 10 Why do you think your heart rate increases during exercise? Think in terms of stimulus and response.
- 11 How did your heart rate compare to your resting heart rate after 1 min? after 3 min?
- 12 Why do you think your heart rate stays high even after you've stopped exercising?
- 13 Which was the best way to measure your pulse and why?

#### Applying and Connecting

If you've ever watched a really scary movie, or have felt very nervous, you might have noticed that your heart is beating fast even though you haven't been exercising. Why do you think this is?

The processes that you learned about earlier, osmosis and diffusion, play important roles in the circulatory system. Diffusion is the process responsible for transporting oxygen from your blood into your cells and carbon dioxide from your cells into your blood. Diffusion is also used to transport some nutrients from your small intestine to your blood. The diffusion of nutrients and gases occurs in specialized blood vessels, located between arteries and veins, called capillaries. Capillaries have two adaptations for exchanging gases and nutrients: (1) they are made of specialized epithelial tissue that is only one cell layer thick, and (2) they are very narrow so that the blood cells must pass through in single file. Both of these adaptations help increase the rate of gas exchange between the blood and the cells.



Figure 3.20 A capillary sliced lengthwise. The red squiggles are red blood

# Give it a TRY

#### ACTIVITY

# THE SIGHT OF BLOOD

How many different types of blood cells can you identify in a prepared slide of human blood? Look at the slide, first on low power, then switch to high power. In your notebook, make a drawing of each type of blood cell you observed.

· How many different blood cells were you able to see?



Figure 3.21 Human blood cells

#### THE BLOOD

Your blood is the second largest example of connective tissue in your body. (Your bones are the largest example.) Your blood consists of red blood cells; white blood cells; tiny cells called platelets; and plasma—the liquid portion of blood. Plasma makes up 55% of your blood, while the other parts make up 45%.

Figure 3.22 This blood sample has been allowed to separate. The yellowish liquid is plasma.



Healthy Human Function Depends on a Variety of Interacting and Reacting Systems

#### reSEARCH



Dr. Charles Drew In the 1940s, Dr. Charles Drew made many important discoveries about blood-such as how to store blood so it wouldn't spoil. Although he was an American, Drew attended medical school at McGill University in Montreal because, at the time, medical schools in the U.S. would not admit black students. Find out more about the discoveries and life of Dr. Drew.

Blood cells are highly specialized in order to perform their functions. The function of red blood cells is to carry oxygen. In order to carry the most oxygen possible, mature red blood cells have no nuclei—making more room for oxygen. Red blood cells are also very flexible, allowing them to bend and twist through the tight spaces of your capillaries. White blood cells are specialized to fight infection. Some of them are capable of eating bacteria at infection sites such as cuts. Platelets are cells that help to stop the bleeding at cuts. Plasma, the liquid portion of your blood, transports nutrients to your cells and carries wastes, such as carbon dioxide, away.

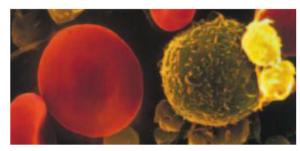


Figure 3.23 Red blood cell (left), white blood cell (right), and two platelets (far right)



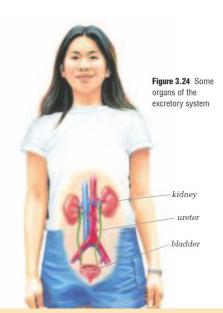
Using your resting heart rate (pulse), calculate how often your heart would beat in a day, in a year, in a lifetime (about 78 years if you're male or 85 years if you're female). Do you think this is an accurate estimate of heartbeats over a lifetime? Why or why not?

# CHECK AND REFLECT

- Name the organs and cells of your circulatory system and describe what they do.
- 2. Create a concept or mind map to show how the three systems you've studied so far are related.
- 3. Diffusion is a slow process. How does the structure of the capillaries help diffusion occur fast enough to keep you alive?
- 4. Describe why diffusion is an important process to your body.
- 5. Name and describe the four chambers in the human heart.

# 3.4 Excretory System

The body produces a number of different types of wastes. These wastes are poisonous, and, if not removed from the body, can cause you serious harm. The job of waste removal, excretion, is done by the excretory system. The interesting thing about the excretory system is that it involves organs from other systems. So different organ systems interact to get rid of wastes. What organs that you've learned about so far remove waste from the body?



# Give it a TRY

ACTIVITY

# WHERE DOES IT GO?

On any given day, you may take in about 2.5 L of water from what you eat and drink. What happens to this water? Below are the three main mechanisms for getting rid of water in your body. Match these mechanisms with the correct volume lost. When you are done, make a pie chart to illustrate your answer.

• sweat a) 0.5 L

• urine and feces b) 0.8 L

breathed out air
 c) 1.2 L



# WASTE PRODUCTS

As you already know, our cells produce carbon dioxide as a waste product, and it is removed from the blood by the lungs during the gas exchange process. But our cells also produce other harmful waste products. When cells break down proteins, they produce a very toxic compound called ammonia. Chemical processes that happen in the cells also produce water and salts as waste products. We need water, but only a certain amount at a time. Each of these waste products has to be dealt with.

#### infoBIT

#### In and Out

The average person takes in about 2550 mL of water a day, by drinking, eating, and processes occurring in your cells. However, you also lose about 2550 mL of water a day through urination, perspiration, breathing, and feces production. Overall, then, the amount of water in your body stays constant.

#### THE LIVER

The liver is an organ of the digestive system, but it also plays a role in excretion. It takes the highly toxic ammonia produced by the body's cells out of the bloodstream and converts it into a less harmful substance called **urea**. Even though it is less harmful, the urea still has to be disposed of. The liver releases urea into the bloodstream.

# THE KIDNEYS

The kidneys are about 10 cm long. They are the main organs of excretion; they act as filters to the blood, straining out the unwanted urea, water, and other salts, and they produce urine. Every drop of your blood is filtered about 300 times a day by the kidneys. Even though about 180 L of blood pass through the kidneys each day, you produce only about 1.5 L of urine. The amount of urine you produce also depends on how much water you drink. The kidneys keep the proper amount of water in your blood. If there is too much water, they excrete lots of water and so produce a lot of urine.

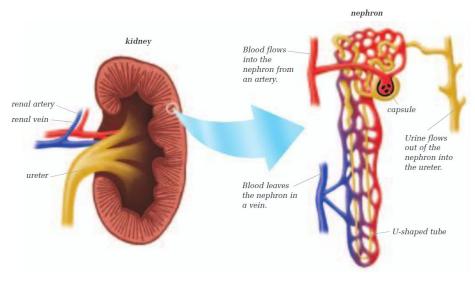


Figure 3.25 The structures of the excretory system

# THE FORMATION OF URINE

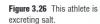
The formation of urine is quite a complicated process. First, the blood enters the kidney by the renal artery. The artery branches into smaller and smaller vessels. These small capillaries enter filtering units called **nephrons**, as shown in Figure 3.25. The kidney has millions of nephrons. These microscopic units remove wastes from the blood and produce urine. The "clean" filtered blood returns to the body through the renal vein. The urine flows out a separate vessel and into the ureter.

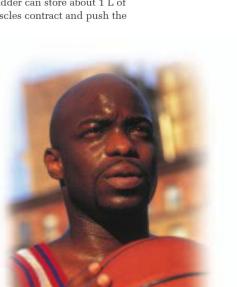
# URETERS, BLADDER, AND URETHRA

Ureters are long tubes that connect the kidneys to the bladder. The bladder is a sac covered in muscle tissue. As the urine enters the bladder, the bladder expands. The bladder can store about 1 L of urine. When it is full, the bladder muscles contract and push the urine out through the urethra.

# THE SKIN

Have you ever tasted your sweat? If you have, you'll have noticed that it tastes salty. Your skin has thousands of tiny sweat glands just below the surface. In addition to producing sweat to keep you cool, these glands remove excess salt from your blood. This salt is added to your sweat, creating the salty taste. So when you sweat, you are excreting salt.







### Transplants

Some organs of the excretory system can be transplanted. Find out which ones.

# Inquiry Activity

#### Materials & Equipment

- · 6 test tubes
- · test-tube rack
- · masking tape
- pen
- water
- · glucose solution
- · protein solution
- · 3 simulated urine samples
- · tweezers
- · glucose test strips
- · paper towel
- · 6 eyedroppers
- · Biuret solution





**Figure 3.27** Step 4

### Caution!

Biuret solution is toxic and corrosive. Handle with care and wear safety goggles for this activity.

# TESTING ARTIFICIAL URINE

Urine contains waste products, but sometimes other compounds can appear in the urine. When they do, they can indicate diseases. Normally, urine does not contain protein or glucose. Protein in the urine is a sign of kidney failure, and glucose in the urine is a sign of diabetes.

#### The Question

Can we find out whether three fictitious patients have diabetes or kidney disease by testing their urine?

# The Hypothesis

Based on the question, form a hypothesis.

# Procedure 🕲 🖨 🥠 🐠







- 1 Place 6 test tubes in a test-tube rack. Place masking tape on each one and label as follows: water, glucose, protein, patient 1, patient 2, and patient 3.
- 2 Fill each test tube about two-thirds full with the solution indicated on its label.

### **Collecting Data**

- 3 Create a data table to record your results.
- 4 To test for glucose, use tweezers to place a glucose test strip on a paper towel in front of each test tube. Then, use an eyedropper to add a drop of the solution from each test tube to the glucose strip in front of it, as shown in Figure 3.27. Note: Clean the eyedropper with water between tests. Record the colour of the test strip.
- To test for the presence of protein, add 10 drops of Biuret solution to each test tube. Gently swirl each test tube. Carefully observe each test tube and record the colour in the data table.

#### Analyzing and Interpreting

- 6 What colour did the glucose test strip turn when the glucose solution was
- What colour did the protein solution turn when Biuret solution was added to

### Forming Conclusions

- 8 Did any of the patient samples show any signs of diabetes? Did any of the patient samples show any signs of kidney failure? Explain your answers.
- 9 What was the purpose of the glucose and protein test tubes?

# **Applying and Connecting**

Several years ago, science students would test their own urine in such activities. Why do you think it is considered no longer safe to do so?

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#### URINE CAN REVEAL DISEASES

Doctors can determine if you have certain diseases by testing your urine. Certain diseases can affect how the kidneys function, and these changes in function will show up in the urine. Patients whose kidneys are failing often have protein in their urine because their kidneys have lost the ability to filter blood properly. People who have diabetes will often have glucose in their urine. Their cells cannot absorb glucose, and glucose builds up in the bloodstream. Because the blood has so much glucose, the nephrons filter it out and add it to the urine.

#### DIALYSIS

Sometimes, as a result of damage or disease, kidneys don't work properly. Luckily, people whose kidneys don't function well can still lead normal lives thanks to a machine that acts as a kidney. It's called a kidney dialysis machine, and it removes all the wastes from the blood that a kidney normally would.

When a person undergoes dialysis, his or her blood flows into special tubing inside the machine. The tubing is made of a selectively permeable material, allowing only certain substances to diffuse through it. This tubing is surrounded by fluid. Wastes from the blood diffuse out of the blood into the fluid, and certain substances from the fluid diffuse into the blood. The blood then flows back into the person. It takes four to six hours to fully clean the blood.



Figure 3.28 People undergo dialysis roughly three times a week.

# CHECK AND REFLECT

- Add the process of excretion to the concept map you started previously.
- 2. What is the function of the excretory system?
- 3. What is urea and how is it formed?
- 4. If your water intake on a certain day were higher than usual, how would your body respond to this?
- A freshwater fish produces a lot of urine, and a camel produces very little urine. Explain why this is so.

# 3.5 Nervous System



Figure 3.29 This goalie is reacting to the stimulus of the flying puck. How might you react to this stimulus if you were sitting in the stands and the puck was flying toward you?

The crowd is going wild! A player sends the puck flying toward the net. The goalie makes a split-second decision and catches the puck with one swift movement. The goalie is reacting to a stimulus. As you learned earlier, a stimulus is a change in your environment. Stimuli (the plural form of stimulus) can occur in many forms, such as changes in pressure, heat, cold, light, sound, or body chemistry. Stimuli may be external (outside your body), such as when you walk from the cold outdoors into a warm room, or they can be internal, such as the arrival of food in your stomach. It is the job of the nervous system to monitor and respond to these stimuli.

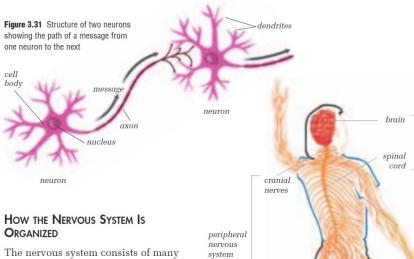


Figure 3.30 MRI scan showing the structures of the human brain

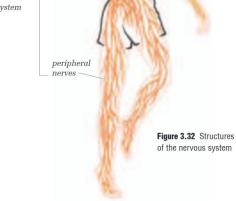
#### **N**EURONS

Unlike the other body systems, the nervous system is mostly made up of one type of tissue called **nervous tissue**. Nervous tissue is made entirely of specialized cells called **neurons**. Your brain, spinal chord, and nerves are all made of them. A neuron's job is to send and receive messages.

A neuron receives messages from small branches of the cell called **dendrites**. The incoming messages are passed from the dendrites through the cell body to the **axon**. The axon is a long extension of the cell that ends in small branches. It carries impulses away from the cell body to its branches. These branches transmit the message to the dendrites of neighbouring nerve cells.



The nervous system consists of many divisions. Two of the most important are the central nervous system and the peripheral nervous system. The central nervous system is composed of the brain and spinal cord, while the peripheral nervous system is made up of the cranial (head) and spinal nerves. These nerves travel to all parts of your body.



Healthy Human Function Depends on a Variety of Interacting and Reacting Systems

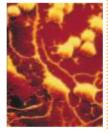
central

nervous system

#### infoBIT

#### **Making Connections**

Humans have the most sophisticated brains of any organism. Our brains are composed of about 100 billion neurons. Interestingly, scientists think that we don't learn by growing new neurons, but rather by forming new connections between our existing neurons.



#### The Peripheral Nervous System

Each nerve of the peripheral nervous system is composed of two types of neurons. **Sensory neurons** carry information from the body to the central nervous system, and **motor neurons** carry information from the central nervous system to the muscles or organs.

The peripheral nervous system can be divided again. You may have conscious control over your responses to stimuli. For example, when you hear a noise, you can decide whether or not to turn your head to see what caused it. These voluntary responses are controlled by the **somatic nervous system**.

Your brain also responds to certain stimuli unconsciously. This means you don't have to think about it. For example, your body automatically adjusts the size of your pupils, your heart rate, blood pressure, breathing rate, and peristalsis in your digestive system. It's a good thing you don't have to remember to do all these things; otherwise, you would have very little time to think of anything else! These automatic responses are controlled by the **autonomic nervous system**.

#### The Central Nervous System

The brain receives stimuli from the outside world, gathered by the sense organs: the eyes, ears, mouth, nose, and skin. What are the senses? The brain also receives internal stimuli from the body itself. It reacts to these stimuli and sends messages to the appropriate body parts. The brain is generally divided into three main sections: the cerebrum, the cerebellum, and the medulla. Figure 3.33 shows what each part of the brain does.



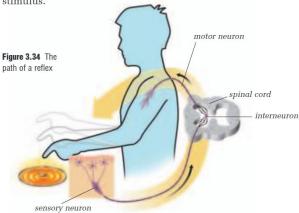
Figure 3.33 Functions of the brain

The spinal cord connects the brain to the peripheral nervous system, and it acts as a highway for messages between the brain and the body. It contains a type of neuron called an **interneuron**. These neurons connect one neuron to another.

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#### THE REFLEX RESPONSE

In some situations, sensory and motor neurons may work together without involving the brain. This is known as a reflex. A **reflex** is an automatic response by the nervous system to an external stimulus.



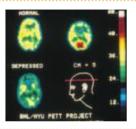
Suppose you accidentally touch a red-hot element on the stove. The stimulus is the intense heat. Sensory nerves in your hand react to the stimulus by sending nerve impulses to the spinal cord. Interneurons relay the message to the motor neurons. The impulse travels to the muscles of your arm, which quickly contract to remove your hand from the element.

The sensory neurons also send a message to your brain. But, by the time the message gets there and your brain decides to change your facial expression to a grimace and have you cry out in pain, your hand is already off the element. Reflexes protect you from injury by reducing the time it takes to react to harmful stimuli.



# Watching the Brain at Work

Brain researchers have always wanted to be able to look inside the brain to find out which part of a person's brain is working when solving a math problem or reading a book. Researchers now have a tool that allows them to do this. It's called a PET scanner (PET is short for "positron emission tomography"). Use your school library or the Internet to find out how a PET scanner works, and what it has revealed about the brain.



# Inquiry

# Activity

#### Materials & Equipment

- drafting divider, or 2 straightened paper clips
- ruler



**Figure 3.35** Step 3

# A SOFT TOUCH

#### The Question

Sensory receptors in your skin that detect heat, cold, pain, pressure, and touch are distributed over the surface of your body. Are touch receptors distributed evenly over the surface of the body?

#### The Hypothesis

Create a hypothesis based on the question.

#### **Procedure**

- 1 Copy the data table into your notebook.
- In this activity, you will act as a tester, and your partner will be the subject. At the end of the activity, you will switch roles.

Body Area	Distance between Points (mm)
fingertip	
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	~~~

- 3 Have your partner sit down and close his or her eyes. With the divider about 4 cm apart, gently touch the person's fingertip with both points of the divider, as shown in Figure 3.35. Ask the subject whether they feel one point or two. If the subject says two, then decrease the distance between the points and repeat the test. Continue decreasing the distance between the points until the subject can feel only one point.
- 4 Repeat step 3 for the following areas: centre of palm, back of hand, inner forearm, back of neck, upper arm, and lower back.
- 6 Before you start, predict which body parts are the most sensitive to touch.

# Collecting Data

- 6 Measure the shortest distance between the points with a ruler and record it in the data table.
- 7 Repeat the test on the remaining areas listed on the data table. You may occasionally want to touch the subject with only one point to test the accuracy of their responses.

#### Analyzing and Interpreting

8 Look at your data and rank the seven areas tested from most sensitive to least sensitive.

# Forming Conclusions

9 Does your data support the hypothesis? Explain why or why not.

# **Applying and Connecting**

It is important for certain areas of your body to have a keen sense of touch and not so important for other areas. Look at the areas of the body that you found are well supplied with touch receptors. Why do you think these body parts require extra sensitivity?

#### AN UNEVEN SENSE OF TOUCH

Unlike other senses such as vision, hearing, smell, and taste, the sense of touch is not found in one specific place. The sense of touch is found in all areas of your skin, making it the largest sense organ.

When blind people read, they pass their fingertips over tiny bumps that form the braille letters. There is a reason they use their fingertips: they are loaded with touch receptors. But not all parts of the body have the same amount of touch receptors. Think of your body surface. Which areas are the most sensitive?

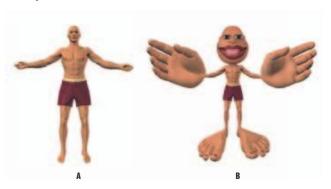


Figure 3.36 Drawing A represents the human body drawn to normal proportions. Drawing B represents the body when each area of the skin is drawn in proportion to its sensitivity to touch.

# CHECK AND REFLECT

- Add the nervous system to the systems concept map you started previously.
- List at least six stimuli you have experienced so far today and which sense was responsible for experiencing each of them.
- 3. What is the role of the nervous system?
- Describe the similarities and differences between the central and peripheral nervous systems.
- 5. Current brain research suggests that the more a particular set of neurons is used in the brain, the more automatic the response becomes. Use this information to explain why practising is so important in learning to play a musical instrument or in playing a sport.
- 6. How does the structure of a neuron help it to carry out its function?



# CELLS IN 3-D!

Actual cells look much more exciting than the two-dimensional representations you see in photos or through a microscope. Using your current understanding of cell structures, design a three-dimensional model of a cell that is made from common household items.

Make a chart or mind map listing all the household items that you would use to make your cell model. Which cell structures did you include? Why did you choose the item to represent each structure?



# Careers Profiles

# MEDICAL LAB TECHNOLOGIST

How would you like a job that saves people's lives? A job that helps people get better from sickness? Most people think only doctors and nurses have jobs like this, but there's another important life-saving job—that of a lab technologist.



Figure 3.37 Technologist testing a blood sample

When doctors see a sick patient, they sometimes have an idea of what the problem is from the symptoms, but they are not totally sure. To find out exactly what's wrong, the doctor sends the patient's specimen (such as a blood or urine sample) to a medical laboratory. At the medical laboratory, a lab technologist takes the specimen and tests it. Infections, such as strep throat, and many serious diseases are often hard to identify without a lab technologist's help.

- 1. How does a medical lab technologist contribute to human well-being?
- 2. Does being a lab technologist seem like an interesting career? Why or why not?

# SECTION REVIEW

# **Assess Your Learning**

- Imagine you have just eaten a meal containing the sugar, glucose. Using a concept map or flowchart, plot the path and roles for glucose in the body. You should be able to include almost all of the body systems you have studied in your flowchart.
- 2. a) Which two body systems work together during the process of gas exchange?
  - b) Describe how they work together in this process.
  - c) Is this an example of interaction? Why or why not?
- 3. What is the difference between an artery and a vein?
- 4. Draw and label the parts of the heart.
- 5. If you were lost in the desert and you hadn't had any water for a day, how would your body respond?
- 6. What is the role of skin in your excretory system?
- 7. What is the difference between the somatic nervous system and the autonomic nervous system?
- Are there any body systems that a person could live without? Give reasons to explain your answer.



# THE NATURE OF SCIENCE

Scientific ideas help organize, interpret, and explain findings. Review the information you have learned in this section.

- 1. Models are often used in interpreting and explaining observations. What models have you been introduced to that help explain how parts of the body work?
- 2. Scientific language is precise and uses specific terms. What are some new terms you have encountered in this section?
- 3. Why do you think these terms are necessary?



4.0

Scientific investigation leads to new knowledge about body systems and new medical applications.

# **Key Concepts**

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

health and environmental factors

# **Learning Outcomes**

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

- describe examples of research into how the body does or doesn't work
- understand how research has led to improvements in health and nutrition
- describe factors that affect different body systems



Surgeons rely on scientific knowledge about body systems.

Scientific research and modern medicine have improved many aspects of our lives. Humans are now living longer and leading healthier lives than ever before. Even those people who, against the advice of their doctors, continue self-destructive activities—such as smoking cigarettes—can do so knowing what the health effects of this decision may be. Others, who decide to live healthier lifestyles, have the benefit of sound advice on how to maintain good health through proper diet, exercise, and lifestyle choices.

# 4.1 Developing a Theory for Disease

Have you ever fallen off a bike and received a wound that needed attention in the hospital? Have you ever cut yourself with a knife so that you needed stitches? Have you or has anyone you know ever seriously broken a bone?

If you answer "yes" to any of these questions, consider yourself lucky. Why? Because you're alive. If you had lived before the mid-1800s, you would probably have died from your injury. In those days, 50% of people who had some kind of punctured wound and went to the hospital died of infection. That means that if you and your friend lived before that time, and you both cut yourselves and went to the hospital for treatment, the chances were that one of you would be dead within a week!

# THE FIRST VACCINE

That's quite a startling fact. Doctors long ago were really quite helpless when it came to treating their patients for some illnesses and injuries.

During the 1600s and 1700s, people in Europe and the rest of the world suffered and died from a disease called **smallpox**. Victims broke out in a rash filled with pus (called pox). They developed chills, high fever, nausea, and muscle aches. Up to 40% of those infected died and many of the survivors were left blind.

Then in the late 1700s, Edward Jenner, an English country doctor, noticed an interesting coincidence. Milkmaids who had had

cowpox, a mild and related form of smallpox, rarely got smallpox. He concluded that contracting the milder cowpox made them immune to the more serious smallpox. Jenner began infecting people with cowpox on purpose. These people became immune to smallpox. Jenner had created the world's first vaccine.

Figure 4.1 Edward Jenner (1749–1823) discovered how to prevent smallpox. He called his procedure vaccination, from the Latin word vacca, which means "cow." Here he is pictured vaccinating a small boy.



### The End of Smallpox

The last recorded case of smallpox occurred in Merca, Somalia, in 1977. The World Health Organization has considered the disease eradicated from the planet since 1979.





#### WATCH OUT FOR GERMS!

But what caused disease and infection? That's what doctors and scientists couldn't figure out. Jenner and others tried for nearly 90 years to come up with at least one other vaccine that would prevent disease. They failed, because they just didn't understand what they were dealing with.

The French chemist, Louis Pasteur, did. He was the first person to identify living micro-organisms (organisms too small to be seen with the naked eye) as "germs." He suggested and later proved that germs were the cause of most infectious diseases. Using his knowledge, he found a way to prevent and cure many common but deadly diseases.

# Louis Pasteur and the Beginning of Modern Medicine



Figure 4.2 Louis Pasteur (1822–1895) was originally a chemist. His first "great" discovery was finding out why wine and beer spoiled. He proved that yeast was actually a micro-organism and not a chemical, which is what people had thought. More importantly, he showed that it was a microorganism floating in the air that made the wine and beer go bad.

Figure 4.3 Pasteur realized he needed to kill the harmful micro-organisms in wine and beer to keep them from spoiling. His solution was simple but effective. He heated the wine and beer to 60°C, which killed the microorganisms but didn't change the taste. This process of heating food became known as pasteurization. It is still used today for fruit juices, milk, wine, and beer.

Figure 4.4 Pasteur worked tirelessly to produce vaccines and cures for cholera, anthrax, swine erysipelas, and rabies. Now each year, pet owners take their dogs and cats to veterinarians for annual rabies vaccination shots.

#### CLEANING UP THE GERMS

Pasteur's discovery of germs led to other discoveries in medicine. For example, Joseph Lister (1827–1912) was an English surgeon. Many of his patients died of infection even though their operations were successful. He thought that these infections were caused by Pasteur's "germs" entering the surgical wounds. So he introduced the practice of cleanliness and sterilization to medical procedures. Before Lister, doctors and nurses never thought about keeping themselves or their patients' wounds and incisions clean.

# Inquiry Activity

# Materials & Equipment

- · clean test tubes
- · labels for test tubes
- eyedroppers
- · protective gloves
- · standard solution
- · phenol red solution (



# TRACKING DOWN DISEASE

#### Before You Start ...

Long before modern medicine, people realized that certain diseases were spread from person to person. It was important then to find the source and isolate the person or persons until the disease had run its course.

This simulation models how an infectious disease might spread in a group. Your job is to find out which of your classmates is the source of the disease.

How difficult is it to find the source of a disease?

### The Hypothesis

Form a hypothesis based on the question.







- 1 Write your name on a label to place on your test tube.
- 2 Don't allow the solutions to touch your skin. Remember, you are simulating an infectious disease!
- 3 Obtain from your teacher 5 mL of a standard solution in a test tube.
- 4 Label your test tube.
- 5 Choose a partner. Put one drop of your solution into your partner's test tube. Have your partner add a drop of solution to your test tube. Gently shake the test tube to mix the solution.



Figure 4.5 Step 5



- · If your test tube turned red, you are disease-free!
- · If your test tube turned yellow, you are infected!

# Collecting Data

- 6 Record the name of your partner in your notebook.
- Repeat steps 5 and 6 with two other partners.
- 8 Add 1 drop of phenol red solution to your test tube. Record the colour of your solution.

# Analyzing and Interpreting

- 9 What colour was your test tube? Were you infected or are you disease-free?
- 10 If you were infected, from whom did you get the disease? How many in the class became infected?
- 11 As a class, try to track the transmission of the disease. Who was its source?

# Forming Conclusions

12 What inferences can you make about the way diseases are spread?



Figure 4.7 Early expeditions to find the Northwest Passage took months and sometimes even years.

#### NUTRITIONAL RESEARCH

When early sailors went on voyages of discovery to find the Northwest Passage, the only foods they could take with them were those that would not spoil on the long journey: salt beef, hard bread, dried peas, and cheese. After months at sea, many sailors developed scurvy. They had sores that would not heal, bleeding gums, loose teeth, and an unsteady gait. But in 1747, a British naval surgeon called James Lind successfully treated sailors by feeding them oranges and lemons. It wasn't until very much later that the cause of scurvy was discovered: a lack of vitamin C in the diet.

By studying various diseases such as heart and liver disease, researchers have determined that diet affects the human body. Too much of some foods and too little of others can interfere with the proper functioning of all the body systems. Canada's Food Guide has been developed to show you how much of certain foods you should eat on a regular basis.



Figure 4.8 Canada's Food Guide

# CHECK AND REFLECT

- In your opinion, how important is scientific research in solving problems of human health? Give reasons to justify your answer.
- 2. How does the smallpox vaccine work?
- 3. Describe how Joseph Lister contributed to human health.
- 4. Give an example of how nutritional research on cells, organs, or body systems has brought improvement to human health.

# 4.2 Factors That Affect the Healthy Function of Body Systems

You are outside skating on a frozen pond when all of a sudden your friend stops. He is doubled over and is having trouble breathing. You skate over and ask him what's wrong, but he is having trouble getting enough air to tell you. What do you do?

Luckily, you know your friend has asthma. You notice that he has dropped his inhaler. You pick up the device and give it to him immediately. After taking the medication, your friend feels weak and tired, but he's all right.

Asthma is a condition where the airways become narrowed temporarily. About half a million Canadian children under the age of 19 have asthma. An asthma attack can be triggered by a variety of environmental factors including colds, allergies, dust, cold air, pets, and pollution.



Figure 4.9 Asthma can be managed with medication.

#### Give it a TRY

#### ACTIVITY

#### **IMITATING ASTHMA**

You've just read about the effects of asthma. Now you will have a chance to know what having asthma feels like. Breathe normally, first through your nose, then through your mouth. Observe what it feels like. Then, put one end of a drinking straw into your mouth and pinch your nose so that you cannot breathe through it. Now try inhaling air through the straw for 10 s.

 How did your breathing pattern change when you breathed through the straw? Did you feel short of breath?

### Caution!

Do not perform this activity if you have any medical condition that could be worsened by temporary shortness of breath.

#### FACTORS THAT AFFECT HUMAN HEALTH

Scientific research has shown that many factors affect the health of your cells and, therefore, your body systems. These factors include:

- $\bullet$  diseases or conditions that you have inherited from your family
- sensitivity to environmental conditions, such as smog, or specific substances such as pollen, dust, or dairy products
- how you respond to physical, emotional, and psychological stresses
- how you treat your body in general (for example, the choices you make about diet, exercise, sleep, and whether or not to smoke)

### infoBIT

### How Old Are You?

Smokers are more likely to show signs of aging prematurely and get deeper wrinkles than non-smokers.

# **Making**Activity

# THE SCIENCE OF HEALTH

#### The Issue

What is the best way to maintain the health of our body systems?

### Background Information

- 1 To make your recommendations, you need more information. Working in groups of three, have each group member choose one of the following body systems to investigate further:
  - a) circulatory system
  - b) digestive system
  - c) respiratory system
- 2 Use the guidelines below to focus your investigation. Record the process and results of your research with notes, diagrams, flowcharts, tables, and graphs. (Some of these may not apply in all cases. Use your judgment to choose the best methods for recording your data and information.)
  - a) List the system's main organs, tissues, and cells. Give examples of key features or specializations of the cells that contribute to the healthy functioning of the system.
  - b) List other body systems that support this system. Briefly describe how they support it.
  - c) List at least three examples of scientific developments that have improved our understanding of this system and its cells. Briefly describe each example.
  - d) Describe at least three ways that we have used our new understanding to improve or safeguard human health.
  - e) Identify at least two helpful and two harmful substances that alter the way the cells of this system function. Describe the impact of these changes on its tissues and organs. Include possible effects on other body systems and on the body as a whole.
- 3 Share your discoveries with other members of your group. Consult with other groups as well. You may have gathered information that they can benefit from, and they may have done the same for you.

### **Support Your Opinion**

- 4 What do you think is the best way to maintain your body's health? Develop a plan and outline your recommendations. For example:
  - Describe the kind of exercise you would like to maintain for your body and body systems.
  - · Write up a balanced diet plan that provides you with the nutrition you need.
  - · List the things you can do to reduce stress and enjoy each day.
- 5 Think back to when you worked in your group. What did you do well as a group? What would you improve upon next time?



Figure 4.10 Maintaining a healthy body

#### FACTORS AFFECTING THE RESPIRATORY SYSTEM

You have already read that asthma is a disease that affects the proper functioning of the respiratory system. The decision to smoke is an example of a behaviour that can influence how your respiratory system functions.

#### The Contents of Cigarettes

Because cigarettes have such huge effects on the respiratory system, it's worth taking a closer look at them. There are over 4000 different chemicals in a cigarette. Tar, carbon monoxide, and nicotine are the most destructive. Tar is a dark, sticky substance that forms as a cigarette burns. When a smoker inhales, the tar in the smoke settles on the surface of all the organs of the respiratory system. There are small hair-like projections called cilia on the lining of the respiratory tract. Their function is to move mucus from the lungs and nasal passages to the throat. Research has shown that tar makes the cilia clump together and prevents the movement of mucus.

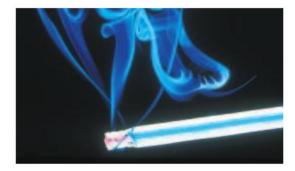


Figure 4.11 Smoke from a cigarette contains over 4000 chemicals.

Carbon monoxide is a colourless, odourless gas that is released when a cigarette burns. In the gas exchange process, carbon monoxide gets absorbed by red blood cells instead of oxygen, so smokers then get less oxygen into their bodies. This causes their hearts to beat faster.

Another chemical found in cigarettes is **nicotine**. Nicotine is a drug that speeds up the heart, and raises the blood pressure. Nicotine is also addictive. Even though tar is more damaging to the body, it's nicotine that keeps smokers smoking.

#### **Smoking-Related Diseases**

Smoking can cause a number of serious respiratory diseases including bronchitis, emphysema, and lung cancer. Bronchitis occurs when mucus builds up in the bronchi and causes them to become narrower. People with bronchitis have a hard time breathing. Infections and permanent damage to the lungs can occur if left untreated. Smokers are five to ten times more likely than non-smokers to develop bronchitis.



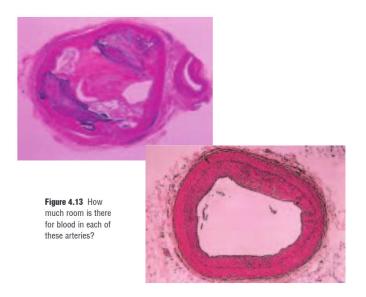
Figure 4.12 A healthy lung and a damaged lung caused by smoking

Emphysema occurs when the smoke from a cigarette damages lung tissue. The damaged tissue is unable to function properly and breathing becomes difficult. People with emphysema have trouble breathing and are always short of breath. The damage is permanent.

Of the 4000 chemicals in a cigarette, 40 are known to cause cancer. When people develop lung cancer, a tumour or cancerous growth starts to form in the lungs. As the tumour grows, it takes up space in the lungs and makes it harder for the person to breathe. Unfortunately, these tumours are very difficult to locate early on. As the cancer spreads, it becomes much harder to treat. In 1999, 17 400 Canadians died of lung cancer.

#### FACTORS AFFECTING THE CIRCULATORY SYSTEM

Diet can affect the healthy functioning of the circulatory system. One reason why French fries and chocolate taste so good is that they contain lots of fats. (Recall that oils and fats together are called lipids.) When you eat these fatty foods, these fats are turned into cholesterol, a lipid that is found in the blood. The more fat you eat, the more cholesterol enters the bloodstream. Over time, it builds up on the walls of arteries. Look at Figure 4.13. Notice how much narrower the diameter of the artery on the left is.



This build-up of cholesterol in the arteries is called atherosclerosis. As the arteries become narrower, the heart has to pump harder to move blood through them. If the arteries that feed the heart become blocked, the heart muscle can't get enough oxygen to do its work. This can lead to a heart attack. During a heart attack, heart cells begin to die through lack of oxygen. If people with heart attacks aren't treated immediately, they can die. Sometimes hearts that have been damaged by heart attacks or other diseases can be replaced with heart transplants.

#### **PESEARCH**

#### Hypertension and Strokes

High blood pressure, or hypertension, is often called "the silent killer." Find out more about hypertension and why it can be so dangerous.

Another factor that can affect the circulatory system is having a stroke. Find out what strokes are and how they can be prevented.

#### FACTORS AFFECTING THE DIGESTIVE SYSTEM



Figure 4.14
Stomach ulcers can be very painful.

There are a variety of factors that can affect the healthy function of the digestive system. A common problem of this system is **ulcers**. They are painful sores of the stomach lining. For a very long time, it was believed stomach ulcers were caused by stress. When a person was under stress, the stomach wouldn't produce enough mucus to protect the lining of the stomach. The gastric juice would then attack the stomach lining causing a painful sore. Now researchers have found that stomach ulcers are caused by a bacteria called *Helicobacter pylori* (or *H. pylori*). Unlike other bacteria you swallow with your food, *H. pylori* is not killed by the strong acidic digestive juices. When this bacteria is present in the stomach, it can break down the mucus layer in the stomach wall. For some reason not yet understood by researchers, not everyone who is infected with

H. pylori gets a stomach ulcer. Because the cause has been found, the treatment is quite straightforward: taking antibiotics to kill the bacteria.



Figure 4.15 A computer model of *H. pylori* 

#### CHECK AND REFLECT

- Give an example of research involving the study of functional or dysfunctional body systems.
- 2. What are three diseases caused by smoking?
- 3. What is atherosclerosis?
- 4. What is a stomach ulcer and what causes it?
- 5. What is one thing you learned in this subsection you didn't know before?

### SECTION REVIEW

#### **Assess Your Learning**

- Identify and describe two environmental factors that can affect the health of your cells, organs, or body systems.
- 2. Name three people whose research led to our early understanding of diseases and how they can be prevented. What did each of those individuals discover?
- 3. What is pasteurization? Describe a food that has to be pasteurized.
- 4. Why is it important to know how nutrition affects human health?
- Describe three chemicals found in cigarettes and explain their effect on the human body.





### THE NATURE OF SCIENCE

Scientific knowledge results from the shared work of many people over time. Scientific knowledge also changes as new evidence is gathered.

- 1. What scientific knowledge did Jenner discover, and what evidence did he interpret?
- 2. How did Pasteur's work build on Jenner's discoveries?
- 3. Why did Lister need to know about Pasteur's work in order for him to make his discoveries?



## Do Energy Bars Boost Performance?

#### The Issue

Out training for that next track-and-field or triathlon event? Do you wish there were a way you could boost your performance to give you that edge over the competition? Why not reach for the latest in athletic food supplements, an energy bar! You've seen the ads. They claim these bars give you a superhuman burst of energy, allowing you to run faster, jump higher, and throw farther. As a result, athletes are gobbling up energy bars at an unprecedented rate. But are the claims true? Can you believe everything you read? Do energy bars really work?

### Should you eat energy bars to boost your athletic performance?

Yes, you should.	No, you shouldn't.
Energy bars are loaded with carbohydrates. Your body uses carbohydrates as fuel to do strenuous activities, like running a marathon. If you run out of carbs during an athletic event, your performance drops. Eating more carbs boosts your performance.	Other foods like rice, pasta, and bread contain carbohydrates. Recent scientific studies have shown that a bowl of oatmeal provides the same amount of carbohydrate energy as a typical energy bar.
Energy bars have been endorsed by famous athletes. If famous athletes are endorsing these bars, they must boost your performance.	Energy bars are expensive. A bowl of oatmeal costs a lot less than an energy bar.
Energy bars are convenient. An energy bar fits neatly into your pocket so that you can take it with you and eat it on the go. You could not do this with a bowl of oatmeal.	There is no need for energy bars if you exercise for only a short time. The body can store enough fuel from carbohydrates to give you about two hours of non-stop, strenuous activity.



#### Go Further

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

- Look on the Web: Check out energy bars and nutrition on the Internet.
- Ask the Experts: Try to find an expert such as a nutritionist or exercise physiologist. Experts can be found in all sorts of places: your community's health department, universities, hospitals, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about energy bars or nutrition
- Check Out Scientific Studies: Look for scientific studies about exercise and sports nutrition.

#### **In Your Opinion**

Write a memo to your coach or local athletic association stating your point of view, and don't forget to support your opinion with facts.

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#### UNIT SUMMARY: CELLS AND SYSTEMS

#### **Key Concepts**

#### 1.0

- · organisms
- cells
- · organs
- structure and function
- systems
- · response to stimuli

#### Section Summaries

### 1.0 Living things share certain characteristics and have structures to perform

- All living things share certain characteristics. They are made of cells, require energy, grow and develop, respond to their environment, reproduce, and have adaptations for their environment.
- Organisms have structures that allow them to do functions needed to keep them alive.
   These structures can be very different in different plants and animals. The structures can be slightly different in closely related plants and animals.
- Most animals have organs. Different organs that work together to perform a common function are organized into organ systems.

#### 2.0

- cells
- tissues
- organs
- · structure and function

#### 2.0 Cells play a vital role in living things.

- The microscope is an important scientific tool. It allows scientists to see extremely small structures, such as cells.
- The cell is the basic unit of life, and all organisms have at least one cell. Cells have structures in them called organelles, which carry out specific functions. The cells of plants and animals are similar, but plant cells have some organelles that animal cells don't have.
- Organisms can be made of a single cell or many cells. Multicelled organisms have specialized cells.
- Substances move in and out of cells by diffusion and osmosis. Diffusion is the movement of particles from areas of high concentration to areas of low concentration. All cells have a selectively permeable membrane. Diffusion of water through this membrane is called osmosis.
- In multicelled organisms, cells combine to form four tissue types in animals and three tissue types in plants. These tissues combine to form organs.

#### 3.0

- cells
- · organs
- tissues
- structure and function
- · response to stimuli
- systems

#### 4.0

 health and environmental factors

### 3.0 Healthy human function depends on a variety of interacting and reacting systems.

- Organs in organ systems all interact to perform certain functions, such as digestion, circulation of the blood, breathing, getting rid of wastes, and responding to stimuli.
- All these organ systems interact to keep the body functioning normally. All the systems react to internal stimuli in the body. The nervous system monitors external and internal stimuli and responds to them.

### 4.0 Scientific investigation leads to new knowledge about body systems and new medical applications.

- Research into diseases such as smallpox has led to an understanding about what causes diseases. These discoveries have led to improvements in health and nutrition.
- Human health is affected by a variety of factors. Any of these factors can lead to the poor health of cells, organs, or organ systems.



#### **Getting Started**



Experiments offer many opportunities for making new discoveries for yourself. In this activity, you will plan and carry out an experiment based on your own "what if" questions. Using a unicellular organism, you will try to determine what its basic needs for survival are. You may wish to refer to Toolbox 2 for further information on planning an experiment.

#### Your Goal

To determine what ways unicellular organisms meet their basic needs.

#### What You Need to Know

This activity involves asking your own questions about unicellular organisms, planning your own experiments to investigate one of these questions, and drawing your own conclusions from them. Use the question, "In what ways do unicellular organisms meet their basic needs?" to help you brainstorm all the questions you have about the lives and behaviours of unicellular organisms. Then, review your questions to see which one intrigues you enough to investigate further. Do you see opportunities for experiment that could help you answer your questions?

#### WHAT IS NEEDED?



#### Steps to Success

- 1 Select a question and write a hypothesis to answer it. Then, plan an experiment to test your hypothesis.
- 2 Make sure your experiment is a fair test of your hypothesis. How will you know?
- 3 Decide what equipment and materials you will need. Ask your teacher what live unicellular organisms are available.
- 4 Write up the procedure you'll follow to perform your experiment.
  Obtain your teacher's approval, and carry it out.
- 5 Decide how you will record your results in a clear, meaningful manner. Examples include diagrams, data tables, graphs, and flowcharts. The method or methods you

use will depend on the kind of experiment you design.

- 6 Explain how you decided on the experiment you planned. Which variable did you consider changing? Did you have a control?
- 7 What do the data you collect mean? Are there other ways to interpret them?

#### Caution!

Be careful when handling microscopic organisms. Wash your hands thoroughly when you've finished this activity.

#### How Did It Go?

Based on the experiment you planned and carried out, write a summary statement that answers a question that you have asked. Remember to use your data and observations to support your answer



### UNIT REVIEW: CELLS AND SYSTEMS

#### **Unit Vocabulary**

 Create a mind map that illustrates your understanding of the following terms.

understanding of the five cell diffusion organ multicellular organelle osmosis tissue selectively permeable system

unicellular

 Explain the following terms: enzyme, peristalsis, arteries, atrium, capillaries, digestion, nervous system

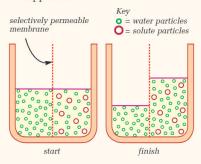
#### **Check Your Knowledge**

1.0

- 3. What is an organism?
- 4. Are your fingernails a living thing? Why or why not?
- 5. Name three different structures animals use for the same function.
- What is an organ? Name six different organs.

2.0

- 7. a) Which of these terms do scientists use to describe the most basic unit of all living things: tissues, organs, cells, body systems?
  - b) Explain how the other three terms are related to the one you chose in a).
- a) Draw a labelled diagram comparing a typical plant cell and a typical animal
  cell
  - b) Explain any differences between the cells you drew.
- 9. Different kinds of specialized cells have different shapes. They often have different organelles, or different numbers of them. For example, the cells that make up muscles have many mitochondria, while the cells that make up skin have very few. Infer a reason why.
- 10. a) In the illustration below, which particles can move through the selectively permeable membrane? Explain why.
  - b) Is this an example of diffusion or osmosis? How do you know?
  - c) Look closely at this illustration. What do you notice? Why do you think this happened?



Unit Review

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#### UNIT REVIEW: CELLS AND SYSTEMS

3.0

- 11. a) What do these terms have in common, and how are they different: artery, capillary, vein?
  - b) The layer of muscle tissue that surrounds your arteries is much thicker than the layer that surrounds your veins. How does this difference in structure suit the function of arteries and veins?
- 12. Agree or disagree with this statement, and give two examples to support your decision: The organs of humans interact.
- 13. Infer from the following information which person could have emphysema.
  - a) Marta is breathing (inhaling and exhaling) 12 times a minute. She is filling her air sacs with 4200 mL of oxygen-rich air each minute.
  - b) Douglas is breathing 20 times a minute. He is filling his air sacs with 3000 mL of oxygen-rich air each minute.
  - c) Cathy is breathing 30 times a minute. She is filling her air sacs with 1500 mL of oxygen-rich air each minute.
- **14.** How does the structure of a villus help the small intestine absorb nutrients?
- 15. You are playing soccer and you are running to kick the ball. What parts of the brain are active, and what are they doing?

4.0

- 16. What was Pasteur's contribution to our understanding of disease?
- 17. What is scurvy?
- **18.** List some of the factors that can affect your health.
- 19. What is tar, and how does it affect the health of your cells?

#### **Connect Your Understanding**

- 20. Explain how the four sections that you have explored are related to one another. Your explanation can be in the form of a mind map, an illustration, or a written summary.
- 21. When scientists think about the possibility of life on another planet, they want to know if that planet has water. In fact, scientists find it hard to imagine life without water. Why might that be?
- Explain the similarities and differences between a cell organelle and an organ system.
- 23. Meat and fish are sometimes preserved from spoiling by salting them or by placing them in a salty solution. What effect do you think the salt has on these foods?
- 24. Choose three types of cells in your body. For each, describe how it contributes to your health.
- 25. Your friend has a bad cold, and has been coughing and sneezing around you. Several days later, you develop a cold. Explain how this could have happened.

- 26. Identify at least two things that you can do to improve your health. Describe the impact and effect of each of your choices.
- 27. Based on what you have learned, give two examples of ways that research has improved human health.
- 28. Give two examples of substances that change the way cells function. Describe their effect, and the consequences of their effect.

#### **Practise Your Skills**

- 29. Your classmate is viewing a specimen using high power and is about to refocus using the coarse adjustment knob. What would you recommend your classmate do and why?
- 30. A neighbour has brought in a water sample from a nearby pond. He would like you to check the sample for any microscopic organisms. Describe how you would prepare the sample.

#### **Self Assessment**

- Describe one idea that you learned in this unit you would like to explore further.
- 32. When you did activities in groups, what did your group do well? What did your group need to improve?
- 33. During this unit, what did you learn about the role, contributions, and limits of science and technology?
- 34. Do you think that the choices you make about your lifestyle affect the environment?

### Focus

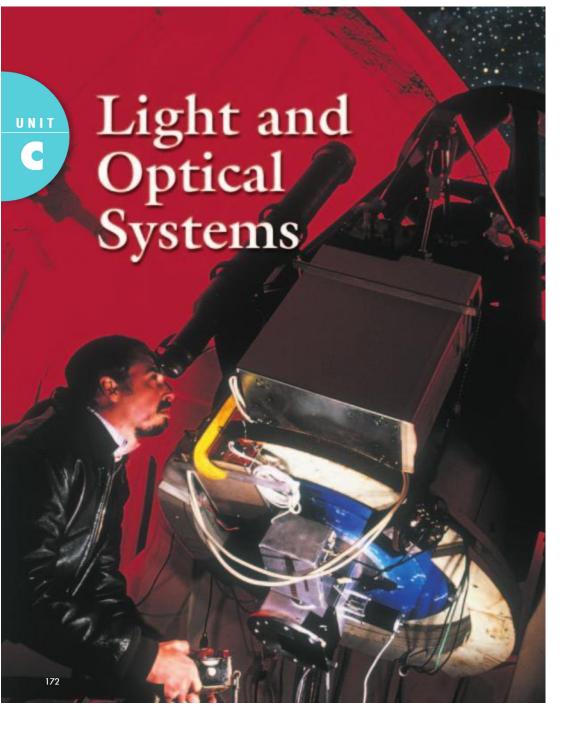
#### THE NATURE OF SCIENCE

In this unit, you have investigated the nature of science in relation to cells and systems. Consider the following questions.

- 35. Turn back to the Focus on the Nature of Science on page 83 of this unit. Use a creative way to demonstrate your understanding of one of the questions.
- **36.** Describe the process of doing a scientific investigation. What are the steps involved?
- 37. Do you think we know everything there is to know about cells and organ systems? Explain your answer.

Unit Review

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In this unit, you will cover the following sections:

Our knowledge about light and vision comes from explanations, inventions, and investigations.

- 1.1 The Challenge of Light
- 1.2 Optical Devices

#### Light behaves in predictable ways.

- 2.1 Light Travels in Rays and Interacts with Materials
- 2.2 The Law of Reflection
- 2.3 Reflecting Light with Curved Mirrors
- 2.4 Transparent Substances Refract Light
- 2.5 Lenses Refract and Focus Light

### Light is part of the electromagnetic spectrum and travels in waves.\*

- 3.1 The Wave Model of Light
- 3.2 The Electromagnetic Spectrum
- 3.3 Producing Visible Light
- 3.4 The Colours of Light

### Eyes and cameras capture images using the properties of light.

- 1.1 Image Formation in Eyes and Cameras
- 4.2 Other Eyes in the Animal Kingdom
- 4.3 Image Storage and Transmission

<sup>\*</sup> Extension material

# Exploring

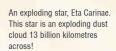
#### **OPTICAL WONDERS**

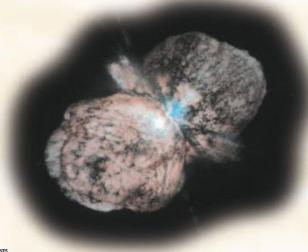




What do the Hubble Space Telescope (left) and the capsule endoscope (right) have in common?

Have you ever wanted to know what a star looks like up close? How about seeing inside the human body? Our eyes can't see details of distant stars or through human flesh. However, with a little help from optical devices, you can see amazing images from across the galaxy or inside a living, breathing human being.



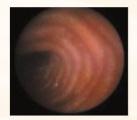


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Unit C: Light and Optical Systems

The optical devices on the previous page were designed to overcome the limitations of our eyes. The Hubble Space Telescope was put into orbit by the space shuttle. It has a large mirror to collect and focus the light from distant stars. It can produce much higher quality images than ground-based telescopes because light does not have to travel through the interference of Earth's atmosphere. This unique telescope continues to send never-beforeseen images back to astronomers on Earth.

The capsule endoscope is a new optical invention that is swallowed like a pill. This small package has its own light source and a miniaturized video imager that can transmit pictures by radio signal to a video recorder outside the body. The doctor can then see high-quality images of the inside of the patient's digestive tract on a television screen.



The inside of a person's stomach as seen by a capsule endoscope.

#### Give it a TRY

#### ACTIVITY

#### TWISTED RAYS

Make a strip of paper about 2 cm wide and about 20 cm long. Using a black marker, draw a line of arrows one after the other along the length of the paper strip. All the arrows should point the same way. Fill a glass or beaker with water and place it in front of you. Then hold the strip about 15 cm behind the glass with the arrow side facing you. Look through the glass and move the strip from side to side.



- · What do you see?
- · Discuss with your classmates possible explanations for what you see.

### Focus On

### THE NATURE OF SCIENCE

As you work through this unit, you will be reading and doing activities about light and optical systems. At the end of the unit, there is a project that will require you to apply the principles of light and optics. Use the following questions to help guide your reading and study.

- 1. What do we know about the nature of light?
- 2. What technologies have been developed that use light?
- 3. What principles of light do these technologies show?

Exploring

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1.0

Our knowledge about light and vision comes from explanations, inventions, and investigations.

#### **Key Concepts**

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

- microscopes and telescopes
- contribution of technologies to scientific development

#### **Learning Outcomes**

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

- identify challenges in explaining light and vision
- analyze how microscopes, telescopes, and other optical devices use the properties of light
- describe how the development of optical devices contributed to other discoveries in science
- investigate light beams and identify phenomena that show the nature of light



Have you noticed that you can't see a thing in a completely dark room? Why is light necessary for vision? Why can your eyes see what is directly in front of you but not what is around a corner? The answer is in the form of energy that is almost always around you. It's light! Our eyes are able to see an object only if light is emitted from the object or bounces off it. Since light travels in straight lines from its source, there must be a direct path for light to strike your eyes to make vision possible. The way vision works is just one of the interesting features of the nature of light.

There are many natural events that make us curious about light. How is a rainbow formed? On hot days, why do roads appear to be wet? Why does the sun seem brighter at noon than at sunset? People have been studying light for thousands of years to try and explain these and other aspects of light.

## 1.1 The Challenge of Light

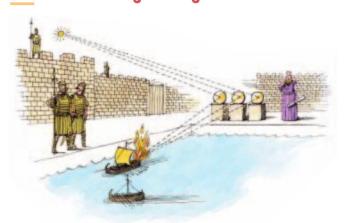


Figure 1.1 Archimedes' plan to destroy the Roman fleet using light reflected off mirrors

Since the earliest times, people have put light to work. Mirrors and lenses were used in China and ancient Greece. The Greek scientist Archimedes even developed a plan to reflect light from mirrors to burn enemy ships in the Syracuse harbour, Figure 1.1.

But even though the Greeks and Chinese used light, they didn't have a clear idea about what light was or how we experienced light. Over the centuries many people have asked questions, have done experiments, and have tried to explain how light works. Explaining light properly has taken centuries, and even now, scientists still have questions about light.

#### EARLY LIGHT IDEAS

In ancient Greece, many people studied light. In the sixth century B.C., a mathematician called Pythagoras tried to explain how we see light. He thought light consisted of beams. These beams came from a person's eyes in straight lines, and the sense of sight occurred when these beams touched the objects a person was looking at.

There was a problem with this theory. If it were true, then we would be able to see in the dark. In spite of this problem, Pythagoras's theory was accepted for many years.



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Years Away
Astronomers use a
unit of measurement
called a light year.
But it's not a unit of
time. It actually
measures the
distance that light
travels in space in
one year, about
9 460 500 000 km!

Figure 1.2 How Pythagoras viewed vision

Continued on page 180 →

### Inquiry **Activity**

Figure 1.3 Station A

#### LIGHT UP YOUR LIFE

#### Before You Start ...

Working in groups, you will experiment with light. There will be six stations to visit. It doesn't matter in which order you visit the stations.

What are some properties of light?

#### Procedure 🕕



At each station, do the investigation and write down what you observed about light.

- · Put three coloured filters: blue, red, and green, separately over three light sources of equal brightness (three flashlights or ray boxes). Shine each coloured light source at a white screen.
- · Overlap (mix) two different coloured lights together in different combinations. What happens?
- · Keep a chart of your combinations and results.
- · Lastly, overlap all three coloured lights together on the screen. What do you observe?

#### Station B

· Look at your image in a flat mirror. If you step back from the mirror, how does your view change? Can you see more or less of yourself?

#### Station C

- · Look at a sheet of graph or lined paper using a convex lens (thicker in the middle than at the edges) and a concave lens (thinner in the middle).
- · What happens to the distances between the lines when you move each lens further away from the paper?
- · What happens when you move each lens closer to the paper?



Figure 1.4 Station C

Unit C: Light and Optical Systems

#### Station D

- This is a demonstration station. Your teacher will turn the lights off and shine a laser through a container filled with water mixed with a little cornstarch.
- As your teacher holds the laser below the waterline (Figure 1.5, left) and shines
  the laser through the water at different angles, observe the laser and the light
  beam in the water. What do you notice?
- If your teacher then holds the laser above the waterline (Figure 1.5, right) and shines the laser through the water at various angles, do you notice anything different?

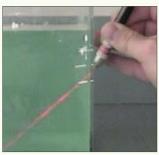




Figure 1.5 Station D

#### Station E

- Shine a light source through a glass, tissue paper, and a book.
- · What happens to the light in each case?
- · Shine a light through other materials.

#### Station F

- Using solar-powered devices, can you find a way to show that light is energy?
- Try changing the amount of light that reaches the devices to see how the level of power varies.





#### Caution!

Lasers are used in grocery store scanners and CD players, but they are very dangerous. Make sure you are not in the path of the laser beam.
Laser light can permanently damage your eyes.



Figure 1.6 Station E

#### **More Light Ideas**

Other Greeks looked into how light worked. Euclid discovered that when you shine a beam of light onto a flat mirror, the angle between the incoming beam and the mirror is equal to the angle between the reflected beam and the mirror. He also suggested that light travels in straight lines. In about the first century A.D., the astronomer Ptolemy described how light beams bend when they go from air to glass.

#### LIGHT IDEAS IN THE MIDDLE AGES

In about A.D. 1000, a great Arab scientist called al-Haytham took up the study of light. He studied the work of Euclid and Pythagoras and wrote a book on optics. He was the first to accurately describe how vision worked. He showed that light bounces off objects and then travels to the eye, showing that light does not come from the eves but rather light travels to the eyes. Because al-Haytham's explanation was so detailed, Pythagoras's theory was abandoned. Al-Haytham studied many other properties of light, and tried to explain how rainbows were formed but didn't have much success.



Figure 1.8 al-Haytham's diagram of the eve

#### NEWTON'S LIGHT EXPERIMENT

The English scientist Sir Isaac Newton also was fascinated by light, and he was especially interested in the colours of a rainbow. A French thinker called Descartes had proposed that sunlight was somehow changed or modified to form coloured light. By shining a light through a prism, Newton showed that white light is actually a mixture of different colours of light. As the light passed through the prism, it split up into many separate colours. Passing the rainbow colours through a second prism, Newton showed that the separate colours combined back into white light.

#### A SPEEDY DISCOVERY

All of the early scientists understood that beams of light travelled, but they didn't know how fast they travelled. In the past, people didn't have instruments to record very high speeds, but they thought that light must travel extremely fast. The first reasonably accurate measurement was made by Ole Romer in 1676. His measurement was refined in the 1920s by a scientist named Albert A. Michelson. He placed two mirrors on the tops of two mountains in

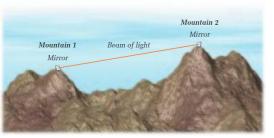


Figure 1.9 Timing a beam of light as it travelled from one mountain to another was the first accurate measurement of the speed of light.

California and measured the distance between the two mirrors, which was 35.4 km. He then sent a beam of light from one mirror to the other. He used extremely accurate timing devices to measure how long it took the beam to reach the second mountain. By dividing the distance by the time, he calculated the speed of light as it travels through Earth's atmosphere to be 299 798 km/s.

#### SOME PROPERTIES OF LIGHT

Over the years, many different people have contributed to our knowledge of light and how we perceive it. We now know about some of its basic properties.

- · Light travels in straight lines.
- Light can be reflected.
- Light can bend.
- · Light is a form of energy.

As you work through this unit, you will encounter these and other characteristics of light and study them in more detail.

#### CHECK AND REFLECT

- 1. What did Ptolemy discover about light?
- 2. What was Pythagoras's theory of how we see?
- 3. What was the problem with Pythagoras's theory?
- 4. What did al-Haytham try to explain?
- 5. Based on Michelson's measurement of the speed of light, if the distance between the sun and Earth is 149 596 000 km, how long does it take light to travel from the sun to Earth?

#### **TESEARCH**

#### How Fast?

Michelson found out how fast light travels through Earth's atmosphere. Find out how fast light travels in other substances such as water, space, and other materials.

## 1.2 Optical Devices



Figure 1.10 Astronomers use telescopes to explore the universe.

Scientists, craftsmen, and hobbyists learned they could take advantage of the tendency of light to reflect off surfaces and bend (refract) through others. How could these properties of light be used in inventions?

An **optical device** is any technology that uses light. An optical device can be as simple as a mirror, or as complex as the Hubble Space Telescope. The invention of optical devices has led to big improvements in our daily lives, and has allowed huge scientific advances. Here we will take a brief look at some of these optical devices and the impact they have had.

#### **MICROSCOPES**

It is believed that the father and son team of Hans and Zacharias Jansen of the Netherlands first built a microscope in about 1595. The first microscopes might have been very simple in design, but they led to incredible discoveries.

Antonie van Leeuwenhoek, a Dutch amateur scientist, experimented with a simple microscope of his own design in the 17th century. He looked at things like pond water, blood, and the plaque scraped from his own teeth. The things he saw astounded him! He wrote about his discoveries of "little animalcules," which were really the first descriptions of microscopic items such as bacteria, protozoa, algae, and red blood cells.

Van Leeuwenhoek's discoveries shocked the scientific world. Up until then, people had no idea there were organisms so small you couldn't see them. As curiosity about this hidden world grew, more scientists started using microscopes. The invention of the microscope led to a whole new branch of science: microbiology. Microbiology is the study of micro-organisms.

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In Focus



Did you know we have been wearing optical devices for 700 years? Alessandro della Spina, an Italian monk, made the first eyeglasses to correct vision around A.D. 1300. The glasses pictured here were made in the 15th century.

All microscopes allow you to see great detail by combining the power of at least two lenses. These two lenses are the eyepiece and the objective (see Toolbox 11: Using a Microscope). When a light source shines through the specimen, a large image is produced that you can see by looking through the eyepiece. Microscope designs have improved greatly since van Leeuwenhoek's day, but they all use the same basic principle.

#### **TELESCOPES**

The earliest astronomers, people who study stars and planets, were fascinated by the movement of stars and planets in the night sky. Even though people used single lenses to get a slightly closer look at the stars, it was the invention of the **telescope** that revolutionized astronomy. The first telescope was made in the Netherlands in the late 17th century. When the great Italian scientist Galileo heard about the telescope, he built one himself in one day. It didn't magnify very well, but Galileo was so impressed with it, he made more, stronger telescopes.





phases just like the Moon. see so much. Telescopes both magnify and collect light. The magnifying power of his telescopes allowed him to see Venus, and

Using these telescopes, Galileo made amazing astronomical discoveries. He discovered mountains and craters on the moon, small objects circling Jupiter, and he discovered that Venus had

There were two characteristics of telescopes that allowed him to the light-collecting ability of the microscope allowed him to see the faint objects around Jupiter.

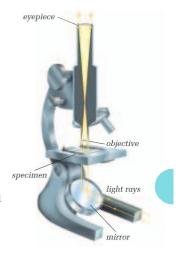


Figure 1.11 A microscope uses lenses to create an enlarged image of a tiny object.

Figure 1.12 Galileo made astonishing discoveries about the solar system once he started using a

#### **Types of Telescopes**

Telescopes provide enlarged images of distant objects by using lenses and mirrors, or a combination of both, to collect light from distant objects and bring it to your eyes. Usually telescopes are used to collect light from space, allowing astronomers to see objects that they could not see with the unaided eye.

There are two main types of telescopes: refracting telescopes and reflecting telescopes.

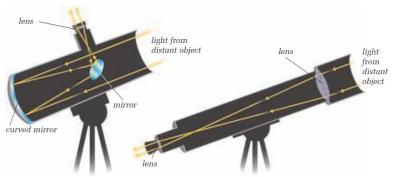


Figure 1.13 Refracting telescopes (right) use a combination of lenses; reflecting telescopes (left) use lenses and mirrors to form an image.

Refracting telescopes have two lenses, one on each end of a long tube. The larger lens is the objective lens that gathers light and focusses the rays toward the eyepiece, which in turn allows you to see the object larger than it appears with the unaided eye.

Reflecting telescopes use a large circular mirror that curves inward. This curved surface gathers light extremely well. Another mirror inside the telescope directs light to the eyepiece, which leads to your eye.

#### **I'ESEARCH**

#### **Liquid Mirrors**

This telescope mirror looks solid, but it's actually made of liquid. Find out why astronomers are using liquid mirrors and how they work.



### Inquiry

### Activity

#### Materials & Equipment

- · paper or styrofoam cup
- · rubber band
- · wax paper
- · light bulb



Figure 1.14 Step 2

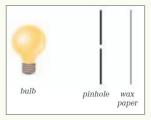


Figure 1.15 Copy this diagram into your notebook.

#### MAKE A PINHOLE CAMERA

You have read about various optical devices. Here is a chance to make and investigate your own optical device.

#### The Question

How does a pinhole camera work to form an image?

#### **Procedure**

- 1 Use the pin to make a tiny hole in the centre of the bottom of the cup.
- 2 Place a piece of wax paper over the open end of the cup using the rubber band to hold it in place.
- 3 Turn off the room lights. Point the end of the cup with the hole toward the light bulb.
- 4 Look at the image formed on the wax paper.

#### Collecting Data

- 5 Make a drawing of the image that appeared on the wax paper.
- 6 Move the pinhole camera closer, then farther away from the light bulb. Note the results.

#### Analyzing and Interpreting

- 7 What do you think is happening to produce the image on the wax paper?
- Reproduce the drawing in Figure 1.15 in your notebook.
- 9 Use a ruler to draw a straight line (#1) that starts at the top of the bulb and goes through the pinhole to the screen. Now draw another line (#2) that starts at the bottom of the bulb and also goes through the pinhole.
- 10 Remember that line #1 represents light from the top of the bulb, and line #2 represents light from the bottom of the bulb. Does this diagram help explain the drawing you made in step 5?

#### Forming Conclusions

11 Write a summary sentence or two that answers the question: "How does a pinhole camera work to form an image?" Include at least two diagrams that illustrate the images formed by objects at different distances from the

#### **BINOCULARS**

You can buy telescopes for home use, but they can be large and difficult to move around. You might want to use **binoculars** instead. They are simply two short refracting telescopes fixed together. Binoculars are not as powerful as telescopes but they are much more convenient.



#### LIGHT INTERACTIONS

Investigating how light interacts with objects can reveal interesting information about the nature of light. Light tends to travel straight, but will bounce and bend predictably when it strikes various substances. In the next section, you will learn more about how light bounces off, is absorbed by, and bends in different substances.

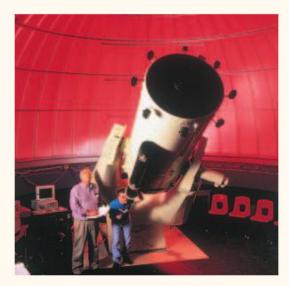
#### CHECK AND REFLECT

- 1. What optical device would you use to view the peak of a nearby mountain and why? Is there another device you could use?
- 2. How is a microscope similar to a refracting telescope? How is it different?
- 3. Compare and contrast refracting and reflecting telescopes.
- 4. How does a microscope work?

### SECTION REVIEW

#### **Assess Your Learning**

- 1. What did Euclid discover about light?
- 2. Describe three properties of light.
- Could a mirror be called an optical device? Explain why or why not.
- 4. Why was the invention of the telescope so important?





### THE NATURE OF SCIENCE

Scientific knowledge results from the shared work of many people over time, and new interpretations are made as new evidence is gathered. Reflect on what you've learned in this section.

- 1. How did Pythagoras contribute to scientific knowledge?
- 2. How did al-Haytham build on Pythagoras's ideas?
- 3. How did Newton change scientific ideas about how coloured light is formed?



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### Light behaves in predictable ways.

#### **Key Concepts**

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

- transmission and absorption of light
- reflection and refraction
- · images

#### **Learning Outcomes**

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

- describe how light is reflected, transmitted, and absorbed
- identify materials that are good absorbers, reflectors, and transmitters of light
- measure and predict angles of reflection and refraction
- describe how the refraction of light varies through different materials
- demonstrate the formation of images using a convex lens



Have you ever been window-shopping on a bright day? The glare from the glass can be quite annoying. What is glare? Glare is light reflected from the glass. You may have had to cup your hands around your eyes in order to see into the store. When you block out the sunlight with your hands, it makes it easier to see the light coming through the glass from inside the store.

You may have noticed another annoying problem when reading a glossy magazine. If you hold the magazine at a certain angle, light reflects off the page and makes it difficult to read. Change the angle of the magazine a little, and the words and pictures are once again easy to see.

Depending on the situation, light will reflect, transmit, or both. Is it possible to tell what will happen when light strikes a surface? Does light behave in regular, predictable ways? In this section, you will find out.

# 2.1 Light Travels in Rays and Interacts with Materials

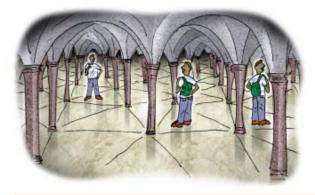
A popular attraction at fairs and carnivals is a mirror maze. It's fun because you can't tell whether you're looking at a person or their reflection, and so you can't tell where a person is actually standing.

When you think about it, the whole way you relate to the world is based on the assumption that light moves from objects to your eyes in straight lines. Suppose this assumption was false: then a person who appears to be right in front of you might actually be behind you. It would truly be a wild world if light twisted and turned at will. Life would be like a mirror maze all the time!



#### The Closest Star

The star closest to us (apart from the sun) is Alpha Centauri. Rays from this star take 4-3 years to reach our eyes. If astronauts travelled to this star at the same speed at which they travelled to the moon, the trip would take several thousand years!



**Figure 2.1** A mirror maze is fun because it's confusing.

#### Give it a TRY

#### ACTIVITY

#### PENCIL SHADOWS

Place a gooseneck lamp on a table and hold a pencil in an upright position about 20 cm from the lamp. Make sure the light bulb is higher than the top of your pencil. Look at the shadow created by the pencil. Have your partner place a metre-stick so that it touches the top of the lamp, the top of the pencil, and the tabletop. Look at where the metre-stick touches the tabletop.

- Where is the pencil shadow in relation to the end of the metre-stick on the table surface?
- Repeat the procedure holding the pencil at different angles. Do the results change?
- · What does this tell you about how light travels?



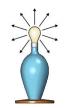


Figure 2.2 A simple ray diagram

#### RAY DIAGRAMS

Scientists use ray diagrams to show how light travels. The light travelling from a source is shown as straight lines called rays. Each ray ends with an arrow to indicate the direction of travel. Although ray diagrams are useful, they don't show the complete picture. Light rays travel away from a light source in every direction. To show all the light rays, you would have to draw millions of arrows, not just the few rays as in Figure 2.2. But ray diagrams are useful because they can illustrate how light behaves in different situations.

Ray diagrams can help explain why the brightness, or **intensity**, of a light changes with distance. Figure 2.3 shows the same number of rays leaving the light source, but fewer hit your eyes as you move farther away.

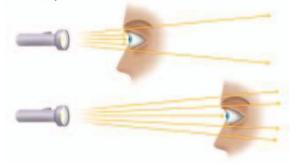


Figure 2.3 Fewer light rays reach your eyes the farther you are from a light source.

Ray diagrams also help explain shadows. If light hits an object, it can't go any farther. So if an object gets between the light and our eyes, we perceive this lack of light as a shadow.



Figure 2.4 A shadow is created by the absence of light.

#### LIGHT INTERACTS WITH MATERIALS

When light strikes objects, it behaves in different ways depending on the type of material each object is made of. **Transparent** materials, such as glass or clear plastic, can transmit light, meaning light travels straight through them. That's why you can see clearly through a window pane.

Translucent materials allow some, but not all, light to pass through. A frosted window pane is a good example of a translucent material. Some light can pass through, but you can't see what's on the other side of the frosted glass in any detail.

Opaque materials do not allow any light to pass through them. They absorb or reflect the light that hits them. Since light cannot get through an opaque object, a shadow is created behind it. Wood, metal, and brick are examples of opaque objects.

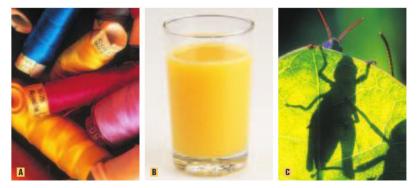


Figure 2.5 Light of various colours reflects off the spools of thread, A, and does not pass through; the spools are opaque. The glass is transparent, B, allowing you to see the juice inside. The leaf is translucent, C; some light from behind the insect passes through the leaf, but you can't see the insect through the leaf.

You may have a pencil or pen in your hand right now. So if you can see your pencil, then light must be coming from the pencil to your eyes. But where is the light from the pencil coming from? Pencils and other opaque objects are **non-luminous**, meaning they don't produce light. The light that gets to your eyes from the pencil (or from any other opaque object) is actually light reflected from a light source. A light source is **luminous**; it produces light. Light from a light source (the sun, a lamp) bounces or reflects off the pencil and hits your eyes. The same thing happens when light hits every opaque object in the room. That's why you can see your surroundings.

### Inquiry

### Activity

#### Materials & Equipment

- · light source
- light meter
- ruler
- large selection of sample materials such as coloured construction paper, wax paper, cloth, pieces of wood, tin foil, glass, and plastic

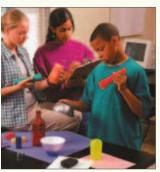


Figure 2.6 Testing different materials



wear reflective clothing. How do you think this helps keep them safe?

#### LIGHT REFLECTION

#### The Question

What material is the best reflector of light?

#### The Hypothesis

Based on the question and the materials you have collected, form a hypothesis for this investigation.

#### **Procedure**

- Organize the materials you have chosen to test for reflectivity. Predict which materials you think will reflect the best and which the worst.
- In step 3, you will shine the light source onto the materials and make a qualitative measure of reflectivity. This type of measure is one in which you decide on characteristics and attributes. For example, you may choose to rank the materials against each other from "least reflective" to "most reflective." In step 4, you will use a light meter to obtain a quantitative measure of reflectivity. This type of measure determines an amount using numbers and units.

#### **Collecting Data**

- 3 Hold the light source 15 cm away and shine it directly onto one of your chosen materials. Looking from behind and to the side of the light source, observe how much the light reflects from the material. In a table, record the reflectivity of the material. Repeat for the other materials. Make sure that the distance between the object and the meter stays the same.
- 4 Next, aim the light meter at the material so that it receives the reflected light. Hold the meter just to the side of the light source, so no light from the source strikes the meter directly. In a table, record the meter reading. Repeat for the other materials.

#### Analyzing and Interpreting

- 5 Decide on the best way to present your findings. For example, you might generate a list, or use a bar graph, or create a computer spreadsheet.
- 6 Which materials reflected the best? Did this agree with your prediction? Why or why not?
- 7 Which materials reflected the worst? Did this agree with your prediction? Why or why not?
- 8 Were there any instances where your qualitative results did not match your quantitative measures? If there were discrepancies, explain.

#### Forming Conclusions

9 Write a summary sentence or two that answers the questions: "What material is the best reflector of light?" and "What properties of a material would make an ideal reflector?"

#### TYPES OF REFLECTION

Regular reflection occurs when light rays hit a smooth surface. The incoming rays travel parallel to one another. When these rays strike a smooth surface, they all bounce off in the same direction, and so the reflected rays stay parallel to one another. All the rays are reflected at the same angle, so when these reflected rays reach your eyes, they are almost the same as if they had travelled directly from the source to your eyes without reflecting. Regular reflection produces a clear image but your eyes must be in the direct path of the reflected rays in order to see the reflected image.



Figure 2.8 Regular reflection (left) and diffuse reflection (right)

When light rays strike a rough or uneven surface, diffuse reflection occurs. When the light rays hit the surface, they reflect, but due to the rough surface, each of the rays is reflected at a different angle. So the reflected rays do not remain parallel. Some surfaces, such as a kitchen counter, may appear to be smooth, but they actually have very small bumps that scatter light rays in many directions. Because the light is scattered, you can see the kitchen counter from any position.

#### **CHECK AND REFLECT**

- Explain how you could change the direction of a ray of light. Include a diagram in your answer.
- A basketball does not give off light. Explain, with the help of a ray diagram, how you are able to see a basketball.
- 3. What happens to light when it hits a translucent object?
- Which would make a better reflector, a piece of metal or a piece of wood? Explain why.
- Explain, with the help of ray diagrams, why the shadow created by your hand on a wall grows bigger when you move your hand toward the light source.



#### When the Moon Turns Red



During a full lunar eclipse, Earth (an opaque object) passes between the moon and the sun, and casts a shadow over the moon. If Earth completely blocked the sun's light to the moon, you would expect the moon to disappear completely. However, the moon doesn't disappear: it appears orange or "blood red." Use the Internet and other sources to find out why the moon turns red.

#### infoBIT

#### **Making Mirrors**

Today, most mirrors are made of glass with a thin film of silver applied to the back. Two-way mirrors are specially designed to reflect 50 percent of the light and transmit the other 50 percent. So, on one side of the mirror, people see a reflection like that in an ordinary mirror. However, people on the other side can see right through. This works only if the room on the reflective side is brighter than the viewing room.

### 2.2 The Law of Reflection



Figure 2.9 Is this photograph printed upside down? What is real and what is reflection? Shiny smooth surfaces make excellent reflectors.

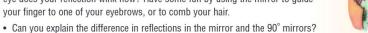
As you have just learned, a smooth surface allows all of the incident (incoming) rays to bounce off as a parallel beam, giving a regular reflection. The shinier and smoother the surface, the better the reflection. Still water, mirrors, glass, or even polished metal will allow you to see your image. Plane mirrors (flat mirrors) provide the clearest reflections. Using plane mirrors, you can investigate how reflected light behaves.

#### Give it a TRY

#### ACTIVITY

#### WHICH SIDE IS WHICH? 4

Look at your face in a mirror. Wink your right eye. Which eye does your reflection wink? Now, set two mirrors at right angles (90°) to each other. Tape them together so they will stand safely. Look directly into the corner of the two mirrors, so that one eye falls on each mirror. Now wink at your reflection. Which eye does your reflection wink now? Have some fun by using the mirror to guide your finger to one of your eyebrows, or to comb your hair.





### Inquiry

### Activity

#### Materials & Equipment

- pencil
- paper
- ruler
- protractor
- · modelling clay
- · plane mirror
- ray box



Figure 2.10 Step 3

#### HINT

Use the abbreviations "i" for angle of incidence, and "r" for angle of reflection. Then state your angle as an equation, for example, "i = 37°."

#### THE LAW OF REFLECTION

What rule can you make that describes how light reflects off a mirror?

#### Procedure (1)



- 1 Draw a horizontal line. Use a protractor to draw a line perpendicular to it (90°). This is the **normal**. This should make a "T" on your page.
- 2 Use the modelling clay to hold your mirror upright. Place the mirror on the horizontal line you have drawn. The normal should now be perpendicular to the reflective surface of the mirror.
- 3 Darken the room and shine a ray of light (the incident ray) at the mirror that is parallel to the normal. Where is the reflected ray?
- 4 Move the light source so that the incident ray hits the mirror at an angle. Make sure the light beam hits the mirror where the normal meets the mirror. Where is the reflected ray?
- 5 Using your ruler, draw the incident ray and the reflected ray. Show the direction of the light rays using arrows.
- 6 Repeat the procedure using several different angles of incidence. For each repetition, use a different colour of pencil to draw the incident and reflected

#### **Collecting Data**

7 Measure the angles of incidence and angles of reflection using a protractor. Make sure you measure both angles from the normal, as in Figure 2.11, and not from the mirror surface.

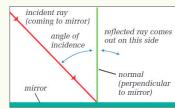


Figure 2.11 The angle of incidence is measured from the normal.

#### Analyzing and Interpreting

- 8 How does the angle of incidence compare with the angle of reflection?
- 9 What happens to the angle of reflection when you increase the angle of incidence?

#### Forming Conclusions

10 Now that you have an idea of how light reflects, how could you use this information? Give an example of building a device that might require knowledge of the law of reflection.

#### TESEARCH

#### Mirrors on the Moon

In 1969 and 1971, astronauts on the Apollo missions placed special mirrors on the surface of the moon. It doesn't matter at what angle a laser light shone from Earth hits these mirrors. The beam will always reflect back in exactly the same direction from which it came. Find out more about these special mirrors. How do they work? Why were they placed on the moon?

#### THE LAW OF REFLECTION

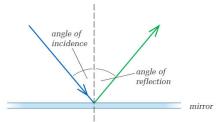
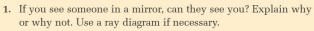


Figure 2.12 The law of reflection

When a ray of light hits a plane mirror at an angle, it bounces off the mirror surface at exactly the same angle. If you use straight lines to represent the mirror and rays in a drawing as in Figure 2.12, a line perpendicular to the mirror at the point of reflection is called the **normal**. The angle between the incident ray and the normal is the **angle of incidence**. The angle between the reflected ray and the normal is the **angle of reflection**. According to the **law of reflection**, the angle of incidence is equal to the angle of reflection.

#### **CHECK AND REFLECT**



- 2. Why do you think mirrors are so useful in magic acts?
- 3. Draw a "view from above" ray diagram that illustrates an arrangement of mirrors that would allow you to see the back of your head while looking straight ahead. (Hint: Draw a circle to represent your head. Draw a light ray leaving the back of your head, remembering to include the arrow.) How can you direct this light ray to your eyes? Mark the angles of incidence and reflection on your diagram.
- 4. With a diffuse reflection, do you think light rays obey the law of reflection?



Unit C: Light and Optical Systems

# 2.3 Reflecting Light with Curved Mirrors

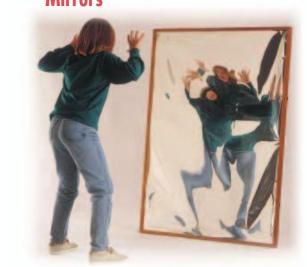


Figure 2.13 Fun-house mirrors distort your reflection.

Standing in front of a fun-house mirror at the carnival can make you look pretty weird. The strange image you see is produced by flat, outward-curved, and inward-curved sections in the same mirror. While they may be fun to look at, mirrors with multiple curves have no real practical uses. However, mirrors with a single curvature find many uses in our homes and optical devices. Let's take a close look at two types of curved mirrors.

#### **CONCAVE MIRRORS**

A **concave mirror** has a surface that curves inward like a bowl. Like any other mirror, concave mirrors obey the law of reflection. However, when parallel light rays approach a curved surface and strike at different points on the curve, each ray will reflect at a slightly different direction. These rays all head to a common point, called the **focal point**.

As you can see from Figure 2.14, concave mirrors are good at collecting light and bringing it to a single point. This is why concave mirrors are ideal for reflecting telescopes where you want to gather as much dim light as possible.

#### infoBIT

#### That's a Big Mirror!

The largest telescope mirror is located in the Keck Observatory in Hawaii. The concave mirror is 10 m wide! Astronomers are planning to build bigger mirrors up to 100 m wide.



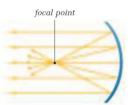


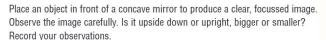
Figure 2.14 Concave mirrors reflect parallel rays of light back through the focal point.

Imagine a light bulb at the focal point, sending rays out in all directions. By reversing the direction of the arrows in Figure 2.14, you can see that the light rays would leave the mirror as parallel rays. That's why you will find concave mirrors in flashlights and car headlights. The concave mirror directs most of the light rays out in front of the flashlight or car, exactly where you need them.

#### Give it a TRY

#### ACTIVITY

#### CONCAVE MIRROR IMAGES



Predict what the image will look like when the object is placed at the following locations: a) closer to the mirror, b) farther away from the mirror, and c) very far from and very close to the mirror.

At each location, will the image be bigger, smaller, upright or upside down, or will there be any image at all? Record your predictions and then test them by moving the object. Were your predictions correct? Record your observations.

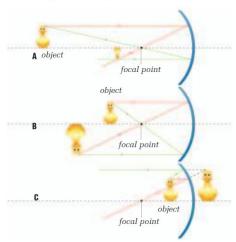


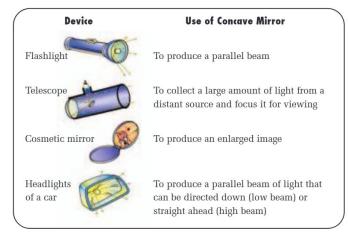
#### CONCAVE MIRROR IMAGES

The image formed by a concave mirror depends on how far the object is from the focal point of the mirror. If the object is far away from the focal point, the reflected rays form an upside-down image.

The closer the object gets to the focal point, the larger the image becomes. If the object is between the focal point and the mirror, the image becomes upright and enlarged.

Figure 2.15 If an object is farther from the focal point, the image is upside down, as in A and B. If the object is between the focal point and the mirror, the image appears upright and enlarged, as in C.





#### **CONVEX MIRRORS**

A mirror with a surface curved outward is called a **convex mirror**. As you might expect, it does the opposite of a concave mirror. Instead of collecting light, it spreads out light rays.

If you look in a convex mirror, it appears as if the image is originating from a smaller point behind the mirror. Because of these smaller images, convex mirrors on cars often have the warning "Objects in mirror are closer than they appear."

#### It's a Wide, Wide View

Find out about uses for convex mirrors. Try drawing ray diagrams to prove that convex mirrors can be useful in certain situations.

**PRSEARCH** 

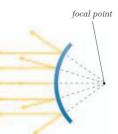


Figure 2.16 A convex mirror reflects parallel rays of light as if they came from a focal point behind the mirror.

#### CHECK AND REFLECT

- 1. Do curved mirrors obey the law of reflection? Explain.
- 2. Someone has left a shiny metal bowl outside in the sun. Which may have the potential to damage your eyes: looking at the outside of the bowl or the inside of the bowl? Explain.
- 3. An object is held extremely close to a concave mirror. Describe how the image will appear. Draw a ray diagram to explain.
- If you look in a convex mirror, would your image ever appear smaller? Explain why or why not.
- 5. Describe one practical use of a concave mirror.

#### infoBIT

#### **Pumpkin Sun**



When the sun is near the horizon, the rays from the lower edge of the sun bend, or refract, more than the rays from the upper edge as they pass through Earth's atmosphere. This makes the sun look slightly oval instead of round.

# 2.4 Transparent Substances Refract Light



Figure 2.17 Catching salmon in water is challenging.

British Columbia has some beautiful rivers where grizzly bears hunt for salmon. The grizzlies have to be patient, though. Often they will grab for a salmon and miss, especially when the salmon is in deep water. The closer to the surface the fish is, the easier it is for the grizzly to catch. Why is this so? It has to do with how light behaves in water.

If you tried to catch a fish with your hands, you would face the same problem as the grizzly bear. A fish in the water is not where it appears to be. The problem is that light bends when it leaves the water. When a light ray strikes a boundary where two different substances meet (often referred to as the interface) at an angle, it will change direction.

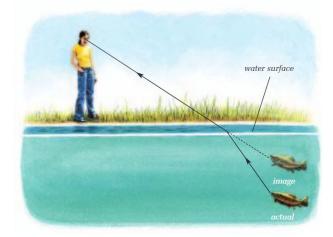


Figure 2.18 The fish is not where it appears to be.

Figure 2.18 shows the light rays coming from the fish bending as they leave the water. Our eyes assume that light travels in straight lines. If you trace the light rays that reach the eye backward in a straight line, you will find that they do not lead to the fish. Instead, the light from the fish in deep water appears to be coming from shallower water, thus fooling you into grabbing where the fish is not.

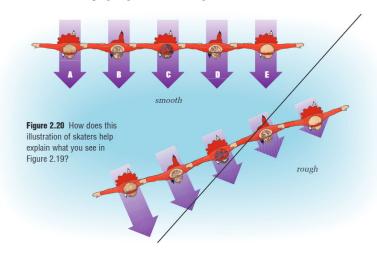
#### How Light Refracts

When light travels at an angle from one medium (substance) to another, it bends or refracts. You might be surprised to learn that **refraction** is due to changes in the speed of light. In space, light travels at around 300 000 km/s. Space is a vacuum, and there are no particles to get in the way of light and slow it down. However, just like a student trying to move from class to class when the hallways are full, it's impossible to move at top speed when particles (students) get in the way. What happens when light suddenly slows down as it hits a medium? If it strikes a medium of different density at an angle, it refracts.

How does this happen? Imagine light travelling like the line of skaters in Figure 2.20. Initially, they are all travelling at the same speed. In front of skaters C, D, and E, lies a patch of rough ice that will cause them to slow down. If the rest of the skaters continue to skate at the original speed, the result is a bend in the line. The same thing happens with light. When part of a beam of light slows down and the rest keeps going, the beam of light will bend.



Figure 2.19 This object is not really bent.



### Inquiry

### Activity

#### Materials & Equipment

- · glass block
- paper
- · pencil
- ruler
- protractor
- · ray box with a single slit opening
- · transparent plastic block



Figure 2.21 Tracing around the glass block



Figure 2.22 Drawing the

#### FROM AIR TO SOLIDS

#### The Question

What happens to light when it passes from air through different transparent solids?

#### Procedure 🕛



- 1 Place the glass block on a piece of paper and trace around it as in Figure 2.21. Mark a point near the middle of the front edge of the block and draw a normal at right angles to this point, Figure 2.22.
- 2 Direct a ray of light from the ray box so that it shines along the normal. The point where the ray enters the block is the point of incidence.
- 3 Mark the exit point where the ray leaves the glass. Join the incident and exit points. This is the refracted ray.
- 4 Adjust the ray box so that the light ray strikes the glass at the same point of incidence, but this time at an angle from the normal.
- 6 Again, trace the incident ray, and mark the point where it leaves the block. Draw the refracted ray again and make sure to label them.
- 6 Repeat steps 4 and 5, each time using different angles for the incident ray.

#### Collecting Data

- 7 Complete each refracted ray on the paper using a ruler to join the point of incidence to the exit point. Make sure all rays, incident and refracted, are labelled correctly. Add arrows to the rays to indicate their direction.
- 8 Use your protractor to determine the angle of incidence and the angle of refraction in each case. Note that these angles are measured from the normal. Organize all the angles in a table with the headings "angle of incidence" and "angle of refraction" and list the rays in order by their angle of incidence.
- Repeat steps 1 through 8 with the plastic block and a new sheet of paper. Predict how refraction will change using the plastic block. Use the same angles of incidence you used for the glass block.

#### Analyzing and Interpreting

- 10 How does the incident angle compare with the refracted angle?
- 11 What happened when the ray entered the block along the normal?
- 12 What happened to the refracted ray as the angle of incidence was increased?
- 13 How did the refraction of rays in glass and plastic compare?

#### Forming Conclusions

- 14 What two factors affect how much light is refracted?
- 15 Which of the two substances, glass or plastic, refracts light more?

#### REFRACTION IN DIFFERENT MEDIA

Light bends when it hits a new medium at an angle. The denser the new medium, the more the light slows down, and so the more it refracts. A diamond is much more dense than water, and so a diamond refracts light more than water does.



#### Wet Road Ahead!

Have you ever been on a car trip on a hot sunny day and the road ahead seems wet? What you see is an optical illusion called a mirage. Investigate the role refraction plays in causing mirages.



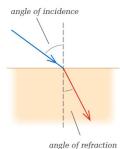


Figure 2.23 Ray diagram showing refraction

#### **CHECK AND REFLECT**

- 1. What happens to light rays when they pass from one medium into another medium? Explain the process of refraction.
- 2. How does the type of medium affect refraction?
- When would it be easier for a bear to catch a fish: as the fish swims or when it jumps in the air? Use your knowledge of how light travels in air and water to explain.
- 4. Why do objects at the bottom of an aquarium filled with water appear closer than they actually are?
- 5. The archer fish fires jets of water with its mouth at unsuspecting bugs on branches above the water. Explain in terms of how light travels, why these fish almost always "shoot" when they are directly beneath a bug. Why don't they shoot at an angle?



Figure 2.24 Question 5

## info**BIT**

#### Wow! That's Intense!



Convex lenses bend parallel light rays to a single point. As a result, the concentrated light energy at that point is hot enough to burn skin and can start fires. Be very careful handling convex lenses, especially in sunlight.

# 2.5 Lenses Refract and Focus Light

In section 1.0, you learned that microscopes, telescopes, and binoculars take advantage of lenses to manipulate light. What is it about lenses that make them great at collecting and moving light around? The answer lies in their shape and the material they're made of.

A lens is a piece of curved glass or other transparent material. It is smooth and regularly shaped so when light strikes it, the light refracts in a predictable way. The most useful aspect of lenses is that the light rays that refract through them will sometimes form images.



Figure 2.25 A magnifying glass is a convex lens.

#### CONCAVE LENSES

A **concave lens** is thinner in the centre than at the edges. As parallel rays pass through a concave lens, they are refracted away from the centre of the lens. So as light passes through a concave lens, the light rays diverge or spread out, and they will never meet on the other side of the lens.



Figure 2.26 Concave lenses spread light out.

#### **CONVEX LENSES**

A **convex lens** curves outward and is thicker in the middle than at the edges. The technical name for a convex lens that curves outward on both sides is a double convex lens, but it's usually just called a convex lens. As parallel light rays travel through a convex lens, they are refracted toward the centre of the lens. So as light passes through a convex lens, the rays move toward each other. The light rays cross at the focal point of the lens. (By changing the curvature of the lens or the substance it is made of, you can alter the focal point.)

The ability to bring light rays together makes a convex lens useful for two reasons. First, it can act as a light collector, much like a concave mirror. This is why a convex lens is used in a refracting telescope. It collects and focusses starlight. (Look back at

the diagram of a refracting telescope on page 184.) Second, a convex lens forms a **real image**. The light rays actually meet at a point, and the image can be projected onto a screen.



Figure 2.27 Convex lenses bring light rays together.

Figure 2.28 A real image can be projected onto a screen.

Depending on how close the object is to the convex lens, you can project images that are smaller or larger than the object. However, as you can see in Figure 2.28, there is one drawback to convex lenses. The image is upside down!

## Inquiry

### Activity

#### Materials & Equipment

- · cardboard stand
- · sheet of unlined white paper
- tape
- · light bulb and socket
- · battery and wires
- · convex lens
- · modelling clay (to support the lens)
- · metre-stick

#### CHECKING OUT IMAGES

#### The Question

How does the distance between an object and a convex lens affect the image formed?

#### The Hypothesis

Based on the question, form a hypothesis for this investigation.

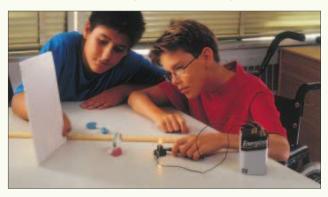


Figure 2.29 Finding the focal length of the lens

#### Procedure 🕛



- 1 Measure the height of the glass part of the bulb.
- 2 Tape the paper onto the cardboard stand. This is your "screen."
- 3 If your teacher has provided you with the focal length of the lens, you may skip this step. If you don't know the focal length of the lens, do the following to find the focal length:
  - · Place the lens in between the stand and the lit bulb.
  - · Move the screen and the bulb slowly inward, then outward, keeping the lens in the middle. At a particular distance, an upside-down bulb of the same size as the actual bulb will come into focus on the screen. Be patient! If you don't get the image the first time, keep trying.
  - . Measure the distance between the bulb and lens. Divide this value by 2. This is the approximate focal length of the lens.
- 4 Record the bulb height and focal length in your notebook.
- 5 You are going to collect data on the size of the image of the bulb, as well as the distance of the bulb from the lens. Draw a data table like the one on the following page.

Distance from bulb to lens (cm)	Image position (upright or upside down)	Size of image (cm)

Place the bulb more than twice the focal length away from the lens. Move the screen until the image comes into focus.

#### **Collecting Data**

- 7 Record the following in your data table:
  - · distance from the bulb to the lens
  - · the position of the image (upright or upside down)
  - · the size of the image
- 8 Place the bulb just over one focal length away from the lens. Move the screen until the image comes into focus. Record the results as in step 7.
- 9 Repeat step 7 again but this time place the bulb less than one focal length away from the lens. Move the screen to attempt focus. If you cannot get an image on the screen, bend down and look at the bulb through the lens. Can you see an image of the bulb in the lens? If you see an image through the lens, estimate its size.

#### Analyzing and Interpreting

- 10 Is the image formed by a convex lens always upside down? If not, under what conditions is the image upright?
- 11 What happens to the size of the image as the bulb moves toward the lens? What happens to the image position?
- 12 What happens when the bulb is placed inside the focal length of the lens?

#### Forming Conclusions

13 Write a summary paragraph explaining how lens placement affects image size and location.

#### Applying and Connecting

Convex lenses are often used in projectors. You may have used a projector to give a slide or film presentation. What happens to the size of the image as the projector is moved closer to the screen? Explain this in terms of what you have learned about convex lenses. How do you think projectors overcome the "upsidedown" problem?

#### Extending

Try repeating this experiment using lenses of different focal lengths.



Figure 2.30 Using a projector

#### reSEARCH

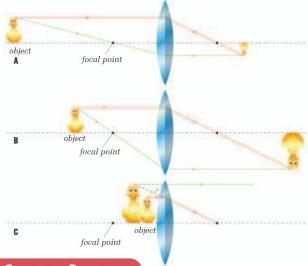
#### The Fresnel Lens

In 1822, Augustine
Fresnel (pronounced
Fray-nell) invented a
lens that was much
more efficient at
collecting and
directing light rays
than other lenses used
at the time. Find out
more about the
structure and function
of Fresnel lenses.

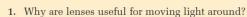
Figure 2.31 The formation of an image with a double convex lens depends on where you put the object.

#### IMAGE FORMATION WITH A CONVEX LENS

The formation of an image by a convex lens depends upon how far the object is from the lens. The ray diagrams in Figure 2.31 help illustrate this. If the object is farther away than the focal point of the lens, as in diagrams A and B, the image appears upside down and smaller or bigger. Both of these images are real images. In diagram C, the image will appear upright and bigger, and forms on the same side of the lens as the object. When you use a magnifying glass, the object you're looking at appears to be bigger on the other side of the glass.



#### **CHECK AND REFLECT**



- Draw a ray diagram that shows the path light rays take through a concave lens.
- 3. What kind of image is formed when an object is placed at the focal point of a convex lens?
- 4. Figure 2.32 shows the view through glass building bricks. How do these bricks let light through but still protect your privacy?
- Suppose you wanted to examine closely the leaf of a plant. What type of lens would you choose? Would you use a lens combination? Explain.



Figure 2.32 Question 4



#### Before You Start ...

You now know how the size and position of images formed by a convex lens can change depending on the position of the object. Would the images be different if you used two convex lenses?

#### The Question

How does image formation vary when two convex lenses are used?

#### Design and Conduct Your Experiment



- 1 Make a hypothesis.
- 2 Decide on the materials and equipment you will need to test your hypothesis.
- 3 Are there any safety aspects you need to consider?
- 4 Plan your procedure. What steps do you have to go through to collect the data you need?
- 5 Write up your procedure and show it to your
- 6 Decide what your data collection table should look like and construct it.
- 7 Before you start your investigation, make predictions about the size and locations of the
- 8 Carry out your investigation and compare your results with your hypothesis. Was your hypothesis correct? If not, how would you explain your experimental result?
- 9 Compare your results with classmates who investigated similar questions. Were your results similar?



Figure 2.33 Think about how you will conduct your experiment.

- 10 Compare your experimental procedure with classmates who investigated similar questions. 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?
- 12 Outline how you would design an experiment to look into these questions or problems.

## Careers Profiles

Ray Boudreau is a professional photographer. His portfolio includes everything from corporate executives to members of the Royal Canadian Air Farce. In fact, he took many of the photographs that appear in this unit.

- Q: When did you first become interested in photography?
- A: My interest in photography began when I was 11 years old.
  A friend of the family gave me a little Kodak printing kit.
  After using it for the first time, I was hooked on it.
- Q: What's the most challenging part of your job?
- Each picture I take has its own photographic problem which
   I have to solve. It's a problem-solving business. Using my
   photographic knowledge to solve problems is fun for me.



Wide Angle Lens: Objects appear farther away than they really are.

Normal Lens:
Objects appear
as they would
to your own eye.

Telephoto Lens: Objects appear closer than they really are.

The camera

Boudreau uses can be fitted with different

lenses.

Each

photographic

lens uses a

combination

of convex and concave

lenses.

## SAY CHEESE!



**Figure 2.34** Ray Boudreau is setting up for a photograph that appears in Cells and Systems.

- Q: What was your most challenging photo?
- A: I had to photograph the city of Toronto for the cover of a magazine. I rented a wide-angle lens and we went up in a helicopter. I was strapped in and I hung out of the helicopter and photographed the buildings from as close as we could get. The wide-angle lens made the tops of the buildings look really big and the bottoms look really small.



- Do you think a photographer has to know about light and optical systems to do his or her job?
- 2. If you were a photographer, what part of the job would you find challenging?

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. Use a labelled diagram to illustrate the law of reflection.
- 2. As Figure 2.35 indicates, it is possible to build a spy device with a long tube or milk carton. This could also be used to see over a crowd at a parade. Using a diagram, explain how mirrors are arranged in this device to make it an effective "spy tool." Make sure to indicate how rays of light would travel through the device.
- 3. Design a reading light that someone could use without bothering others in the room. (Hint: How could a mirror help?)
- 4. If you wanted to block out all of the light from your bedroom, what type of material would you use on the window? What would you use if you wanted to block out half of the light?
- 5. In Figure 2.36, the doll in the tank of water illustrates light from the doll reaching your eyes by three different paths. Explain what is happening to the light rays on those three paths.
- Describe how you would project a bigger image with a double convex lens.
- 7. Why should the pages of a book be slightly rough rather than very glossy?
- Trace Figure 2.37 into your book.
   Assume the light ray moved from substance A to B. Add an arrow to the light ray, draw a normal, and label the angles of incidence and refraction.

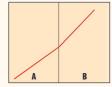


Figure 2.37 Question 8



Figure 2.35 Question 2



Figure 2.36 Question 5

### Focus On

### THE NATURE OF SCIENCE

Scientists strive to gain knowledge of the natural world. Reflect back on what you have learned about how light behaves.

- Why do you think it is important to learn how light reacts in nature?
- 2. How has the development of different types and applications of lenses and mirrors helped us to better understand our world?
- 3. How does an understanding of how light travels aid in the development of new technologies?

Light Behaves in Predictable Ways

211

3.0

# Light is part of the electromagnetic spectrum and travels in waves.\*

#### **Key Concepts**

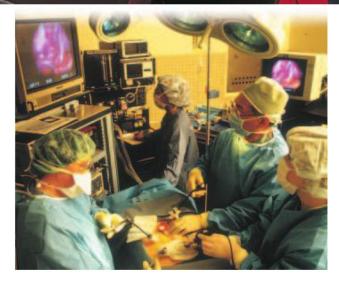
In this section, you will learn about the following key concepts:

- · electromagnetic spectrum
- transmission and absorption of light
- · colour and wavelength
- · sources of light

#### **Learning Outcomes**

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

- describe the characteristics and composition of sunlight
- explain the wave properties of light and the electromagnetic spectrum
- describe some of the technological applications of electromagnetic radiation
- recognize the dangers associated with certain forms of radiation
- evaluate, compare, and contrast different artificial and natural light sources
- describe how primary colours can be added to produce different colours and white light



The medical profession has changed incredibly in the last two centuries. Doctors have a number of different tools they can use to see inside the body without having to operate.

The endoscope is a combination camera/light source. The light is delivered through a thin, flexible fibre-optic cable. It allows the doctor to illuminate the inside of the digestive system and examine the structures clearly to identify any problems. The doctor views the image on a TV screen and can even perform operations this way.

Visible light is just one form of energy used by doctors to advance medical treatment. Lasers are used to make incisions in surgery. X-rays are used to view dense structures inside the soft tissue of our body. Gamma rays are used to treat cancer. Even microwaves have been used to shrink certain enlarged tissues. What do all of these forms of energy have in common?

### 3.1 The Wave Model of Light

An important part of science is developing models. Models are based on what we observe about the characteristics and properties of something. They help make it easier to understand complex concepts. Scientists commonly use the wave model of light.

Waves and light have two big similarities: they are both a form of energy, and they travel out in all directions. If waves describe light, then you need more information about how waves behave.

### PROPERTIES OF WAVES

wavelength—the distance from the crest of one wave to the crest of the next

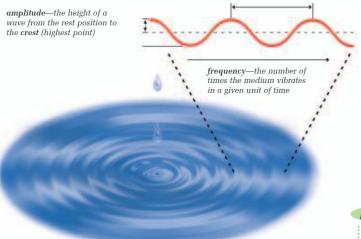


Figure 3.1 All waves have an amplitude, wavelength, and frequency.

All waves have a wavelength, but the wavelengths can vary widely. Think about sitting in the bath. You've probably created waves just for the fun of it. Suppose you were making one new wave every second. Would it take more or less energy to create three waves per second? It takes more energy.

When you create more waves per second, the frequency of the waves increases. As the frequency increases, you'll notice that the crests of each wave are closer to one another. So as more energy is put into making waves, the frequency of waves increases and the wavelength shortens.

#### infoBIT

#### Tsunami!

In 1771, a tidal wave, or tsunami, hit the coast of Japan. It was possibly 85 m high and had enough energy to toss a 750-t rock 2.5 km inland



There is a mathematical relationship between the speed, wavelength, and frequency of a wave. speed = wavelength × frequency

If the speed of a wave on a rope is 50 cm/s and its wavelength is 10 cm, what is the frequency of the wave?

#### LIGHT WAVES

As you learned in the first section, rainbows have fascinated people, especially scientists, for thousands of years. How are the colours of a rainbow formed? You always need sunlight to create a rainbow, so there must be some relationship between the white light of the sun and the coloured light of a rainbow.

**Figure 3.2** Sunlight and raindrops are needed to form a rainbow.



#### Give it a TRY

#### ACTIVITY

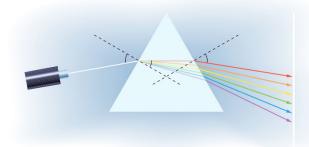
#### WHAT IS WHITE LIGHT MADE OF?

Shine a light through a prism so that the light leaving the prism falls on an unlined piece of paper. What colours do you see? As you hold the prism and light steady, your partner will use coloured pencils to draw the colours on the piece of paper. Switch places with your partner. Again, trace the colours you see onto the piece of paper.

- What colours do you see on the paper? What is the order of the colours?
- · Is it difficult to see where one colour ends and the next begins?
- · Did the order of the colours on the paper ever change?
- The term *spectrum* means a range. How do you think this term is related to what you observed?

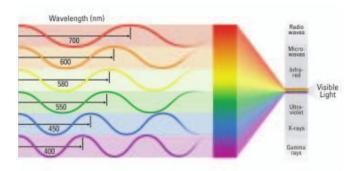


When you shine sunlight or white light through a prism as in Figure 3.3, the light refracts, and splits up into the colours of the rainbow. These colours form the **visible light spectrum**. Each colour of light is refracted at a different angle. So white light is made up of many different colours of light.



**Figure 3.3** Refraction of white light through a prism. Each colour of light that makes up white light refracts at a slightly different angle.

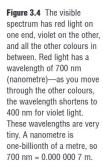
The colours of the spectrum can be explained using the wave model. Figure 3.4 shows that each colour of light in the visible light spectrum has a slightly different wavelength.



#### **! ESEARCH**

#### Two Pots of Gold?

When rainbows form, sometimes a secondary rainbow appears outside the first. Find out how the secondary rainbow occurs. Is the order of colour in the secondary rainbow the same as the first?



#### **CHECK AND REFLECT**

- 1. What properties do light and the waves in your bath share?
- ${\bf 2.}$  Create a concept map that links frequency, amplitude, and wavelength.
- 3. On a piece of graph paper, draw a diagram of a wave with an amplitude of 4 cm and a wavelength of 10 cm.
- Draw a diagram to explain what happens to white light as it passes through a prism.

# 3.2 The Electromagnetic Spectrum

Imagine you are out for a walk in the park. The sun is shining down and there's not a cloud in the sky, but actually you are being drenched! Not by rain, but by energy. In addition to visible light, the sun sends out lots of different types of energy. Most of them you cannot see or feel.

#### THE INVISIBLE SPECTRUM

There is a whole world of energy that lies beyond our sense of

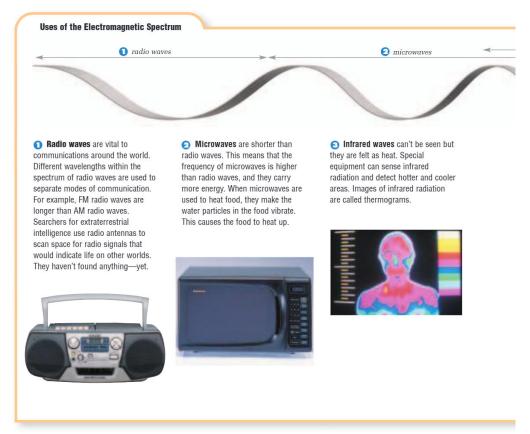


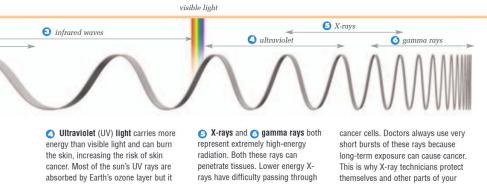
Figure 3.5 Electromagnetic radiation strikes Earth in many different forms.

vision. The wavelengths that make up visible light are just a small part of a very large range of electromagnetic radiation. The wave model works perfectly to explain the invisible parts of the electromagnetic spectrum (Figure 3.5). At the end of the spectrum with longer wavelengths than visible light, you find the lowfrequency radio waves, microwaves, and infrared radiation. At the other end of the spectrum where the wavelengths are shorter and frequencies higher than visible light, you find ultraviolet radiation, X-rays, and gamma rays. Human eyes are not sensitive to either end of the electromagnetic spectrum that lies beyond visible light, so these rays remain invisible.



#### Not on the Same Wavelength

The longest wavelengths in the electromagnetic spectrum are long radio waves, at 100 km. The shortest are gamma rays, at 0.000 000 000 0001 mm



is still advisable to wear sunblock creams when outdoors. A sunblock provides an opaque layer that prevents UV rays from reaching your skin.



bone, making them useful for medical imaging. Gamma rays are used to kill



body with lead aprons that X-rays cannot penetrate.



Cloud chamber showing radiation trails

#### APPLICATIONS OF ELECTROMAGNETIC RADIATION

Although we cannot see the invisible parts of the electromagnetic spectrum, these waves can be transmitted, reflected, and absorbed, just like visible light.

#### Radio Waves

Radio waves can be used in medicine to produce images of tissues deep inside the body. A magnetic resonance imaging (MRI) device sends short bursts of radio waves into the body. With the help of a magnetic field, the radio waves energize atoms and make them line up. When the radio pulses are turned off, the atoms return to their original orientation, releasing radio waves back to the machine. Different types of tissue release energy at different rates. The MRI uses these radio waves to construct a computer image of the tissue.



Figure 3.6 Magnetic resonance imaging is useful for examining the brain and spinal cord.

#### Microwaves

You may have heard the term *radar* before. The word is actually an acronym for radio detection and ranging. Older radar devices used radio waves. Today, radar devices send out short bursts of microwaves in order to detect objects. Like visible light, microwaves obey the law of reflection, so some of the waves sent out by radar reflect off objects and return to the radar receiver. By knowing the speed of the microwaves and the time it took them to return, the receiver calculates how far away the object is. Radar is now an indispensable technology, allowing us to track ships, airplanes, and even weather systems.



Figure 3.7 Air traffic controllers use radar to monitor planes landing and taking off at airports.

#### Give it a TRY

#### ACTIVITY

#### GIVE IT A GLOW

Your teacher will provide you with a variety of materials and two light sources: a regular bulb and a black light bulb. The regular bulb emits infrared radiation (heat) as well as light. The black light bulb emits mostly ultraviolet light. Darken the room as much as possible and turn on the regular light bulb. One by one, hold the materials up to the light and note the appearance of each. Record your observations. Repeat the process using the black light.

- · Which substances appear different under the regular light?
- · Which substances appear different under black light?
- Why do you think that certain substances glow in the presence of ultraviolet radiation and not in the presence of infrared radiation? Discuss possible explanations with your classmates.



#### **Ultraviolet Rays**

Ultraviolet (UV) light is also a form of electromagnetic radiation. UV light has a higher frequency than visible light, so it carries more energy. Because the energy of UV rays is great enough to kill living cells, UV light can cause skin damage that can lead to cancer. This high energy level is useful to hospitals and food processing plants, which use ultraviolet lamps to kill micro-organisms on equipment.

Small doses of ultraviolet light can be beneficial to humans. Skin cells produce vitamin D, which keeps teeth and bones healthy. In order to create the vitamin, the cells need small amounts of UV light. Some babies are born with jaundice, a liver condition that causes yellowing of the skin. To treat the condition, newborns are placed under ultraviolet lamps.



Figure 3.8 This baby is being treated for jaundice under an ultraviolet light. The baby's eyes are covered because too much ultraviolet light could damage them.

#### reSEARCH

#### What's Cooking?

The microwave oven is an extremely useful application of microwave radiation. Did you know that the discovery that microwaves could cook food happened purely by accident? Use the Internet and other sources to find out more about the development of the microwave oven.

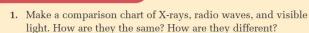
#### Gamma Rays

Gamma rays have the shortest wavelengths and highest frequency of the electromagnetic spectrum, and they contain the greatest amount of energy. Gamma rays can penetrate the body to a much greater extent than X-rays, and they can cause serious illness. But, like ultraviolet light, small amounts of gamma radiation can treat illnesses. Small doses of gamma rays are used in radiation therapy to kill cancer cells.



Figure 3.9 A person undergoing radiation therapy

#### CHECK AND REFLECT



- 2. Is the statement "the sun only gives off visible light" correct? Why or why not?
- 3. Why is it a good idea to wear a hat and sunblock creams when spending time in the sun?
- 4. Explain how radio waves can be used to determine the position of icebergs at sea.
- Electromagnetic radiation can be used to treat cancer. What type of radiation would you use if you were the oncologist (cancer specialist)? Explain.
- 6. Many people operate their home electronics with remote controls. Using what you have learned about electromagnetic radiation, explain how a remote control might work.
- 7. When you go to the dentist, he or she sometimes takes X-rays of your teeth. Why does the technician put a lead apron over you, and why does he or she go behind a metal screen when taking the X-ray picture?



# 3.3 Producing Visible Light



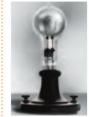
Figure 3.10 Without sunlight, there would be no life on Earth.

Of the wide spectrum of electromagnetic radiation, visible light is probably the most important to us. Think about how often you are exposed to visible light. Where does most of it come from? How is it produced?

Look at the photos in Figure 3.11 and classify them as natural or artificial light sources. Artificial light sources are human made. Check how your classmates have classified the photos. Do you agree with them?

#### infoBIT

#### Bamboo Light



Thomas Edison was one of the first to design light bulbs in the late 1800s. His first bulbs didn't last that long, though. Edison used pieces of bamboo for the filament of the first light bulbs; these filaments would burn out after about 30 hours. Today, filaments are made of tungsten.



-

Light Is Part of the Electromagnetic Spectrum and Travels in Waves



Figure 3.12 Think how short winter days would be without any artificial light.

#### ARTIFICIAL SOURCES OF LIGHT

Can you imagine how different your life would be without artificial sources of light? Think about how many times a day you flip on a switch and are greeted with light. Why is it now so easy to produce artificial light? What types of devices produce light?

#### **Incandescent Light**

At the heart of an **incandescent** bulb, there is a filament (thin piece of wire). When you turn it on, electrical energy flows through the filament, heating it to extremely high temperatures. As electricity flows through the filament, it causes the wire to glow white-hot. The light you see from the bulb is the filament glowing.

#### Fluorescent Light

A **fluorescent** bulb is a glass tube filled with a small amount of a gas such as mercury vapour. The inside of the bulb is coated with a white powder called **phosphor**. Electricity passes through a fluorescent bulb many times per second. Each time it passes through, it makes the gas in the bulb emit ultraviolet radiation. This ultraviolet radiation strikes the phosphor on the inside of the bulb, which then glows and emits visible white light. The emission of white light in this way is called fluorescing.





**Figure 3.13** An incandescent bulb, A, and a fluorescent bulb, B

#### **Phosphorescent Light**

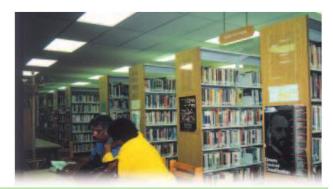
Phosphorescence is slightly different from fluorescence. In fluorescent lights, the phosphor emits light only while the ultraviolet light is hitting it. However, some substances have the ability to store energy from the radiation that hits them, and they can emit light for a long time after the source of radiation has stopped. This ability to emit light is known as **phosphorescence**. Phosphorescent materials are often used in novelty items because they will glow in the dark for some time after being energized by light. This also explains why glow-in-the-dark toys will eventually grow dim but can be re-energized simply by being held under a lamp for a few minutes.

#### INCANDESCENT VS. FLUORESCENT LIGHTS

Choosing an artificial light source depends on a number of things. Convenience, appearance, and durability all contribute to the choice of what light to use. The cost of operating the light is

another factor. It may make sense to use a more expensive device if it costs less to run and lasts longer. These are some factors to consider when choosing between incandescent and fluorescent light bulbs.

**Figure 3.14** Fluorescent lights are commonly used in offices and public buildings.





#### ACTIVITY

#### THE LOOK OF LIGHT

Check out the lighting around your home. You probably have incandescent and perhaps some fluorescent or halogen lights as well. Compared with sunlight, how would you describe the light from each of these light sources? Warm? Cool? Does each one have a slightly different colour? Look at objects lit by these lights. Do their colours appear different? If so, how are they different? Record your observations. Do the same thing with lights in public places such as malls and parking lots.



### Inquiry Activity

#### Materials & Equipment

- · light bulbs: 60-W incandescent, 60-W halogen, and 15-W fluorescent (or any other variety of light bulbs that give off similar amounts of liaht)
- · gooseneck lamps
- · thermometer
- beaker
- · water at room temperature
- · test tube
- · felt marker
- timer

#### Caution!

After bulbs have been turned on, do not touch them even after they have been turned off! They can reach very high temperatures. If there are not enough lamps for each group, your teacher will change the bulbs for you.



Figure 3.16 What lighting will keep this chick warm?

#### COMPARING DIFFERENT TYPES OF LIGHT BULBS

#### The Question

Which type of light bulb gives off the most heat?

#### The Hypothesis

Form a hypothesis for this investigation.

#### Procedure 😃

- 1 Screw each of the three bulbs into a gooseneck lamp. Your teacher may have done this for you already by setting up lamps in different parts of the room. Do not turn them on yet.



Figure 3.15 If available consider using a computer

- 2 Make a table for recording temperature data for each bulb. You will be taking readings every 30 s for 5 min.
- 3 Use the felt marker to draw a line about halfway up the test tube. Fill the tube with water from the beaker up to the mark.
- 4 Put the thermometer into the test tube. With one hand, hold the test tube around its top rim. Use your other hand to support the thermometer.
- 5 Have your partner start the timer and turn on the lamp. Hold the water-filled part of the test tube about 2 cm in front of the bulb you are testing. Make sure the lamp is facing forward, NOT upward (see Figure 3.15). Never hold water above a lamp or light socket. Be careful not to bump the bulb with your test tube. Very gently move the thermometer up and down in the water during the trial, to ensure it heats evenly.

#### **Collecting Data**

- 6 Every 30 s, record in your table the temperature shown on the thermometer. Continue doing this for 5 min.
- 7 Repeat the procedure described in steps 4 and 5 for the other two light bulbs. Before doing so, replace the water in the test tube with water from the beaker and let the thermometer cool down. Record temperatures in your table.

#### Analyzing and Interpreting

8 Construct a graph, using time as your manipulated variable and temperature as the responding variable. Plot the data for each of the bulbs on your graph.

#### Forming Conclusions

- 9 Write a summary statement that answers the question "Which type of light bulb gives off the most heat?"
- 10 The bulbs you tested produce similar amounts of light, but different amounts of heat. Where does the energy for the production of the heat come from?

#### Applying and Connecting

What type of lighting would you recommend for your school? an office building?

#### **ENERGY-EFFICIENT LIGHT BULBS**

Most light bulbs should really be called "heat bulbs" because they produce far more heat than light, or more infrared radiation than visible light energy. Incandescent bulbs produce about 95% heat and only 5% light. When you were a child, you may have used an incandescent bulb to bake cakes in a toy oven! Fluorescent bulbs are much more efficient than incandescent bulbs, but they still release up to 80% of their energy as heat.

#### NATURAL SOURCES OF LIGHT

The most important natural source of light on Earth is the sun. There are, however, other natural sources of visible light. If you've ever walked through a meadow on a warm summer evening, you may have seen points of light flickering on and off. This flickering light is produced by fireflies. When living organisms produce their own light, it's called **bioluminescence**.

The firefly has a light-producing organ, or **photophore**, on the underside of its abdomen. The light produced by the photophore is created by a chemical reaction. Unlike electric light, this chemical light is very efficient because it gives off no waste heat. Because of this, bioluminescent light is often called cool light.

Fish that live deep in the ocean have to create their own light because no sunlight can reach that far down. Some produce light in the same way as fireflies do, but other fish have bacteria in their photophores that do the light-producing chemical reaction for them. The black sea dragon and the angler fish have a special long spine with a bulb on the end of it, filled with light-producing bacteria. The spine acts as a fishing rod, and the bulb as a lure, attracting smaller fish into their waiting jaws. Flashlight fish use light from their photophores to keep their school together as they swim. They can quickly turn their photophores off if a predator approaches.

#### **TRSEARCH**

#### **Glowing Organisms**



Some algae, jellyfish, insects, crustaceans, fish, bacteria, and even earthworms produce light by bioluminescence. Find out more about species that produce light. Prepare a report on the organism and exactly how and why it produces light.



Figure 3.17 A flashlight fish

#### CHECK AND REFLECT

- 1. Explain how an incandescent light bulb works.
- 2. Your watch dial may have glow-in-the-dark numbers. Is this phosphorescence or fluorescence? Explain your answer.
- 3. Why would a business choose fluorescent instead of incandescent lights?
- 4. What is bioluminescence?

#### What Do You See?



Can you see the figure in this circle? If you can't, you have redgreen colour blindness. People with this form of colour blindness cannot detect the colours red and green. About 8% of males and i% of females have this type of colour blindness. Only one person in 40 000 is totally colour-blind.

### 3.4 The Colours of Light



Figure 3.18 The TV is colourful but the room is not.

Imagine you've woken up in the middle of a dark night and gone to the kitchen to get a glass of water. When your eyes adjust to the darkness, you can see all the items in your kitchen but everything appears black or grey. In very dim light, colour is very difficult to make out. If you stumble in the dim light (don't spill your water!) into another room and turn on the television set, the vivid colours coming from the screen briefly stun you. You then turn it off and notice that the sun is rising. As the sky gets brighter and brighter, you can see your surroundings come alive with colour. The more you think about it, the more light and colour seem to be related. What is the link between light and colour?

#### ADDING COLOURS TOGETHER

When you studied the electromagnetic spectrum earlier in this unit, you learned that visible light comprises a spectrum of colours, ranging from red to violet. Since all the different colours have slightly different wavelengths, each colour refracts by a slightly different amount. These colours can be recombined again to form white light.

The production of white light by combining all the colours of the visible spectrum can be simplified. All you really need to produce white light are three colours: red, green, and blue. These three colours are known as the **primary colours**. If you mix correct intensities of all three primary colours, you will observe white light. This new colour is called a **secondary colour**. The secondary colours are cyan, magenta, and yellow as shown in Figure 3.19. This mixing of three colours of light to produce many different colours of light is called the **theory of colour addition**.

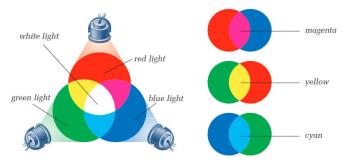


Figure 3.19 The three primary colours can create three secondary colours: cyan, yellow, and magenta.

#### **TELEVISION**

A television set is a technology that puts this theory to work. If you take a slightly moist tissue and dab it on a television screen, you will discover that the screen is made up of rows of tiny dots as shown in Figure 3.20. Each row of dots gives off either red, green, or blue light. The television works by fooling the eye into seeing colours that are not really there. If neighbouring blue, red, and green dots glow, the eye will see white. If neighbouring red and green dots glow, you will see yellow. As the neighbouring dots glow in different combinations, the screen can produce all the secondary colours. By changing the brightness of each dot, the screen can produce a wide range of colours.



The theory of colour addition explains different colours of light. Find out about the theory of colour subtraction. How does it explain the colour of objects?

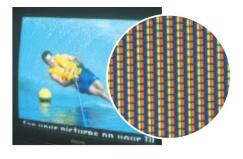


Figure 3.20 Television sets combine the three primary colours to produce a wide range of colours. When all three colours are projected equally, white light is produced. How do you think a TV set produces black?

#### **CHECK AND REFLECT**

- 1. What are the primary colours of light? How is white light produced?
- 2. Explain how a prism can demonstrate what white light is composed of.
- 3. You are a lighting technician in a theatre. The director asks for a magenta light on stage, but you have only red, blue, and green lights. What could you do to produce magenta light?

### Careers Profiles

#### COMPUTER GRAPHIC ARTIST

**D**oes the thought of working with colour and light interest you? Do you like creating and drawing pictures? There is a high demand for individuals who can create art and manipulate images using a computer.



Figure 3.21 Computers have opened up a new world of creative possibilities.



Figure 3.22 A 3-D rendering of an image

- Graphic artists have traditionally worked with paper and paints to create their art. New, powerful computers and software have allowed graphic artists to create their art using computers instead. Now, graphic artists can change the colours, textures, and even the orientation of their artwork in seconds using computer software. This allows them to be even more creative. By using special drawing software, graphic artists can create 3-D images which can be animated by computer, and now entire movies can be made by computer graphic artists.
- 1. How have computer graphic artists changed the world of entertainment?
- **2.** What training would you need to be a computer graphic artist?
- 3. Does being a computer graphic artist seem like an interesting career? Why or why not?

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. What model is used to describe and explain the properties of light?
- 2. If someone said that violet light has a higher frequency than red light, what do they mean? Are they correct?
- The electromagnetic spectrum ranges from low-energy to highenergy waves. Explain how wavelength is related to the energy of electromagnetic radiation.
- 4. a) Where does infrared radiation appear on the electromagnetic spectrum?
  - b) Can you detect infrared radiation with your body? If so, how?
  - c) What is the importance of infrared radiation to you?
  - d) Answer parts a) to c) for ultraviolet radiation.
- 5. Electromagnetic radiation is used in engineering. Technicians will direct radiation at thick concrete or steel in order to detect tiny cracks. What type of radiation (infrared, radio, gamma, etc.) would be most suited to the task? Explain.
- 6. Explain how fluorescent lights work.
- 7. Explain how a firefly produces light. Why is this light called cool light?
- 8. Using the theory of colour addition, how would you produce cyan-coloured light?



### THE NATURE OF SCIENCE

Scientific ideas help organize, interpret, and explain observations. Review the information you have learned in this section.

- Scientists often use models to help explain their observations.
   What models have been introduced to help explain the nature of light?
- 2. How has your understanding of colour changed with what you have learned in this section?
- 3. Scientific language is precise and specific terms are used. What terms have you learned that are specific to the study of light and optical systems?



4.0

# Eyes and cameras capture images using the properties of light.

#### **Key Concepts**

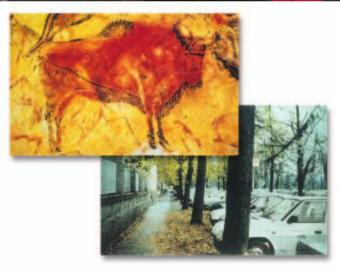
In this section, you will learn about the following key concepts:

- · vision and lenses
- · reflection and refraction
- · imaging technologies
- · images

#### **Learning Outcomes**

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

- explain how objects are seen by the eye
- describe the similarities and differences between eyes and cameras
- compare the function and design of mammalian and other vertebrate and invertebrate eyes
- investigate new technologies that enhance human vision
- describe how digital images are created, stored, and transmitted



As soon as humans discovered natural pigments in the soil and in plants, they began to record images. As human civilization has progressed, so have the techniques and technologies for recording images.

Look at the above images. How do you think each was recorded? The first picture is a cave painting from Spain. Archaeologists (scientists who study evidence of past human cultures) believe that this painting was made about 12 000 B.C. You might be surprised to learn that the other image is a painting too! It's called *Street #101* by Edmonton artist Vladimir Sevcik. Sevcik uses acrylic paints and takes many hours to produce his beautiful photo-realistic paintings.

If you want to produce realistic images, you have many choices: instant cameras, digital cameras, and video cameras. All sorts of technologies are available for easily capturing images. The interesting thing is that they all use the same optical principles that your eyes use to capture images.

# 4.1 Image Formation in Eyes and

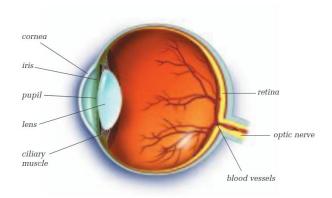


Figure 4.1 The eye is the organ of sight and has a very complicated structure.

Both the eye and the camera can be thought of as image-producing technologies. One happens to be a natural technology, the other is artificial. At the end of section 2.0, you learned how lenses can form images. Now you will get to "see" how lenses are used to form images in the eye and in the camera.

#### HOW LIGHT GETS IN

You already know that light either travels from a source to your eyes or reflects off an object to your eyes. But how does light get into your eye? If you look at Figure 4.2 on the following page, you will see that the eye and the camera use the same method of allowing light in through a hole. In the human eye, the hole is called a **pupil**. In a camera, the hole is known as an **aperture**.

Like a doughnut hole, the pupil is not really there. The pupil is just a hole created by a circular band of muscle called the **iris**. When people refer to their eye colour, they are referring to the colour of the iris. The iris controls the size of the pupil, and so regulates the amount of light that enters the eye. In dim light, the iris opens and the pupil dilates (becomes wider) to let in more light. In bright light, the iris closes and the pupil constricts (becomes smaller) to let in less light. Changes in pupil size happen automatically; you don't have to think about it.

#### infoBIT

#### Red Eye



People's eyes often appear red in photos taken with flashes. The lining at the back of the eye called the retina is very rich in blood vessels. The light from the flash reflects off this red layer to cause the red eye.

Figure 4.2 The pupil of the eve and the aperture of a camera lens work in the same way.



The pupil is not dilated.



The pupil is dilated.



The aperture is closed down.



The aperture is wide open.

In an automatic camera, a light sensor directs the diaphragm to change the size of the aperture in the lens to allow in the proper amount of light. The shutter lies behind the aperture. The shutter acts like a set of doors that open when you press the button to take a picture. The longer the shutter remains open, the more light enters the camera and strikes the film. What part of your eye is like a camera shutter?

#### WHEN LIGHT GETS INSIDE

Getting light through the pupil is only part of the battle. In order to see, light rays must strike the sensitive retina at the back of the eye. The retina is a special layer that is filled with photoreceptors, cells that are sensitive to light. There are two types of photoreceptors. Rods are highly sensitive to light, while cones detect colour. Because rods are sensitive to even small amounts of light, they can function in very low light. Cones can't function in low light, so all you can see are shades of grey. This is somewhat similar to the difference between colour and black and white film in cameras. Black and white film can't detect and record colour.

When light strikes the retina, photoreceptors are stimulated, and they send messages to the optic nerve (the nerve at the back of the eye), which passes the message to the brain. The brain translates the messages into an image. Cameras form an image in a similar fashion. At the back of the camera is light-sensitive film. When light strikes the film, the film changes chemically, forming an image.

#### Give it a TRY

#### ACTIVITY

#### WHERE'S YOUR BLIND SPOT?

There is a small spot on the retina of each eye that has no photoreceptors. Because of this, your brain gets no information about a small area of whatever you are looking at. Try to find your blind spot.



Figure 4.3



Close your left eye and stare at the plus sign in Figure 4.3. Slowly move the book toward you and away from you. When the black dot disappears, you've found your blind spot!

- · Why does the black dot disappear?
- . Why do you think this spot on the retina has no photoreceptors?



#### FOCUSSING THE LIGHT

Good vision and clear photographs rely on one more thing to ensure that light strikes the retina or film properly. Both the eye and the camera have a transparent lens. You learned in section 2.0 that double convex lenses collect light and direct it to a focal point. The lens must be in the right position in order to produce a sharp image. In the eye, muscles attached to the lens relax or contract to change the shape of the lens. Changing the shape of the lens adjusts the focal length so that light forms a focussed image on the retina. In automatic cameras, the lens is automatically moved forward or backward to adjust the focal length. On a manual camera, this movement is done by hand.

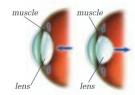


Figure 4.4 The ciliary muscles contract to lengthen the lens and relax to shorten the lens.

#### **IMAGE FORMATION**

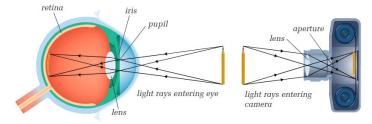


Figure 4.5 The images formed by the eye and by the camera are both upside down.

## **PESEARCH**

## **Artificial Eye**



The man pictured here is blind, and the apparatus he is wearing acts as an artificial eye. Find out how this technology works and what its drawbacks are.

Although the image formed on the retina is upside down, your brain corrects for this and interprets the world right side up. In a camera, it doesn't matter that the image is upside down. The film is removed and then developed whichever side up you like!

## CORRECTING VISION PROBLEMS WITH LENSES

Many people have trouble focusing their eyes properly. Most eye problems fall into two categories: farsightedness and near-sightedness. People who are farsighted cannot see close objects clearly. The eye cannot make the lens fat enough to focus light on the retina, and the image falls behind the retina. People who are near-sighted cannot see distant objects clearly. The eye cannot make the lens thin enough to focus light on the retina, and the image falls in front of the retina. People with these vision problems are usually prescribed eyeglasses or contact lenses.

Recall from earlier in this unit that light converges through convex lenses, and light diverges through concave lenses. By putting these lenses in front of the eye, you can alter the angle at which light enters the eye. For people whose lenses cannot converge light enough, convex lenses are prescribed. For individuals whose natural lenses focus light before it reaches the retina, concave lenses are prescribed.

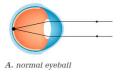
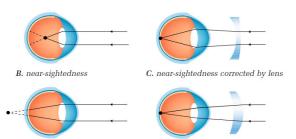


Figure 4.6 Near-sightedness and farsightedness can be corrected by wearing lenses.



E. farsightedness corrected by lens

LASER EYE SURGERY

D. farsightedness

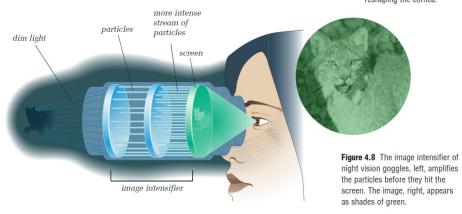
There are now options for people who don't want to wear glasses or contact lenses. Surgeons can use a laser to reshape the cornea of the eye. The doctor first cuts a thin flap of tissue covering the eye and folds it aside. Then the cornea, which is the clear outer covering of the eye, is reshaped with a laser (Figure 4.7). After surgery, the newly shaped cornea acts like a corrective lens, bending the light so that the natural lens can focus the light on the retina.

## NIGHT VISION GOGGLES

No matter how well your eyes can focus light, you can't see very well in low-light conditions. In night vision goggles, light is focussed onto an image intensifier. Inside the intensifier, the light energy releases a stream of particles. These particles then hit a phosphor-coated screen. The phosphors glow green when the particles strike them. The person wearing the goggles sees a glowing green image, as in Figure 4.8.



Figure 4.7 Laser surgery can correct vision by reshaping the cornea.



## CHECK AND REFLECT

- Make a chart that lists the parts of the eye and parts of the camera, and their function. What do the camera and the eye have in common? How are they different?
- There is an expression: "All cats are grey in the dark." Using your knowledge of how the eye works in low light, explain why this expression is true.
- 3. What does the laser surgery method of vision correction have in common with wearing glasses to correct vision?
- 4. If you wish to take a picture of faint stars in the night sky, how should you adjust your camera?
- 5. Describe how night vision goggles enhance human vision.

# 4.2 Other Eyes in the Animal Kingdom

Human eyes may form images the same way a camera does, but what about other types of animals? Do their eyes have the same design as human eyes? Do other animals' eyes even do the same thing as human eyes?

## Give it a TRY

## ACTIVITY

## ANIMAL EYES

Look carefully at the animals in Figure 4.9. Think about how each animal lives. Is it a predator or is it preyed upon by other animals? Does it live in water or air? in light or in darkness? Discuss these questions with your classmates and write down your observations.











• For each animal, what features do their eyes have that help that animal survive?

Figure 4.9

## CAMERA EYES

As you learned previously, the design of the human eye is roughly the same as a camera. For that reason, eyes that have a cornea, a lens, and a retina and are roughly round in shape are referred to as camera eyes. Most vertebrates (animals with backbones) have camera eyes. Depending on how the animal uses the eye, the structure of the camera eye can vary slightly.



Figure 4.10 A fish's eyes are on the sides of its head so they can see danger coming.

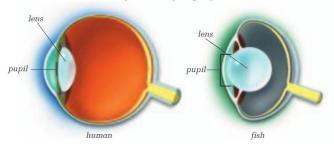


Figure 4.11 Fish have round lenses that stick out through the pupil.

Fish have camera eyes, but instead of an oval-shaped lens, they have a perfectly round lens, and as you can see in Figure 4.11, the lens bulges out through the pupil. Because the lenses stick out, a fish can see in practically every direction. This is useful because the fish has no neck and can't swivel its head to look for danger.

Birds tend to have much sharper vision than humans. Humans have three types of cones: one senses red light, one senses green light, and one senses blue light. Birds have five different types of cones, each sensitive to a different wavelength of light. This means that birds can distinguish many more colours and shades than humans can. Having sharp vision is useful for spotting food while in the air.



Figure 4.13 By having more photoreceptors in the retina, birds can see details more easily.

You may have heard that cats and owls can see in the dark. While these animals are awake at night, or **nocturnal**, no animal can see in complete darkness. The eyes of nocturnal vertebrates allow them to collect as much light as possible. Cats and owls have very large pupils, which allow in as much light as possible. They also have a layer inside their eyes called the *tapetum lucidum*, which acts as a mirror to reflect light inside their eye. Because they need to make their way about in low-light situations, nocturnal animals have more rods than cones in their retinas. Rods are far more sensitive to low levels of light than cones.

Vertebrates aren't the only animals with camera eyes. An octopus has no backbone, and so is an invertebrate. An octopus eye is very similar to a human eye, having a lens, a cornea, and a retina. However, the lens does not change shape to focus. The lens is moved toward and away from the retina.



Bee's Eye View





Some animals, such as honeybees, can see ultraviolet light. These two pictures are of the same flower. The lower image is viewed with a UV-sensitive camera.



Figure 4.14 Octopuses have camera eyes.



**Figure 4.15** The compound eye has many ommatidia.

## reSEARCH

## Four-eyed Fish



This fish is called a four-eyed fish. Use print sources and the Internet to research the fish and find out how it lives. Does it really have four eyes?

## COMPOUND EYES

Insects and crustaceans (shrimps, lobsters, and crayfish) have compound eyes. If you look closely at the eyes in Figure 4.15, you will see that each eye is made up of many smaller units. Each individual unit is called an ommatidium. An ommatidium looks like a long tube with a lens on the outer surface, a focussing cone below it, and then a light-sensitive cell below that (Figure 4.16). When the light-sensitive cell fires, it sends a message to the animal's brain through nerve fibres.

Insect eyes tend to have a convex surface, so ommatidia lenses face in almost all directions. This makes the compound eye excellent at detecting any motion. As light moves across a compound eye, there is a corresponding change in the ommatidia detecting light. Have you ever noticed how difficult it is to swat a fly?

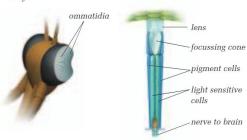


Figure 4.16 The ommatidia make the compound eye very sensitive to movement.

While the compound eye is great at spotting movement, it has drawbacks. Multiple lenses make it difficult to form a single, coherent image. The image formed by a compound eye is somewhat like a TV screen. The image is made up of lots of small dots of light. That's why the image formed by a compound eye is referred to as a "mosaic image." So the number of ommatidia affects how clear an image a compound eye can produce. The more ommatidia, the more detailed the image. While ants have relatively few ommatidia in an eye, the dragonfly has 10 000!

## CHECK AND REFLECT

- 1. How is a human eye similar to and different from a bird's eye?
- 2. How is a compound eye different from a human eye?
- 3. How does an ommatidium help an insect to survive?

# 4.3 Image Storage and Transmission

Imagine a snowboarder whizzing through fresh powder in the Rockies. How were you able to picture the scene? Your brain plays a big role in sorting, storing, and retrieving information about images you have seen. The brain receives and sends signals as electrical impulses travelling along neurons. Unfortunately, scientists still don't understand exactly how those images are stored in the brain, or why some images remain stored for long periods, while other images fade quickly.

If you wish to recall images completely and accurately, you need some other method that will keep all the information intact.





Figure 4.18 Photographs can fade over time.

Traditional photography seems like a good way to capture an image forever, but does it really last? Photographic negatives and film rely on chemicals to store information. Over time, chemicals can react and change. The picture on the left represents the original appearance of a photo taken about 75 years ago. On the right is how it appears today. How do you think it will look 50 years from now? So photography can fade over time.

Most information today is stored digitally. What is digital storage? The answer is quite simple. If you take any form of information and convert it into numbers, that's digital! Think about it: "digits" are numbers, right? This is how a computer stores all of its information, including images. How though, does a computer convert an image into numbers?



Figure 4.17 Like it or not, your brain has now stored this image!

## info**BIT**

## Who Is It?



Large pixels in a small image create such a poor-quality picture that it's difficult to make out who is in the picture. But poor-quality images can be useful. TV producers sometimes reduce the picture quality on purpose in order to hide a person's identity.

## STADIUM IMAGES



Figure 4.19 Thousands of small cards of different colours are used to form one big image.

Have you ever seen people in a stadium form a large image? Each person in the stands holds up a coloured card. When viewed from across the stadium, all these cards form a large picture. Up close, all you see are lots of big, coloured cards.

Creating stadium pictures takes a lot of organization. If the different coloured cards were given out randomly, the stadium picture would be just a jumbled mess of different colours and no image would be formed. To make sure the image turns out, each card is given an "address" based on the seat row and seat number. This is like the coordinates in graphing (x and y coordinates). That way, if the cards get jumbled up, their correct placement will always be known (row 3, seat 5).

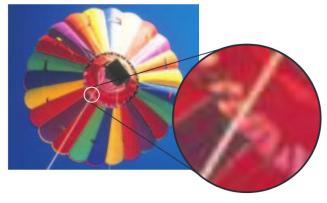


Figure 4.20 Part of the image on the left has been magnified to show the individual pixels that make up the image.

## **DIGITAL IMAGES**

This process of creating a big picture out of small pieces is similar to the process of digital imaging. When a computer receives an image, it divides the picture up into small elements called pixels (short for picture elements), much like the individual cards in the stadium picture. Each pixel is assigned coordinates just like the row and seat numbers for a stadium seat. Now the computer has reduced the picture to a series of numbers. This long series of numbers can be stored and saved in a computer. If someone wants to re-create the image, the computer reads all the coordinates, and reassembles the pixels in the correct order.

## COLOURING A DIGITAL IMAGE

Getting the individual pixels in the right order is only half the task of creating a digital image. In stadium pictures, there are many different colours of cards. In digital imaging, the computer assigns a value to each pixel. This number corresponds to a certain colour. When the picture gets assembled, the computer reads the value of each pixel and makes the pixel that particular colour. If an image is black and white, the value assigned to each pixel corresponds to a shade of grey instead of a colour.

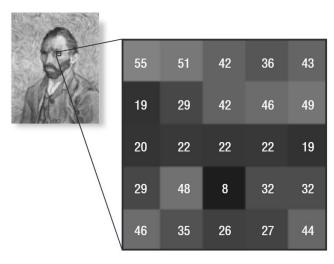


Figure 4.21 A digital image (left) is composed of pixels. Each pixel has a numerical value assigned to it (right). The picture is actually a long list of numbers.

## IMAGE QUALITY, PIXEL BY PIXEL

The quality of a digital image can have great consequences. For example, if your doctor was using a medical image to diagnose your condition, you would want that image to be high quality (that is, having lots of pixels), showing as much detail as possible.

Look at each of the four images here. Which is the best quality? Which is the lowest quality? How can you rank the images in terms of their quality? Counting pixels is one way. Use a ruler and pen to make a 5 mm  $\times$  5 mm square on a sheet of clear acetate. Lay this square over each picture in turn and count the pixels in the square. What do you find about the relationship between pixel number and image quality?









Figure 4.22 Count the pixels in these images.

## DIGITAL IMAGE QUALITY

The quality of a digital image depends on the size of the pixels that make up the image. If the pixel size is large, then you will notice that the image is made up of small squares, and you won't be able to see much detail in an image. If two images are the same size, the one with more pixels will look better. A poorer quality digital image has a low **resolution**. The resolution of an image refers to the number of pixels per unit area. The greater the number of pixels in an area, the higher the resolution, and so the higher the quality of the image.





**Figure 4.23** The number of pixels in an image is related to image quality. Can you see the individual pixels in the photo on the left?

## math Link

If a digital image is 720 pixels by 640 pixels, how many pixels does the image have? If you wanted to keep the pixel size the same, but double the width and length of the picture, how many pixels would the image have to have?

## CAPTURING DIGITAL IMAGES

Scanners, digital video recorders, and digital cameras all use roughly the same method of capturing images. They all work like a regular camera: light enters through an aperture and falls onto a light-sensitive surface. The major difference between regular cameras and digital cameras is that instead of the light falling on film, it falls onto a **charge-coupled device** (CCD). The CCD is a grid similar to a piece of graph paper. As light falls on a square of the grid, it creates a small amount of electricity in that square. This electrical charge is converted into digital information. Once the image is converted into numbers, this digital information can be stored in a computer hard drive, a compact disk, or digital tape.

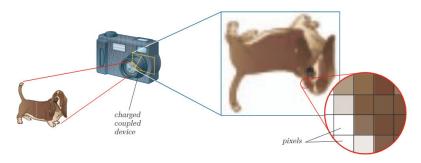
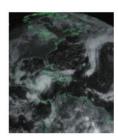


Figure 4.24 The numbers in each of the squares of the charged coupled device represent the colour value assigned to that square.



**Figure 4.25** Digital images of weather systems are transmitted from space.

## reSEARCH

## Space Maps

NASA's Shuttle Radar Topography Mission (SRTM) collected radar data of Earth's surface to create detailed images of Earth. Use the Internet to find out more about the mission and how they created images from radio waves.

## TRANSMITTING DIGITAL IMAGES

The powerful thing about digital information is that you can send it much farther than your hard drive. If you've watched the weather on TV, you've probably seen satellite pictures of weather systems. These pictures are taken from satellites orbiting Earth. If the satellites took pictures with regular film, how would we get the pictures? It would have to be sent back to Earth to get processed by a lab—not very practical! That's the real advantage of digital imaging. These satellites have digital cameras, which capture images, turn them into digital information, and beam the information to computers here on Earth. Computers decode the digital information to reassemble the pictures.

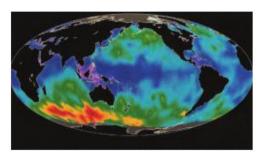


Figure 4.26 This digital image of the world's oceans was created from radar data gathered by satellite. The different colours represent different wave heights.

Another advantage of digital imaging is that digital cameras can be created to collect different parts of the electromagnetic spectrum. For example, some digital cameras can capture infrared radiation. Digital imaging using the various wavelengths allows us to gather huge amounts of information about our planet.

## CHECK AND REFLECT

- 1. Why is digital imaging a good way of storing pictures?
- 2. How does a computer create a digital image?
- 3. What is a pixel?
- 4. What does it mean to have an image of "high resolution"?
- 5. Why can enlarging a picture on a computer screen lower the quality of the image?
- 6. How does a digital camera work?

## SECTION REVIEW

## **Assess Your Learning**

 Match each part of the eye with the part of the camera that performs the same or similar function. Describe the function for each pair of parts.

Parts of the eye	Parts of a camera	
retina	lenses	
pupil	aperture	
iris	film	
eyelid	shutter	
lens	diaphragm	

- 2. It is possible for the retina to detach from the back of the eye (Figure 4.27). What would the effect of a retinal detachment be on someone's vision?
- 3. What is near-sightedness? How can it be corrected?
- 4. Describe a technology that enhances vision. How does it work?
- 5. In what ways is an insect's eye superior to that of a human? In what ways is it inferior?
- 6. Why does it take less computer memory to store a lower resolution image compared with a higher resolution image?
- 7. How does digitizing images make it easy to transmit images?

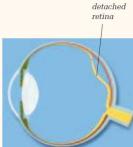


Figure 4.27 Question 2

## Focus On

## THE NATURE OF SCIENCE

The sharing of scientific knowledge and discovery allows for further investigation and knowledge. Accumulated knowledge is adjusted as more information and evidence is gathered.

- 1. How can digital imaging technology help scientists gather data?
- 2. How is the digital camera modelled after a traditional camera?
- 3. How has the digital camera and digital storage changed the way scientific information is shared?

# Optics in Space!

## The Issue

A large part of Russia's land mass lies in the far north. Two things make life difficult in this part of the world: cold temperatures and long, dark winters. In 1999, the Russian Space Agency (RSA) tried to do something about it by launching a 25-m-wide mirror from the *Mir* space station, and sending it into orbit around Earth. The mirror was designed to take advantage of the sun's light and the law of reflection by directing solar energy onto a small band of northern Russia and Europe.

But, as the mirror was released from *Mir*, the deployment mechanism got tangled, and destroyed the mirror. However, the RSA might try launching another mirror in 2004.



An artist's view of the space mirror

## Should space mirrors be used to light up the north?

Should space mirrors be used to light up the north:		
Yes, they should.	No, they shouldn't.	
Space mirrors would provide more daylight during northern winters. More daylight would increase productivity and allow for more outdoor activities for longer periods.	Space mirrors would worsen light pollution. Light from the space mirrors could make many areas useless for astronomy.  Increased radiant energy from space mirrors could alter ecosystems irreversibly. Many plants and animals are adapted to a short summer and a long winter.	
More light could provide enough energy to keep northern ports from freezing each winter. If the ports were open all year, it would make it easier and less expensive to provide goods and services to northern communities.		
Increased light levels would help people cope with northern existence. Many who live in northern communities suffer from lack of sunlight. Seasonal Affective Disorder (SAD) can result from not receiving enough daylight.	Many space mirrors could lead to exploitation of space. Some fear this use of mirrors may lead to other space exploitation, such as orbiting advertising.	

## Go Further

Now it's your turn. Use the following resources to help you form your opinion.

- Look on the Web: Find out as much as you can about space mirrors and northern communities, using the Internet.
- Ask the Experts: Many astronomers are available through question-and-answer sites on the Internet. Is there a local observatory you can consult? Perhaps there is an astronomy department at a university, or an astronomy club you can contact.
- Search Print Media: Check for articles regarding this issue in newspapers and magazines.

## **In Your Opinion**

Write a letter to the RSA stating your point of view. Whatever your opinion, you should support your views with facts

Unit C: Light and Optical Systems

# Unit SUMMARY: LIGHT AND OPTICAL SYSTEMS

## **Key Concepts**

## 1.0

- microscopes and telescopes
- contribution of technologies to scientific development

## 2.0

- transmission and absorption of light
- · reflection and refraction
- · images

## 3.0

- electromagnetic spectrum
- transmission and absorption of light
- · colour and wavelength
- · sources of light

## 4.0

- · vision and lenses
- · reflection and refraction
- · imaging technologies
- images

## **Section Summaries**

## 1.0 Our knowledge about light and vision comes from explanations, inventions, and investigations.

- Scientists have been challenged by light for centuries, and have done experiments to explain how light and vision work.
- Optical devices, such as microscopes and telescopes, have led to improvements in our understanding of light as well as improvements in astronomy and microbiology.

## 2.0 Light behaves in predictable ways.

- Ray diagrams are a useful way to describe light. Transparent materials transmit light, translucent materials transmit only some light, and opaque materials absorb or reflect light.
- . When light reflects off a surface, the angle of incidence equals the angle of reflection.
- Light rays reflected off a concave mirror converge at a focal point. Light rays reflected off a convex mirror diverge, or spread out. Concave mirrors are found in many useful devices such as car headlights and flashlights.
- When light passes at an angle from one medium to another medium of a different density, the light rays refract. This bending is caused by light slowing down or speeding up as it enters the new medium.
- Convex and concave lenses are optical devices that refract light to form images. The formation of an image depends upon how far the object is from the lens.

## 3.0 Light is part of the electromagnetic spectrum and travels in waves.

- Light has the properties of a wave. Visible light is composed of different wavelengths of light, which form the colours of the rainbow.
- Visible light forms a small part of the electromagnetic spectrum. Other forms make up the
  invisible spectrum. They are radio waves, microwaves, infrared, ultraviolet, X-rays, and gamma
  rays. Radio waves carry the least amount of energy; gamma rays, the most. All parts of the
  invisible spectrum have technological applications.
- Visible light can be produced naturally and artificially. Natural sources are bioluminescence and sunlight. Artificial sources of light include incandescent bulbs and fluorescent bulbs.
- White light can be created by combining the light of the three primary colours: red, green, and blue. Different combinations of these colours produce various secondary colours.

## 4.0 Eyes and cameras capture images using the properties of light.

- The human eye is similar to the camera: both are designed to capture and focus light to form an image on light-sensitive material. There are technologies that correct vision problems or enhance human vision.
- The human eye is similar to other vertebrate eyes, though the design changes slightly in different groups of animals. Insects have compound eyes made of many tiny lenses. They are excellent at detecting motion.
- Digital images are images created by computer. An image is converted into pixels, which is a set
  of numbers. Digital images are useful because they can be stored and transmitted by
  computers.

Unit Summary



## LIGHT RAYS THROUGH LIQUIDS



Some materials and equipment you might consider using

## **Getting Started**



Experiments offer many opportunities to discover answers for yourself. In this activity, you will plan and carry out your own experiment, based on your own "what happens" question. Using optical instruments and your choice of materials, you will determine what will happen when light rays strike a variety of different liquids. You may wish to refer to Toolbox 2 for further information on planning an experiment.

## Your Goal

To determine what happens to a ray of light as it is transmitted through different liquids.

## What You Need to Know

This activity involves asking questions about what happens to light when it travels through different media, planning your own experiment to investigate one of these questions, and drawing your own conclusions from the data you collect. Use the question, "What will happen to a ray of light when I pass it through a liquid?" to help you brainstorm all the questions you have about the behaviour of light in liquids. Carefully examine all the questions you have come up with and pick one you would like to investigate further.

## Steps to Success

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1 Select a question and write a hypothesis. Then, plan an experiment to test your hypothesis.

- 2 Make sure your experiment is a fair test of your hypothesis. How will you know?
- 3 Decide what equipment you will need. Are there liquids and materials you can collect from home? Ask your teacher for help with any other materials that you cannot collect yourself.
- 4 Carefully consider any safety issues involved in performing your experiment. Make sure you are fully prepared to handle all materials properly.
- Write up the step-by-step procedure you will follow to perform your experiment. Obtain your teacher's approval before you begin your experiment.
- 6 Decide how you will record your results clearly. Prepare any charts, tables, graphs, or sketches you will need.
- 7 Explain how you decided on your experimental method. Which variables did you control? Which variable did you change?
- 8 What is the meaning of the data you collected? Can you think of other interpretations for the data?

## How Did It Go?

9 Now that you have planned and carried out an experiment, write a summary statement that answers the question you posed. Remember to use your data and observations to support your answer.

Unit C: Light and Optical Systems



## Unit Review: Light and Optical Systems

## **Unit Vocabulary**

 Create a concept map that shows how each of the following terms are connected.

light angle of incidence luminous angle of reflection transparent wavelength opaque frequency light year bioluminescence mirror

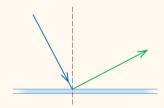
## **Check Your Knowledge**

1.0

- 2. Why was the invention of the microscope so important?
- 3. Describe how binoculars work.
- 4. If you shine a flashlight in a dark room and sprinkle talcum powder in front of the flashlight, what property of light does it show?

2.0

5. Does the green ray in the illustration below obey the law of reflection? How do you know?



6. Look at the illustration below. The bad guy has set up some mirrors in the park so he can spy, unseen, on the good guy. The line indicates the way light could travel. Will the bad guy's plan work? Explain.



- Explain why you agree or disagree with the following statements. For any you disagree with, provide the correct statement.
  - a) The normal is drawn at a 90° angle to the mirror or lens.
  - b) When light is reflected from a curved mirror, the angle of incidence is twice the angle of reflection.
  - c) If you want to see farther into space, build a telescope with a bigger convex mirror.
  - d) The two main lenses of the microscope are the eyepiece and the objective.
- 8. Is light transmitted through frosted glass? Explain.
- Which substance would refract light more: water or glass? Draw a ray diagram for each.

Unit Review

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## UNIT REVIEW: LIGHT AND OPTICAL SYSTEMS

## 3.0

10. The diagram below represents the wavelengths of the electromagnetic spectrum. Copy this diagram, and place infrared, microwaves, X-rays, ultraviolet, radio waves, gamma rays, and visible light on the diagram in the correct order.

- 11. What happens to light when it passes through a triangular prism?
- 12. What colour of light would you observe if you combined equal bright-intensity lights of the three primary colours?
- **13.** What is the relationship between wavelength and frequency?
- 14. What type of radiation is detected in a thermogram? Explain how a thermogram could be useful.
- Explain the difference between a filament and a photophore.

## 4.0

- 16. You are standing outside in the dark, waiting for a fireworks display, and an extremely bright flash goes off right above you. Explain what the pupil of your eye likely looked like before and during the flash.
- 17. Use a ray diagram to explain why the image formed on your retina is upside down. If the image on the retina is upside down, why don't we see the world upside down?

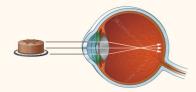
- Based on what you know about the camera, explain the following observations.
  - a) To take a picture in dim light, you must open the aperture wide.
  - b) To take a picture in very dim light, you leave the shutter open a long time.
  - c) Unexposed film must be carried in a lightproof container.
- 19. Looking directly at the sun can blind you. What structure of the eye would be most damaged by looking at the sun? Explain.
- **20.** How are pixels in a digital image related to image quality?

## **Connect Your Understanding**

- 21. A friend tells you that he used a mirror to "collect" light. Did he use a concave, flat, or convex mirror? Draw a diagram to explain the concept of "collecting light."
- 22. Draw a ray diagram and provide a short explanation that helps explain why it is sometimes difficult to accurately grab a coin that is underwater in a pond.
- 23. You observe a camper trying to start a fire using a concave lens. Will this work? Explain.
- 24. Your friend heads out for a late evening bicycle ride on the highway. She can't decide whether to wear her black sweater or shiny yellow vinyl windbreaker. What would you suggest? Why?
- 25. A flashlight does not lose power as you walk away from it, but as you get farther

- and farther away, it appears to be less and less bright. Explain.
- 26. Many grocery stores carry "reading glasses" that you can buy to help you read small print. What kind of lenses do you think these glasses use? Explain.
- 27. A new company called We-See-in-the-Dark Security has just started advertising in the local newspaper. Its logo is a swooping eagle. From a science point of view, explain why this is not the correct symbol for advertising what the company says it does. What other animal do you think would make a more accurate symbol for the company?
- 28. Your uncle has volunteered to photograph local people and scenes as a part of a cultural preservation project. What might you tell him to convince him that he should carry out the job using digital photography rather than traditional photography?

## **Practise Your Skills**



- 29. a) What type of vision problem does this eye have?
  - b) Copy the diagram into your notebook. Add a correcting lens to your diagram and show how the lens bends the light rays to focus the image on the retina.

## **Self Assessment**

- **30.** Are there any optics-related issues or questions you'd like to explore further?
- 31. Is there anything you could do to improve the quality of your work in the activities and investigations you did?
- 32. Is there anything you could do to improve the way you work in a group in class?
- 33. Do you think that using optical systems could affect the environment? Why or why not?

# Focus

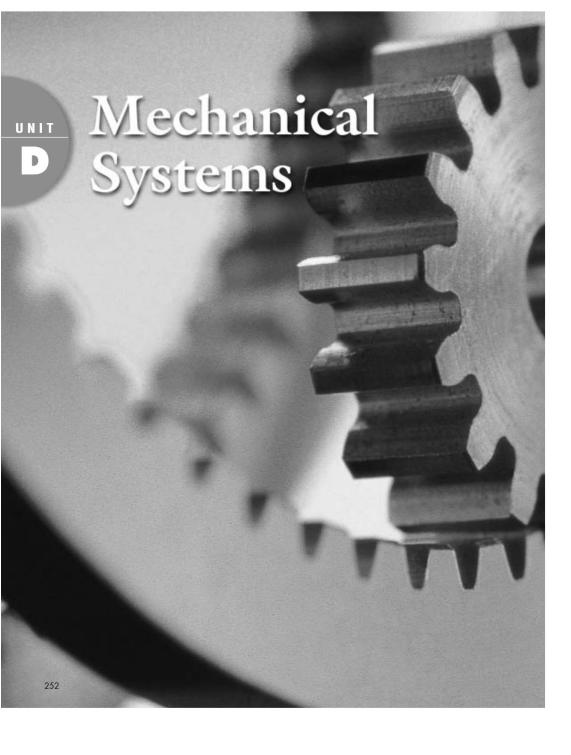
## THE NATURE OF SCIENCE

In this unit, you have investigated the nature of science while learning all about light and optical systems. Consider the following questions:

- 34. Turn back to the Focus on the Nature of Science on page 175 of this unit. Use a creative way to demonstrate your understanding of one of the questions.
- 35. What models and theories have you learned about that help you understand the nature of light?
- 36. Scientific knowledge is a result of the shared work of many people over time. Use examples you've learned about to show that this is true.

Unit Review

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In this unit, you will cover the following sections:

Machines are tools that help humans do work.

- **1.1** Simple Machines—Meeting Human Needs
- **1.2** The Complex Machine—A Mechanical Team

An understanding of mechanical advantage and work helps in determining the efficiency of machines.

- 2.1 Machines Make Work Easier
- 2.2 The Science of Work
- 2.3 The Big Movers—Hydraulics

Science, society, and the environment are all important in the development of mechanical devices and other technology.

- 3.1 Evaluating Mechanical Devices
- 3.2 Technology Develops through Change

# Exploring



The Da Vinci robotic arm allows surgeons to operate through small incisions. It also makes operating at a distance possible.

In July 2000, the first surgical robotic arm was approved for use in North America. Named "Da Vinci," this device helps surgeons perform operations inside people through very small incisions. This type of surgery is called "remote surgery" because the surgeon is not directly touching the patient. In fact, with this new system, the surgeon doesn't even have to be in the same room with the patient. The surgeon can do the operation from another location. The patient's local doctor needs only a connected computer, a video terminal, and the Da Vinci arm.

## MECHANICAL ARM PROVIDES MORE CONTROL

The robotic arm is inserted through one small incision, and a tiny camera is inserted through a second incision. The surgeon then watches on a television screen to perform the operation. The Da Vinci robotic arm has a built-in "wrist" for flexibility. This feature and the size of the arm make it easier for surgeons to work on smaller tissues, such as nerves or blood vessels. With Da Vinci's help, surgeons can work in very small spaces and not worry about trembling from tired hands! The surgical robotic arm gives surgeons more control during surgery than ever before.

Benefits to patients include less recovery time for major operations. In the past, doctors had to make large incisions that would completely expose the organ they were operating on. The tiny incisions in a Da Vinci—assisted operation mean that the patient will heal more quickly.



The Da Vinci arm has a flexible mechanical "wrist" so that it can make the necessary movements for surgery.

Exploring

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## A SYSTEM OF COMPONENTS WORKING TOGETHER

Remotely controlled machines, such as the Da Vinci surgical system, rely on several smaller components and technologies in order to work. A computer controls the instruments as if the surgeon was controlling the very tip of the scalpel in person. The motions of the surgeon's hands are transferred to hydraulic pumps and electric motors that control the scalpel, drill, and scissors at the end of the robotic arm. The sensitivity of the tools is adjusted by combinations of miniature gears, levers, and pulleys.

The development of a complex machine such as a robotic arm is the result of teams of people working together. They use their knowledge of mechanical systems and apply the latest technology to solve problems.

## Give it a TRY

## ACTIVITY

## EMERGENCY!

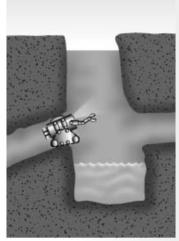


Now you have an opportunity to work as part of a team in solving a problem. You and your group are part of the Emergency Robotic Environmental Response unit at RoboQuest Inc. An accident has just occurred. A robotic probe exploring a mining drainage pit has become wedged in a small passage. The probe is very heavyabout 100 kg. Your task is to retrieve the probe without damaging it. You can see from the diagram of the accident site that this will be a challenge.

Design a device that can help you extract the probe. Include the equipment listed below in your design:

- · a mechanical arm
- · steel beams about 2 m long
- · an assortment of gears
- · an assortment of pulleys with ropes

Before you start, read through Toolbox 3 to learn about problem-solving techniques.



The accident site

# Focus

## SCIENCE AND TECHNOLOGY

As you work through this unit, you will learn how machines help us do a variety of tasks. You will work with different mechanical systems to identify their components. You will also determine their impact on you and on the environment. Through this work, you will be able to understand better how science and technology are related. Scientific knowledge leads to the development of new technologies. In turn, new technologies lead to scientific

The activities in this unit focus on your developing solutions to practical problems. Often these problems have more than one possible solution. You will learn to evaluate the options to find the best solution. You will also develop your problem-solving skills as you analyze working models of different types of machines to determine their strengths and weaknesses. At the end of the unit, you will use your understanding of mechanical systems and your skills in a final project. In this project, you will build a working prototype of a mechanical gripper device.

As you work through this unit, use the following four questions to guide your learning about mechanical systems:

- 1. How is energy transferred in mechanical devices?
- 2. How do mechanical devices provide for the controlled application of force?
- 3. How do mechanical devices work efficiently and effectively to meet human needs?
- 4. What are the social and environmental impacts of mechanical devices?





# 1.0

# Machines are tools that help humans do work.

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

- · systems and subsystems
- transmission of force and motion
- simple machines

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

- describe examples of mechanical devices used in the past to meet particular needs
- describe an example of how a common need has been met in different ways over time
- analyze a mechanical device by describing how different parts contribute to its overall function and identifying the parts that are simple machines
- identify the sources of energy for some familiar mechanical devices
- identify linkages and transmissions in a mechanical device and describe their general functions



Since farming began over 7000 years ago, humans have been creating ever more sophisticated tools and machines. Machines help people use energy more effectively. In other words, a **machine** is a device that helps us do work.

The combine harvester shown here was developed to make harvesting crops easier and quicker for farmers. Early combines were pulled by horses or tractors. Later they were motorized, and today they are computerized and air-conditioned as well. Developments in technology for control systems, motors, materials, and other areas have all contributed to the design of these new combines.

In this section, you will learn about simple machines and how they help people perform tasks. You will learn that simple machines can work together in a system to form a complex machine. You will also discover how linkages and transmissions transfer energy in machines.

# 1.1 Simple Machines — Meeting Human Needs

The earliest machines were very simple devices. For example, people used levers to pry rocks out of the ground. Then they used a ramp to help them raise the rocks as they built walls and other large structures. Each machine was designed to meet specific needs, such as lifting rocks or splitting wood. Although each machine was different, they all had one thing in common. These first machines depended on people or animals for their source of energy.

Working with a partner, try to determine what tasks the historic machines in Figure 1.1 were used for and how they worked. Look for clues in the pictures, or research the names of the machines to find out what needs these machines were designed to meet. Also, try to determine the approximate time periods when these machines were used.







Figure 1.1a) Mill wheel

Figure 1.1b) Nutcracker

Figure 1.1c) Plow

## infoBIT

## Roman Aqueducts

Thousands of years ago, Roman engineers developed a mechanical system for transporting water for many kilometres to supply major cities. These structures, known as aqueducts, were made up of three main parts:

- 1. pumps to raise the water into reservoirs and control the rate of water flow
- 2. sloped channels to carry the water to the cities
- distribution systems in the cities to carry the water to central bathhouses and local reservoirs

The aqueducts were so well designed and constructed that many of them can still be seen today in Europe, more than 2000 years after they were built!



## MEETING THE SAME NEED IN DIFFERENT WAYS

One of the most basic human needs is fresh water. You have running water in your home because of a combination of mechanical systems. These systems move water from its source, through a series of pipes, to your tap. Pumps powered by electricity keep the water moving.

Before pumps were available, people used gravity to move water. Water was stored in large, raised tanks. Gravity caused it to move down from the pipes through tanks to where it was needed in the community.

In the past, one of the most common ways of raising water into these tanks was a type of water wheel called a *sakia* (also called a Persian wheel). A sakia has a series of buckets attached to a long rope, which is draped over a large wheel. Animals such as donkeys, camels, or cows turned the wheel, which raised the buckets of water.

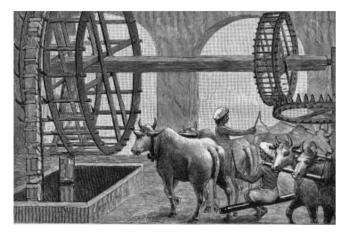


Figure 1.2 A sakia can be used to haul water out of a well for storage in large tanks or for irrigation.

## ARCHIMEDES INVENTS A MORE EFFICIENT WAY

Although the sakia worked well in lifting water, people were always looking for more efficient ways to do this task. One of these methods was invented by the famous Greek scientist and mathematician Archimedes. His device used a large screw inside a tube. One end of the tube is placed in water. When the screw turns, it raises water up to the top of the tube. Called an Archimedes screw, this device can move large volumes of water or other substances. Originally it was powered by hand. Today it is powered by gasoline or electric motors.

Hundreds of years later, the famous Italian scientist Leonardo da Vinci designed a water lift using two Archimedes screws to raise water up to a storage tank in a water tower. His original plans are shown in Figure 1.3. The Archimedes screw is still in use today. Figure 1.4 shows a modern example of an Archimedes screw being used to move grain into a truck.





Figure 1.3 Leonardo da Vinci's design for using two Archimedes screws to raise water up into a water tower.

**Figure 1.4** The spiral motion of the slowly turning screw moves the grain into the truck.

## SIMPLE MACHINES

The earliest machines, known as simple machines, are still used today. A **simple machine** is a tool or device made up of one basic machine. In their work, engineers must be aware of the strengths and limitations of each type of simple machine. This knowledge enables them to design combinations of these machines to do complicated tasks.

Before you read about the advantages and disadvantages of each simple machine, make a chart in your notebook similar to the one below. Fill in your chart as you read about the different machines.

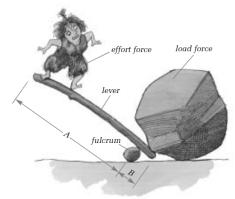
Simple Machine	Advantages	Disadvantages
lever		

There are six simple machines that help us do work: the lever, inclined plane, wedge, screw, pulley, and wheel and axle. Each one is used for specific tasks. Each has its own advantages and disadvantages.

## Lever

The **lever** is a rigid bar or plank that can rotate around a fixed point called a *pivot* or *fulcrum*. Levers are used to reduce the force needed to carry out a task such as pulling a nail, opening a bottle, hitting a baseball, and cutting paper. With a lever you can move a larger load than you could without using it. However, to do that, you must move a greater distance than the load does.

Figure 1.5 The lever is one of the simplest and oldest tools ever used by humans. This drawing shows one way that levers help to move objects. In this example, part A of the lever is seven times longer than part B. This means the force needed to move the object will be one-seventh of the force needed to move the object without using the lever. But look how much farther the person applying the force has to move compared with the distance the rock will move.



Levers can be labelled in three different ways, according to the location of the fulcrum and the load being moved. Figure 1.6 shows the three kinds or classes of levers. A first class lever has the fulcrum between the load and the point where the effort is exerted to move the load. A second class lever has the load between the effort and the fulcrum. A third class lever has the effort between the load and the fulcrum.

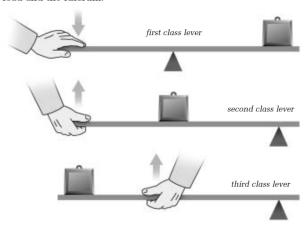


Figure 1.6 Different ways of using a lever

## Inclined plane

Imagine that you had to lift a very heavy box from the floor onto a table. You would have to exert a large force to lift it straight up from the floor onto your desk. An **inclined plane** or ramp would make it easier for you to move the box up onto the desk. An inclined plane makes it possible to lift heavy objects using a smaller force. However, you have to exert the force over a larger distance, compared with lifting the object straight up. As well, a ramp is generally useful only for small inclines. The steeper the angle of a ramp, the harder it is to control the motion of an object as it moves up or down the ramp. Examples of inclined planes include loading ramps on buildings and wheelchair access ramps.

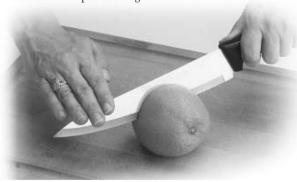




Figure 1.7 An inclined plane or ramp can help move large, heavy objects that are too heavy to lift straight up.

## Wedge

A wedge is similar in shape to an inclined plane, but it is used in a different way. The wedge machine is forced into an object. By pressing on the wide end of the wedge, you can exert a force on the narrow end so it splits an object apart. The wedge increases the force that you apply on the object. But it moves a greater distance into the object than the split it causes. Unlike the ramp, a wedge can be used only in one direction: to push objects apart. Knives and axes are examples of wedges.



**Figure 1.8** A knife blade is a very thin wedge.

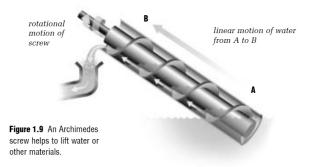
Machines Are Tools That Help Humans Do Work

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## Screw

A screw is a cylinder with a groove cut in a spiral on the outside. Using a screw helps you increase the force you use. It can penetrate materials using a relatively small force. A screw can also be used for converting rotational (turning) motion to linear motion (motion in a straight line). You saw an example of this earlier in the pictures of the Archimedes screw. Figure 1.9 shows how the screw moves in a spiralling motion. This is the rotational motion. However, the screw is also moving the water along a line from point A to point B. Most screws will move objects very slowly.



## reSEARCH

## **Early Tools**

Many of the tools used by Canada's earliest inhabitants were simple machines. Using resources available in your library or on the Internet, identify a tool that was used by Aboriginal peoples in Canada before the year 1800. Once you have identified a tool, determine what needs the tool met, and the simple machine(s) it contained.

## Pulley

A pulley consists of wire, rope, or cable moving on a grooved wheel. Pulleys may be made up of one or many wheels and can be fixed in place or movable. They can be linked together in systems for moving and lifting objects. Pulleys help you lift larger loads than you could lift on your own.



 $\textbf{Figure 1.10} \ \ \text{Two types of pulleys}$ 



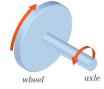
**Figure 1.11** Pulleys make it possible to lift large, heavy loads.

## Wheel and Axle

The wheel and axle is a combination of two wheels of different diameters that turn together. A longer motion on the wheel produces a shorter but more powerful motion at the axle. The steering wheel and steering column in a car together form a wheel and axle. That combination is one example of using a wheel and axle to increase the size of a force. The drawback is that you have to turn a greater distance (a larger wheel) to apply the force. A wheel and axle can also be used to increase speed. Wheels on bicycles are examples of using this simple machine to increase speed. The rider exerts a large force to turn the axle, which causes the bicycle's wheel to turn. The rider moves faster on the bicycle than without it.

Figure 1.12 A doorknob is a wheel-and-axle machine. Which part is the wheel and which part is the axle?





Machines Are Tools That Help Humans Do Work

# Inquiry Activity

## Materials & Equipment

- 30-cm string
- 1-kg mass
- 20-N spring scale
- ramp
- · 60-cm string
- pulley system
- pulley 3y3t
- metre-stick
- 10-cm string
- pivot or fulcrum



**Figure 1.13** Step 4. Pull the mass steadily up the ramp.

# Figure 1.14 Step 6. Use the pulleys to lift the mass up 10 cm.

## THE RIGHT MACHINE FOR THE JOB

## Before You Start ...

Have you ever tried to lift a very heavy object? Did you need to have another person help you, or maybe you used a lever or a ramp to help you? These devices are both simple machines. In this activity, you will investigate a variety of simple machines and determine which machine is best suited for lifting a mass.

### The Question

Which simple machine requires the least amount of force to lift a 1-kg mass?

### Procedure

## Station 1. Lifting without a Machine

- Tie a loop at one end of the 30-cm string, so the loop fits over the hook on the spring scale. Tie the other end of the string to the 1-kg mass.
- 2 Lift the spring scale just until the mass is hanging from the scale. Now slowly raise the load 10 cm. Measure and record the force needed to lift the mass.

## Station 2. Lifting with a Ramp

- Set up the ramp so that the highest point of the ramp is 10 cm above the top of the surface it's sitting on.
- Place the mass on the bottom of a ramp and attach the loop of string to the spring scale again. With your hand at the top of the ramp, pull the mass steadily up the ramp. Measure and record the force needed to raise the mass.

## Station 3. Lifting with a Pulley System

- Tie one end of the 60-cm string to the mass. Place the mass on a table below the pulleys and thread the string between the pulleys.
- Tie a loop at the loose end of the string and attach the string to the spring scale. Use the pulleys to raise the load 10 cm. Measure and record the force needed to lift the mass.



## Station 4. Lifting with a Lever

- Place the metre-stick on the fulcrum so that the fulcrum is in the middle of the metre-stick. Hang the mass from one end of the lever. Use the 10-cm piece of string to make a loop and attach the spring scale to the opposite end of the lever. This end of the lever should be far enough above the table or the floor so you can use the spring scale to pull down on it.
- 8 Pull down the spring scale so the lever raises the mass at the other end. Record the force need to lift the mass.
- Ohange the location of the fulcrum under the metre-stick and repeat step 8.



Figure 1.15 Step 7. The metre-stick is now acting as a lever.

## **Collecting Data**

- 10 Record the force needed to lift the mass in each case.
- 11 Record your observations of the differences when you changed the position of the fulcrum under the metre-stick.

## Analyzing and Interpreting

- 12 What was the most difficult method of raising the mass? What was the easiest method? Why do you think that is?
- 13 For the lever (the metre-stick):
  - a) What effect does the location of the fulcrum have on the force you must use to lift the mass?
  - b) What effect does the location of the fulcrum have on the distance that your hand moved and the mass moved?
- 14 What feature of the lever made it easier to lift the load?
- 15 What change would you make to the ramp to make it even easier to raise the mass to a 10-cm height?

## Forming Conclusions



16 Using sentences and diagrams, describe how a simple machine increases the force that you apply to an object. Include the features of the simple machines in this activity as examples.

## THE EFFECTS OF SIMPLE MACHINES

Simple machines can be used to obtain one of the effects shown below. Remember that a simple machine can increase the force that you apply, or change the direction of the force, but there is a cost. The force that you apply has to move farther than the load does.

- 1 Changing the direction of a force (for example, a pulley on a flagpole)
- 2 Multiplying force (for example, a screwdriver)
- 3 Increasing or decreasing speed (for example, scissors)
- 4 Transferring force (for example, a staple remover)



Figure 1.16 To raise the flag, you pull down. The pulley changes your downward pull to an upward pull on the flag.



Figure 1.17 A small force on the handle of the screwdriver becomes a large force in the shaft. This large force can then be used to undo screws that would be impossible to remove with your fingers alone.



Figure 1.18 To cut, you move the scissors' handles together. The scissors' blades cut the paper more quickly than you move the handles together. And they cut farther than the distance the handles move. Try it and see!



Figure 1.19 A lever like this staple remover transfers force to the object being moved. In this case, it is transferring the force from the student to the staple.

## CHECK AND REFLECT

Figure 1.20 Question 4

- Identify which simple machines you would use in each of the following situations:
  - a) digging a deep hole
  - b) moving a heavy rock from one side of your yard to the other
- a) Give examples of energy sources used for modern machines, such as cars and sewing machines.
  - b) Are the energy sources in question 2a) the same as those used in machines before the 1900s? Explain your answer.
- 3. When a simple machine increases the force you exert, what other factor changes?
- 4. One of the most important tools for pioneers in Canada was the axe. What two simple machines make up the axe?

# 1.2 The Complex Machine — A Mechanical Team

As time passed, people began living in larger communities. They needed to find ways to build larger buildings, provide running water, and develop transportation systems for moving people and goods. To do these and other tasks, they developed ever more complicated machines. They also found new ways to power these machines.

Within the last two centuries, scientists, engineers, and other inventors have developed machines that use sources of energy such as coal, oil, and electricity. These large supplies of energy, combined with new materials and new technologies, caused an industrial revolution. Large factories were now possible.

The first factories used powerful new machines to massproduce goods. The newly invented steam engine transported these goods across countries in record time. People now had access to more food, clothing, tools, and raw materials than they ever had before, and their standard of living improved.

The development of new technologies has continued at a tremendous rate. Today we are almost completely dependent on machines. Think of the things that you enjoy doing that depend on a machine for delivering energy or for moving objects. Can you imagine how your life would change if you could *not* use machines?

## infoBIT

## The Changing Bicycle

The bicycle is one of the most efficient machines ever invented to translate human energy into motion. The pennyfarthing shown here was an early bicycle design. It had only levers for steering, and the wheel and axle for moving.





Figure 1.21 The invention of the steam engine led to the development of trains. Trains could travel faster than horses and haul much larger loads.

#### **COMPLEX MACHINES**

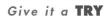
Most of the devices that we use today are made up of several simple machines. These devices are called **complex machines**. A complex machine is a system in which simple machines all work together. A **system** is a group of parts that work together to perform a function. For example, the bicycle in Figure 1.22 is a system for moving a person.

Within the bicycle are groups of parts that perform specific functions, such as braking or steering. These groups of parts are called **subsystems**. The subsystems in a complex machine have just one function each. A subsystem usually contains a simple machine. All the subsystems work together to complete the task that the complex machine was designed to do.

The bicycle is a good example of a complex machine. Several subsystems work together to move you forward at different speeds, allow you to turn, and help you stop. Each subsystem uses a simple machine to help you do the task more easily. Figure 1.22 shows the major subsystems in a typical bicycle.



**Figure 1.22** A bicycle is a complex machine made up of simple machines that work together. The whole bicycle is a system, made up of many subsystems.

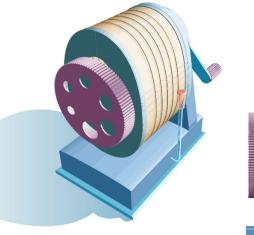


#### ACTIVITY

# ANALYZING A MECHANICAL DEVICE



You are surrounded by a wide variety of machines, both big and small, in your daily life. Now you have an opportunity to look inside one of those machines and see how it works. You can use the one illustrated here or a device provided by your teacher.



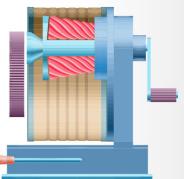


Figure 1.23 What is the function of this device?

Figure 1.24 How does each subsystem contribute to the device's function?

Work with your partner to answer the following questions.

- What is the overall function of the device?
- · How many individual subsystems can you identify in the device? Describe how each one contributes to the device's function.
- . Do any of these subsystems contain a simple machine? If so, describe them.

Use a flowchart or diagrams to show how all the subsystems work together to make the device function.



#### **SUBSYSTEMS THAT TRANSFER FORCES**

Some of the subsystems in complex machines that produce motion play a role in the transfer of energy or force. In mechanical devices, these subsystems are called linkages and transmissions. Gears are often an important part of these subsystems.

#### Linkages

A complex machine moves an object by transferring energy from an energy source to the object. For a bicycle, you are the energy source. The bicycle's wheels are the objects that you must turn to make the bicycle move. The linkage is the part that transfers your energy from the pedals to the back wheel. In a bicycle, the chain is that linkage.

Many machines use high-tension belts instead of chains to rotate objects. You may have seen a belt used as a linkage in older car engines. This is the fan belt, which transfers energy from the engine to spin the cooling fan. The fan moves air through the radiator to keep the engine from overheating.

Chains or belts form a direct link between two separated wheels, so that when one turns, the other will turn in the same direction. If one wheel is larger, it will rotate more slowly, but with a larger force, than the smaller wheel. Chains have less chance of slipping than a belt, but belts are more flexible.



Figure 1.25 In a bicycle, the chain is the linkage that drives the gearwheels. When you shift gears, you move the chain from the larger gearwheel to the smaller ones or vice versa.

#### Transmissions

Most machines that move objects are more complex than a bicycle. They usually move much larger loads than just one person. These machines use a special type of linkage called a **transmission** to transfer the energy from the engine to the wheels. A transmission contains a number of different gears. This allows the operator to apply a large force to move objects slowly, or a smaller force to move objects quickly.

Transmissions are similar to the gears on a bicycle, except that they are designed to transfer much larger forces. In a car, for example, the driver can select a low gear to start the car moving, and then change to higher gears when driving on a highway.

In a low gear, the transmission connects a small wheel to a larger wheel, so the wheels rotate more slowly than the engine does. This increases the amount of power but reduces the car's speed. In a high gear, the transmission connects a large wheel to a smaller wheel, so the wheels rotate faster than the engine. This reduces the amount of power but increases the car's speed.

#### **G**EARS

Gears are essential components of most mechanical systems. They consist of a pair of wheels that have teeth that interlink. When they rotate together, one gearwheel transfers turning motion and force to the other. The larger gearwheel rotates more slowly than the smaller gearwheel, but it rotates with a greater force. Gears can be used to increase or decrease speed in a machine. Both cars and bicycles use gears to change speed. Gears can also be used to change the direction of motion of a mechanical device like the eggbeater in Figure 1.26.

**Figure 1.26** The gears on an eggbeater change the vertical motion of your cranking to the horizontal motion of the beaters.

#### **PESEARCH**

#### Automatic and Manual Transmissions

What is the difference between an automatic transmission and a manual transmission in a car or truck? Which one is better? Which one costs more? Why?



# Inquiry Activity

#### Materials & Equipment

- · multi-geared bicycle
- · spring scale
- metre-stick or measuring tape

#### Caution!

Turn the pedal slowly and keep your fingers away from the wheel spokes and gears.



rear sprockets

**Figure 1.27** The gears on a bicycle are divided between the front and the rear.

# BICYCLE GEARS

#### The Question

What are the differences among three different gears on a bicycle?

#### Procedure

- With your group, observe the two sets of gears on the bicycle—front and rear. The rear set has more gears than the front one does. The gears are made up of flat, toothed disks called sprockets.
- 2 As a group, decide which three gears you will study. Count the number of teeth on the front and rear sprockets for each gear. Record this information in your table.
- Measure the distance from the centre of the rear wheel to the edge of the tire. This is the radius of the rear wheel.
- Measure the distance from the centre of the front sprocket to the outer-most point of the pedal. This is the radius of the circle that the pedal makes when it moves.
- Attach a spring scale to the pedal. Apply just enough constant force to turn the pedal for one complete revolution. How much force is required to turn the pedal one turn? Record your result.
- 6 How many times did the back wheel turn for one turn of the pedal? Record your result.
- Repeat steps 5 and 6 for the other two gears. Record your results.

#### Collecting Date

8 Record your observations in your notebook in a table like the one below.

Gear	Front sprocket: No. of teeth	Rear sprocket: No. of teeth	Radius of rear wheel	Radius of pedal	Force needed for 1 pedal turn	No. of back wheel turns
Lowest gear						
Middle gear						
Highest gear						

#### Analyzing and Interpreting

- 9 For each gear, divide the number of teeth on the front sprocket by the number of teeth on the rear sprocket. Record your results in your notebook.
- 10 Find the circumference of the circle the pedal makes when it goes through one turn. To do this, multiply the radius of the pedal's circle by  $2\pi$  or 6.28. This is the linear distance the pedal travels in one turn. Record your result in your notebook.
- 11 Find the circumference of the rear wheel by multiplying the wheel's radius by  $2\pi$  or 6.28. This is the linear distance the wheel travels in one turn. Record your result in your notebook.
- 12 For each gear, determine how far the rear wheel travelled with one complete turn of the pedal. This can be calculated by multiplying the circumference of

#### How Gears Work

Almost any device that contains spinning parts uses gears. If you look inside a VCR, you'll see gears. You may have an electric meter with a clear plastic cover on the outside of your house. Take a look in it and you will see many different sizes of gears.

Gears are important in mechanical systems because they control the transfer of energy in the system. For example, in a bicycle, they control the transfer of energy from the rider to the wheels. They allow the rider to control and change the speed at which the wheels turn. In a car or other motorized vehicle, they control the transfer of energy from the engine to the wheels.

Gear wheels work together in gear trains of two or more wheels, like the one shown in Figure 1.28. The gear that has a force applied to it from outside the gear train is the driving gear. It then applies a force to the other gear, called the driven gear.

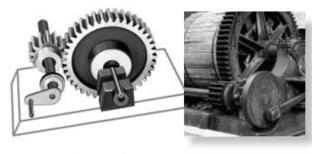


Figure 1.28 A gear train

#### **How Gears Affect Speed**

If the driving gear is larger than the driven gear, the turning speed in the system increases. When you rotate the large gear once, it rotates the smaller gear several times. Think about the gears in an eggbeater like the one shown in Figure 1.26. When you turn the crank, you rotate the large gear, which is the driving gear. It rotates the smaller gears attached to the beaters through four complete turns. This makes the beaters move much faster than the handle, so you can beat the eggs more quickly.

Gears like these that increase the speed of rotation in a device are called multiplying gears. Reducing gears decrease the turning speed in a device. In reducing gears, the driving gear is smaller and has fewer teeth than the driven gear, as shown in Figure 1.29.

In a bicycle, gear wheels do not mesh directly with each other. They are joined by the chain, which provides the linkage between the different sizes of gear wheels. When you shift gears, you move the chain from one gear wheel to another. In this way, you can change how fast you go when you pedal.



Figure 1.29 Reducing gears decrease turning speed in a

# CHECK AND REFLECT

- 1. What is the difference between a simple and a complex machine?
- 2. What improvements have been made to bicycle designs over the last century?
- a) Your body is made up of several simple machines that help you move. Identify three parts of your body that act as simple machines. Identify the kind of machine for each one and explain what it does.
  - b) What parts of your body act as linkages?
- Picture yourself riding a bicycle in a race. Describe how energy is transferred from your body to the bicycle wheels.
- 5. What are gears? How are they used?



#### ACTIVITY

## HOW MANY MACHINES ARE IN YOUR HOME?

You have lived with machines all of your life, so you may not be aware of how many machines you depend on for comfort, security, and convenience. The machines you have in your home help you and your family do many jobs—even when you're not there!

- Make a list of all the machines that you can think of in and around your home. Some machines may not be obvious. Remember that a machine is any device that moves an object or transfers energy.
- Next to each machine in your list, describe the task that the machine performs.
- Identify the source of energy for each machine in your list. What source of energy do most of the machines use?
- On a typical school day, which of these machines do you use or does someone use to help you? Write a short story describing what your day would be like if you didn't have any of these machines. Would you be able to do the same things? How would you do them?



# SECTION REVIEW

# **Assess Your Learning**

- a) How can you determine if a device is a simple or a complex machine?
  - b) Use your answer to question (a) to determine if your body is a simple or a complex machine.
- 2. Why does a car have a transmission but a bicycle doesn't?
- Explain how using levers, gears, or other ways of linking components improves the operation of the following devices:
  - a) scissors
  - b) bicycle
  - c) eggbeater
- Describe three jobs that depend on the use of machines. List the type of machine(s) used with each job.
- 5. Look at the machine in Figure 1.30, and then answer the questions below.
  - a) Is this device a simple or complex machine? Explain your answer.
  - b) What do you think the source of energy is for this machine? How do you know?
  - c) Draw a simple sketch of a similar machine in your notebook. On your sketch, show how energy is transferred through the machine. Label any levers, gears, or belt drives.
  - d) Do you think this device could work in real life? Why or why not?

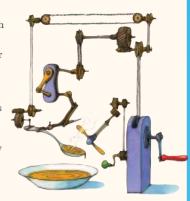


Figure 1.30 Question 5

# Focus On

# SCIENCE AND TECHNOLOGY

The products of technology are devices, systems, and processes that meet given needs and wants. For example, a CD player is a system of devices that work together to provide us with entertainment or educational information. Think back to the information you learned and the activities you did in this section.

- Describe two devices or systems that you read about in this section.
- 2. What needs were these devices invented to meet?
- 3. Identify any other devices or systems that you know about that can meet these same needs. Why do you think more than one device or system exists to meet the same need?

# 2.0

An understanding of mechanical advantage and work helps in determining the efficiency of machines.

#### **Key Concepts**

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

- mechanical advantage, speed ratios, and force ratios
- mechanical advantage and hydraulics
- measurement of work in joules

#### **Learning Outcomes**

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

- determine the mechanical advantage and the speed ratio of a mechanical device
- modify a model mechanical system to achieve a given mechanical advantage
- identify the reason for differences between theoretical and actual mechanical advantages
- identify work input and output for a simple machine or mechanical system
- describe how hydraulic pressure can create a mechanical advantage



The size of sailboats used to be limited by the size and number of sails that sailors could raise on their own. Once pulley systems were introduced, sailors could lift much larger sails. Larger sails meant bigger boats. Bigger boats were able to carry more people and cargo—and travel farther than ever before. An understanding of simple and complex machines opened up the world for exploration.

By understanding and using simple and complex machines, people have created today's world of machines. In this section, you will learn how a machine can increase a force, and how it affects the speed of an object.

The scientific definition of work is another important concept in understanding machines. Examples in this section will help you develop an understanding of work.

You will also explore more hydraulic machines. You will have an opportunity to build your own simple hydraulic system.

# 2.1 Machines Make Work Easier



Figure 2.1 A machine can help us do things we wouldn't be able to do on our own.

Imagine that you are on a car trip with friends, far from the nearest city, and suddenly the car gets a flat tire. The driver opens the trunk to take out the spare tire—but there is no car jack! What can you do? The car is too heavy for anyone to lift. The answer is to use a machine—one that you can assemble quickly from available materials. A lever would work. One person can lift a corner of a car using a long lever, such as a sturdy log placed securely on a large rock.

### infoBIT

#### Winding Mountain Roads

Roads across the open Prairies extend in straight lines for long distances or bend in gentle curves. Roads that have to climb steep hills or mountains bend sharply back and forth. This style of road building is used wherever the slope is too steep for vehicles to drive straight up. Vehicles don't have enough power to climb a steep slope, so each section of road is built so that it raises the vehicle a little higher. After a sharp turn, called a switchback, vehicles can climb higher again. So a mountain road is actually a series of simple machines—ramps that make it easier for vehicles to climb.



#### infoBIT

#### The Newton

The newton (N) is the unit for measuring force. It is named after Sir Isaac Newton, the great scientist who studied force and motion. One newton is equal to the amount of force exerted by Earth's gravity on a mass of about 100 g (e.g., an egg, an orange).

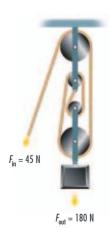


Figure 2.2 This pulley has a mechanical advantage of 4. It multiplies the force you use to pull on it by 4. This enables you to lift a much heavier load than you could on your own, without the pulley.

#### MECHANICAL ADVANTAGE

A machine can make work easier by increasing the amount of force that you exert on an object. In the car example on the previous page, the lever increased the force that the person could exert on the car. A person alone could not exert enough force to lift a car. But using a machine—the lever—made it possible. The scientific explanation is that the lever provided mechanical advantage.

The mechanical advantage of a machine is the amount by which a machine can multiply a force. The force applied to the machine is called the input force. The force the machine applies to the object is called the output force. In the car example in Figure 2.1, the person applies an input force to the long end of the lever. The short end of the lever applies the output force to the car. The output force is much larger than the input force, and the car is lifted. Input and output forces are measured in newtons.

#### CALCULATING MECHANICAL ADVANTAGE

You can calculate the mechanical advantage of a machine if you know the input and output forces. The mechanical advantage equals the output force divided by the input force.

$$\label{eq:Manda} \mbox{Mechanical Advantage (MA)} = \frac{\mbox{Output force}}{\mbox{Input force}}$$

The mechanical advantage is actually a ratio of forces in the mechanical device. For this reason, mechanical advantage is also called the *force ratio* of the machine.

Here is an example of how to calculate mechanical advantage. This example is shown in Figure 2.2. It takes 45 N to lift a 180-N box with a pulley. (If you lifted it by yourself, you would have to use 180 N.) So the pulley has a mechanical advantage of 4 (180  $\div$  45). This calculation is also shown below. The more a machine multiplies force, the greater its mechanical advantage.

$$\label{eq:Mechanical Advantage} \mbox{Mechanical Advantage} = \frac{\mbox{Output force}}{\mbox{Input force}}$$

0

$$MA = \frac{F_{\text{output}}}{F_{\text{input}}} = \frac{180 \text{ N}}{45 \text{ N}} = 4$$

Where F =Force in newtons (N)

#### SPEED RATIO

Calculating the speed ratio is another way of analyzing how machines work. Speed measures the distance an object travels in a given amount of time. A measure of how the speed of the object is affected by a machine is called the **speed ratio**. The speed ratio is calculated by dividing the *input distance* by the *output distance*.

Speed Ratio (SR) = 
$$\frac{\text{Input distance}}{\text{Output distance}}$$

Figure 2.3 shows the input distance and output distance for the same pulley that was used in Figure 2.2. The calculation of this pulley's speed ratio is shown below.

$$Speed \ Ratio = \frac{Input \ distance}{Output \ distance}$$

$$SR = \frac{d_{\text{input}}}{d_{\text{output}}}$$

Where d = distance

$$SR = \frac{4 \text{ m}}{1 \text{ m}}$$

$$SR = 4$$

The speed ratio of 4 means that the part of the pulley where you apply the input force moves four times faster than the part where the output force is—the load that you are lifting.

Using these formulas, you can calculate mechanical advantage and speed ratio for any device. Here is an example.



I m

Figure 2.3 This pulley has a speed ratio of 4.

Figure 2.4 A pulley system lifts a load 5 m when two people pull the rope 10 m. What is the speed ratio of the pulley system?

# LESS FORCE BUT GREATER DISTANCE

The examples and calculations you've done for speed ratio demonstrate you do not get "something for nothing" when you use a machine. The pulley system in Figures 2.2 and 2.3 multiplies the force you exert, which is an advantage. But in using the pulley, you have to pull much farther than the load actually moves.

You can also see this effect if you use a ramp to help you lift a large object. Figure 2.5 compares two ramps used to raise the same load to the same height. Which ramp has the greater mechanical advantage? Which ramp is longer (which means you have to push the load farther)? What is the speed ratio of the ramp?



So far, we have looked only at examples where the mechanical advantage of a device is greater than 1. In those cases, the machine is multiplying the input force to create a larger output force. But sometimes the mechanical advantage of a mechanical device may be less than 1. Does this mean the machine isn't useful? No, it means that the machine is useful for tasks that don't require a large output force.

Think about the bicycle again. It has a mechanical advantage less than 1. For example, a cyclist may apply an input force of 650 N to the pedals. Through the bicycle's linkages, this results in an output force of 72 N. Recall the formula for calculating mechanical advantage: MA = Output force  $\div$  Input force = 72  $\div$  650 = 0.1. The mechanical advantage of the bicycle is 0.1.

The output force causes the bicycle to move much faster than the rider would walk. So even though the mechanical advantage is less than 1, the bicycle is still a very useful machine.



7.0 m 2 m

Figure 2.5 What factors affect the mechanical advantage of a ramp? What factors affect the speed ratio?

Figure 2.6 The mechanical advantage of a bicycle is less than 1. Do you think the speed ratio of a bicycle would be less than or greater than 1?

# Problem Solving Activity

### Materials & Equipment

- · pulleys
- · ramps
- material for levers (lengths of wood)
- string
- · plastic gears
- · wheel and axle
- · screws or adhesives
- · spring scale



Figure 2.7 The ramp is an inclined plane that helps to lift the boat onto the trailer. The winch is a wheel and axle with a cable on it. It pulls the boat up the ramp and onto the trailer.

# BUILDING A MECHANICAL SYSTEM

#### Recognize a Need

Lifting large loads sometimes requires a combination of simple machines. For example, Figure 2.7 shows a boat being hauled out of the water and onto a trailer.

#### The Problem

Use 2 simple machines to create a mechanical system to raise a 1-kg mass 30 cm with the greatest possible mechanical advantage.

#### Criteria for Success

For the construction of your mechanical system to be successful, you must meet the following criteria:

- · Your mechanical system must consist of at least 2 simple machines.
- It must raise a 1-kg mass at least 30 cm.
- You must use a spring scale to accurately measure the force needed to raise the 1-kg mass with the mechanical system.
- You must achieve the same mechanical advantage with this mechanical system at least twice.

#### Brainstorm Ideas



1 You will be working in teams. As a team, brainstorm possible solutions to the problem. Once you have several solutions, choose the one you think will work the best to meet the criteria listed above.

#### Build a Mechanical System

- 2 Create a plan of how you will build your mechanical system. Include a diagram of the mechanical system and a list of materials you will need. Show your plan to your teacher for approval.
- 3 Assemble your materials and build your mechanical system. Remember that you may need to modify or change your design as you build your mechanical system. Make sure to note any changes you make to your original design.

#### Test and Evaluate

4 When you have built your mechanical system, test it to see if it meets the criteria. After your test, you may need to make some changes and retest it.

## Communicate

- 5 What was the highest mechanical advantage you were able to achieve?
- 6 Look at your classmates' mechanical systems. Identify one modification that you could make to your system to improve it.
- 7 Calculate the speed ratio for your mechanical system. Is it the same as mechanical advantage? If not, why do you think there is a difference?

#### COMPARING REAL MECHANICAL ADVANTAGE AND SPEED RATIO

In Figures 2.2 and 2.3, the calculated mechanical advantage and speed ratio for the pulley system were the same. In real situations, however, they may not be. Here's an example.

A group of students set up the mechanical system shown in Figure 2.8. They measured the length of the ramp and the distance from the desktop to the highest point. With this information, they calculated that the speed ratio for the system should be 2. Having seen the example of the pulley system earlier in this section, they assumed that the mechanical advantage would also be 2.

They then measured the mechanical advantage by using a spring scale to pull the load up the ramp. Using the measured force, they calculated the mechanical advantage. It was less than 2. Why wasn't the mechanical advantage the same as the speed ratio in their experiment?



Figure 2.8 The measured mechanical advantage of this system was less than the speed ratio when the students tested it.

#### THE EFFECT OF FRICTION

The difference between the theoretical and the real value of the mechanical advantage was the result of friction. Recall from earlier studies that **friction** is a force that opposes motion. Friction is caused by the surface roughness of materials. A rough surface creates more friction than a smooth one. Even surfaces that we think are very smooth are uneven if seen under a magnifying glass or microscope.

Friction can be an important factor in a mechanical system because it opposes motion. This means that extra force is needed to overcome friction whenever you move an object. Think about pushing a box up a ramp. The friction created by the box rubbing against the ramp means you have to push harder than you would if there was no friction. You have to exert a stronger force, so the mechanical advantage of your ramp is less than it would be under ideal conditions, that is, without friction.

The mechanical advantage of a device is affected by friction but the speed ratio is not. Recall that speed ratio is the input distance divided by the output distance. The distance the box is pushed in our ramp example is not changed by friction, so the speed ratio stays the same. The speed ratio represents the *ideal mechanical* advantage of a machine, as if friction did not exist.

Friction also must be considered in a mechanical system because it creates heat. This heat comes from the two surfaces rubbing against each other. If this heat isn't released, it can cause problems in a system. Special fans and lubricants are used to reduce the effect of heat in a system.

#### **E**FFICIENCY

Friction affects the mechanical advantage of a mechanical device, so it also affects its efficiency. **Efficiency** is a measurement of how well a machine or device uses energy.

Recall from section 1.0 that early machines used people or animals as energy sources. Later, water, oil, gas, and electricity provided energy for machines. Any machine, such as a pulley lifting an object, loses some energy as it operates. Usually the energy is lost to heat because of friction. We say it is "lost" because it isn't being used directly for the pulley's task of lifting. It becomes heat, which is not needed or wanted for the task.

The more energy that is lost, the less efficient a machine is. Efficiency is calculated as a percentage. So a machine that is 40% efficient loses more energy than one that is 70% efficient. You can calculate the efficiency of a machine by dividing its mechanical advantage by its speed ratio and multiplying the result by 100. For example, a pulley has a speed ratio of 3 and a mechanical advantage of 2.

$$\begin{split} & \text{Efficiency} = \frac{\text{Mechanical Advantage}}{\text{Speed Ratio}} \, \times \, 100 \\ & \text{Efficiency (\%)} = \frac{\text{MA}}{\text{SR}} \times 100 = \frac{2}{3} \times 100 = 66.67\% \end{split}$$

### **FESEARCH**

#### Designing the Best Transmission

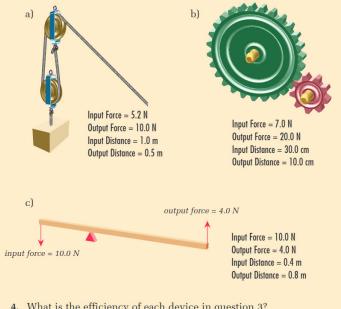
Cars and trucks are designed to handle different sizes of loads and travel in different terrain. Use the Internet or your library to research their different transmissions. How do the mechanical advantage and speed ratio compare for the two different types of vehicles?



In complex machines, the many subsystems are each affected by friction and other factors. Because of this, complex machines are often very inefficient. For example, a typical car engine has an efficiency of only about 15%. That means that 85% of the energy from the gasoline is not used to move the car. Most of it ends up as heat, which is not needed to make the car run. In fact, overheating (too much heat) in a car engine can be a problem.

# CHECK AND REFLECT

- 1. Describe how you would measure the mechanical advantage of a
- 2. It takes 350 N of force on the handle of a jack in order to lift a car. It takes 15 000 N of force to lift the car off the ground. Calculate the mechanical advantage of a jack.
- 3. Calculate the mechanical advantage and the speed ratio for each of the following mechanical devices.



- 4. What is the efficiency of each device in question 3?
- 5. Why are machines never 100% efficient?

# 2.2 The Science of Work

You are out with some friends throwing around a Frisbee. You might think it's all play, but you're actually doing work. Later you go home and sit at a table doing homework. You read a page in a science textbook and think about how you will summarize it. You may feel like you are doing work, but according to the scientific definition of work, you aren't.

What does a scientist mean by the word "work"? Look at the photos in Figure 2.9. They all show people and machines doing work, in the scientific sense. Working with a partner, read the captions and try to determine what all these photos have in common. Using that information, develop your own definition of work. Include with your definition a suggestion for how to measure the work done by a person or a machine. Revise your definition as you work through this subsection.

## infoBIT

# How Much Work Does It Take?

A 75-kg person does about 406 455 J of work in climbing to the top of the CN Tower in Toronto. A I-g bee would do about the same amount of work in flying 42 km.



**Figure 2.9a)** This student has to exert a force on this microscope to lift it up onto the shelf.



Figure 2.9c) This batter is exerting a force to send the ball flying.

**Figure 2.9b)** This snowplow is exerting a force on this pile of snow to push it out of the way.

#### THE MEANING OF WORK

The main difference between how we usually think of work and the scientific definition of work is movement. In the scientific sense, work is done when a force acts on an object to make the object move. Look again at the photos in Figure 2.9. In Figure 2.9a) the student is exerting a force directly on the microscope to move it. He is doing work on the microscope. In Figure 2.9b), the driver of the snowplow is using the plow to exert a force on the pile of snow to move it. The snowplow is doing work on the pile of snow. In Figure 2.9c), the person is using the bat to exert a force on the baseball. The bat is doing work on the ball.

It's important to remember that movement is needed before you can say that work has been done. In Figure 2.9a), the student lifted the microscope onto the shelf. What if he just stayed in place holding the microscope? The microscope feels heavy because of the force of gravity pulling on it. He probably feels like he's working to prevent it from falling. However, as long as he just stays there without moving, he is not doing work.

In Figure 2.10, these people are trying to push the car out of the sand. They are exerting a strong force on the car. But if the car doesn't move, they aren't doing any work at all, according to the scientific definition of work.



Figure 2.10 These people are trying as hard as they can to push this car out of the sand. But if the car doesn't move, they are not doing work.

#### CALCULATING WORK

Work can be calculated using the equation  $W = F \times d$  where F is the force exerted on an object and d is the distance the object moves because of the force. Force is measured in newtons and distance is measured in metres. The amount of work done depends on two things:

- the amount of force exerted on the object
- the distance the object moved in the direction of the applied force

If you lifted your chair onto your desk, how much work would you do? Assume that you have to exert a force of 50 N to lift the chair and your desk is 0.4 m high.

 $W = F \times d$  $W = 50 \text{ N} \times 0.4 \text{ m} = 20 \text{ N} \cdot \text{m}$ 

You did 20 N·m of work. The newton·metre is called a joule, named after the English scientist James Joule. Joule was especially interested in the relationship between work and energy. It's not surprising then that the joule is also the unit used in measuring energy.

Figure 2.11 If you lift the chair or push it along the floor, you are doing work. But if you just hold the chair up without moving, you are not doing any work.

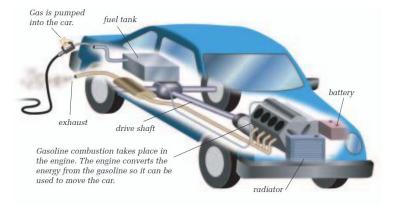


#### **ENERGY AND WORK**

Energy and work are closely related because without energy, there would be no work. When you ride your bicycle, you exert a force on the pedals. The chain transfers that force to the wheels, causing them to move. Your energy is used to provide the force that drives the pedals that move the wheels of your bike. Work is being done because the force you apply to the pedals causes the bicycle to move.

In a car, the energy to drive the wheels comes from gasoline. An energy source (the gasoline) provides the force that makes the work (the car moving) possible. The machine transfers energy from the energy source to the object, causing the object to move. Earlier you learned that machines help us do work. They help us do work by transferring energy.

Figure 2.12 Gasoline is the energy source for a car. The combustion of the gasoline causes pistons to move. The pistons are linked to the transmission. Subsystems within the transmission, such as the drive shaft, work together to cause the car's wheels to move. When the car moves, work is done by the whole system. But within the system, work is being done by every part that moves when a force is applied to it.



#### WORK AND MACHINES

In subsection 1.1, you learned about the different kinds of simple machines and how they can help us do work. But using a machine does not mean that less work is done. You use the machine so you don't have to exert as much force. But you still do the same amount of work.



Figure 2.13 The ramp makes it possible for Serena to use less force in helping Kim to the top of the ramp. A much greater force would be needed to lift Kim straight up from the ground to the height of the top of the ramp.

To show why work done with a machine is the same as work done without it, you can calculate work input and work output. The work input is the work needed to use or operate the machine. Look at Figure 2.13. In this example, the work input is the work done by the student using the machine—the inclined plane—to lift the student in the wheelchair. In this case, the pushing student exerts a force of 320 N for a distance of 5 m. You can use the formula for work to calculate the work input:

$$W_{input} = F_{input} \times d_{output}$$

$$Work_{input} = 320 \text{ N} \times 5 \text{ m} = 1600 \text{ J}$$

The work output is the work done by the machine. So in the example in Figure 2.13, the machine has lifted the student in the wheelchair up 2 m. The downward force exerted by the student in the wheelchair is 800 N. You can use the formula for work again to calculate the work output.

$$W_{output} = F_{output} \times d_{output}$$

$$Work_{output} = 800 \text{ N} \times 2 \text{ m} = 1600 \text{ J}$$

In the example, both the work input and work output equal 1600 J. But the pushing student had to exert a force of only 320 N to move the student in the wheelchair to a height of 2 m. Without the ramp, it would have taken a force of 800 N to lift the student in the wheelchair to a height of 2 m.

Do you think the work input and the work output are always equal?

## *re***SEARCH**

#### Power

Power is the amount of work done in a set period of time. Find out how power is calculated and what units are used for it. In what applications is power measured?

# Give it a TRY

#### ACTIVITY

## WORK INPUT AND WORK OUTPUT

You can see for yourself if the work input and the work output of a machine are always equal. If you were to lift a 1-kg mass 1 m, you would be doing 9.8 J of work.

How much work would a pulley do lifting a 1-kg mass 1 m? Use a single pulley, a 1-kg mass, a spring scale, and a metre-stick to find out.

Calculate the work input and the work output for the pulley. Are they different? If so, why do you think they are different?



#### WORK AND FRICTION

In subsection 2.1, you learned that the mechanical advantage of a machine does not equal its speed ratio in real situations. The reason is friction. Friction is also the reason that work input does not equal work output in real situations. It affects a machine's efficiency. Earlier you learned one way of calculating efficiency. Efficiency can also be calculated using work input and work output. Here's an example of a device that is 75% efficient.

$$Efficiency = \frac{Work_{output}}{Work_{input}} \times 100 = \frac{1200 \text{ J}}{1600 \text{ J}} \times 100 = 0.75 \times 100 = 75\%$$

# CHECK AND REFLECT



- Is work being done in the following examples? Explain your answer in each case.
  - a) A hiker puts her backpack on.
  - b) A gardener pulls on a large weed as hard as he can, but he can't get it out of the ground.
  - c) A student memorizes a poem.
- 2. You use a force of 40 N to push a box of books 3.2 m along the floor. How much work have you done?
- 3. Use an example to explain the effect of friction on a machine.
- 4. a) What is work input?
  - b) What is work output?
  - c) Are they ever equal? Why or why not?
- 5. At the beginning of this subsection, you developed your own definition of work. How close was your definition to the scientific definition? What changes did you make to your definition as you read through the subsection?
- 6. Calculate the work done in the following situations:
  - a) A 15-N box is lifted 0.5 m.
  - b) A 500-N table is pushed 200 cm up a ramp.
  - c) A pulley is used to lift a 1000-N piano up 10 m.
- 7. A person uses a lever to lift a 5-N box 20 cm. Assume that the lever is 100% efficient.
  - a) What is the work input done by the person?
  - b) What is the work output done by the lever?
- 8. A person riding a scooter for 1000 m exerts a constant average force of 10 N. Under ideal conditions, what is the work output done by the scooter?
- 9. A person does 500 J of work to move a box of oranges 25 m. What force was required to move the box?

# 2.3 The Big Movers — Hydraulics



Figure 2.14 The fluid in the hydraulic system of this backhoe transmits forces that move the levers for lifting heavy loads.

Most machines that move very large objects use a hydraulic system that applies force to levers or gears. A **hydraulic system** uses a liquid under pressure to move loads. A hydraulic system increases the mechanical advantage of the levers in machines such as the backhoe shown in Figure 2.14.

Before hydraulic systems were invented, construction projects were done mainly by hand, using simple machines such as ramps, levers, and the wheel and axle. Large structures made thousands of years ago, such as the Egyptian pyramids, are truly amazing. Imagine moving and placing five-tonne blocks of stone using only ropes, wooden levers, and ramps!

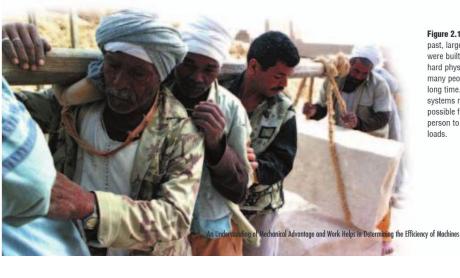


Figure 2.15 In the past, large structures were built with much hard physical work by many people over a long time. Hydraulic systems make it possible for one person to lift huge loads.

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Modern construction projects are much safer and can be done much more quickly with the mechanical advantages of hydraulic equipment. Hydraulic systems are used in many places other than construction sites, however. Hydraulic devices perform tasks ranging from raising the height of a hair stylist's chair to controlling the brakes in a car.

Figure 2.16 The hydraulic system enables the hair stylist to raise or lower the chair easily.



## PRESSURE IN FLUIDS

Hydraulic systems work because they use fluids under pressure. From earlier studies, you may recall that **pressure** is a measure of the amount of force applied to a given area. It can be written as an equation: p = F/A, where p is pressure, F is force, and A is area. The unit of measurement for pressure is the pascal (Pa). This unit is named after Blaise Pascal, a scientist who did important research on pressure in fluids. One pascal equals the force of 1 newton over an area of 1 m<sup>2</sup>. This is such a small amount of pressure that scientists usually use kilopascals when recording pressure measurements. Note that pressure can also be measured in newtons per square centimetre (N/cm<sup>2</sup>).

In his research, Pascal discovered that pressure applied to an enclosed fluid is transmitted equally in all directions throughout the fluid. This effect is known as Pascal's law. This law makes hydraulic and pneumatic systems possible. These two types of systems both use fluids under pressure to move loads. Hydraulic systems use liquids, and pneumatic systems use gases (usually air). You can find out more about pneumatic systems in Unit A: Mix and Flow of Matter.

A common application of Pascal's law is the hydraulic jack. A jack is any device used to lift something. You may have seen a hydraulic jack used for lifting or moving objects in a store. Figure 2.17 shows how a simple hydraulic jack works.

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#### Air Pressure

You have probably heard of low or high pressure systems in weather. We don't think of air having weight. But it's the weight of the air above us that creates pressure. Average air pressure at sea level is about 100 kPa or 100 000 N of force for every square metre.

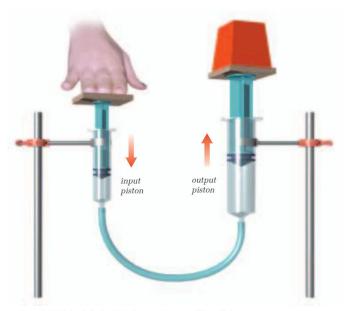


Figure 2.17 A simple hydraulic jack works because of Pascal's law.

#### A PISTON CREATES PRESSURE

In hydraulic systems, the pressure is created using a piston. A piston is a disk that fits tightly inside a cylinder. As the disk moves inside the cylinder, it either pushes fluid out or draws fluid into the cylinder. Pistons can be very small (e.g., 1 cm² in a small syringe). Or they can be very large (e.g., a few square metres in a hydraulic car hoist).

Hydraulic devices use a combination of two pistons attached to either end of a cylinder or flexible pipe. Figure 2.17 shows the parts of a hydraulic system. The first piston is the *input piston*. This piston is used to apply the force to the fluid, which creates pressure in the fluid. The fluid transfers this pressure to the *output piston*. The fluid transfers the pressure equally in all directions. So the pressure on the output piston is equal to the pressure created by the input piston.

This pressure exerts a force on the output piston, which causes the piston to move. The pressure in the fluid provides the mechanical advantage that makes hydraulic systems so useful. Let's look at how it does that.



The human heart is an excellent pump. It distributes blood throughout the body, creating pressure in the blood vessels. Normal maximum blood pressure for a healthy person is 16 000 Pa. The artery carrying the blood from the heart has an average diameter of 1.5 cm. Calculate the force supplied by the heart to produce normal blood pressure.

# Inquiry Activity

- Materials & Equipment · 2 50-mL syringes, each with a platform
- 10-mL syringe with platform
- · small plastic tub
- water
- · 30 cm of latex tubing
- · 4 burette clamps
- · 2 support stands
- 1-kg mass

Figure 2.18 Steps 2 and 3. It is important to make sure that there is no air in the syringes before you begin.

# MECHANICAL ADVANTAGE IN A HYDRAULIC JACK

#### Before You Start ...

A jack is any device used to lift objects. You will use syringes and flexible tubing to create a model of a hydraulic jack. The plungers in the syringes are pistons.

How does pressure create mechanical advantage in a hydraulic jack?

#### The Hypothesis

Write a hypothesis that describes how the pressure in a hydraulic jack creates a mechanical advantage. Hint: Think about the relationship between force and piston area in a hydraulic system.

#### Procedure 🔞 🤵





- 1 Measure the diameter of the plungers in one of the 50-mL syringes and in the 10-mL syringe. Calculate the area of each plunger and enter it in your table.
- 2 Connect the two 50-mL syringes with the latex tubing. Remove the plungers from both syringes. As shown in Figure 2.18, hold the syringes at the same level. Have your partner pour water into one until both are full.
- 3 Remove all the air from both syringes and the tubing. Insert the plunger into one syringe and push it all the way down. Use the plastic tub to catch the overflow from the other syringe. Insert the plunger into the second syringe and push it halfway down. No air should be left in the syringes or the tubing.





- 4 Check that the plungers move easily in each syringe. If one or both of them stick, move first one plunger, then the other until they slide easily.
- 5 Using the burette clamps, mount each syringe on a support stand. Have your partner hold one support stand steady and place the 1-kg mass on that syringe's platform. Hold the other support stand steady as you push down on that syringe's platform until the mass on the other syringe moves.

- 6 Move the 1-kg mass over to the other platform. Hold both support stands steady as you push down on the empty platform until the mass moves. Be aware of how much force you needed to move the mass in this set-up. Record this amount of force as your "control force."
- Remove the 1-kg mass and take both syringes off the support stands. Carefully remove the latex tubing from one of the 50-mL syringes, allowing the water to drain out of both syringes and the tubing into the plastic tub. Keep the latex tubing attached to the other 50-mL syringe.
- 3 Connect the 10-mL syringe to the 50-mL syringe with the latex tubing. Fill the syringes with water, as described in step 2. But this time, insert the plunger in the 50-mL syringe and push it down only halfway. Then insert the plunger in the 10-mL syringe. As before, check that the plungers move easily.
- Repeat steps 4 and 5. Be aware of how much force you needed to move the mass each time in this set-up. Enter this information as "more than control force" or "less than control force" in your table.

#### **Collecting Data**

10 Record your observations in a table like the one shown below.

Area of t	Force needed	
Plunger pushed on	Plunger supporting 1-kg mass	
plunger in 50-mL syringe	plunger in 50-mL syringe	control
plunger in 50-mL syringe	plunger in 10-mL syringe	
plunger in 10-mL syringe	plunger in 50-mL syringe	

#### Analyzing and Interpreting

- 11 Why was the word "control" used to identify the force you used to push down the mass when both syringes were the same size?
- 12 Which situation allowed you to use the least amount of force to raise the 1-kg mass?
- 13 a) A 1-kg mass exerts a force of 10 N. Use the formula p = F/A to calculate the pressure exerted on the water by each plunger when the 1-kg mass was sitting on it.
  - b) Which plunger exerted more pressure on the water?
  - c) Which plunger exerted more pressure on the opposite plunger? Explain your answer.

#### Forming Conclusions

14 Use your observations and diagrams to prepare a brief summary report explaining how pressure creates mechanical advantage in a hydraulic system. Hint: Recall that mechanical advantage is a ratio of output force to input force

#### MECHANICAL ADVANTAGE IN HYDRAULIC SYSTEMS

The mechanical advantage in a hydraulic system comes from the fluid pressure in the system. Figure 2.19 shows another example of a simple hydraulic jack. The force applied to the input piston creates pressure in the fluid. This pressure is transferred throughout the fluid and presses on the output piston. This creates a force on the output piston. So when you push on the smaller input piston, it presses on the fluid, which presses up on the larger output piston, which lifts the object.

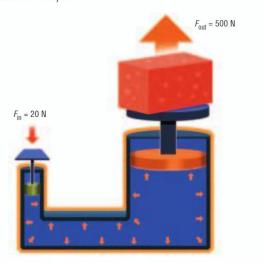


Figure 2.19 This hydraulic jack has a mechanical advantage of 25.

You can calculate the mechanical advantage of a hydraulic jack if you know the input and output forces. In the example shown in Figure 2.19, the input force is 20 N and the output force is 500 N. Recall that the formula for calculating mechanical advantage is MA = Output force  $\div$  Input force. So for this jack:

$$MA = 500 \text{ N} \div 20 \text{ N} = 25$$

The jack's mechanical advantage is 25.

Earlier in this unit, you calculated the mechanical advantage for pulleys and other mechanical devices. Recall that these mechanical advantages were numbers like 4, 8, or 12. So 25 is a large mechanical advantage.

#### PRESSURE AND MECHANICAL ADVANTAGE

The reason for the large mechanical advantage in a hydraulic system is the ability of the fluid to transmit pressure equally. It allows you to use a smaller force on the small piston to produce a larger force on the large piston.

Recall that p=F/A. Assume the small piston has an area of 4 cm<sup>2</sup> and the force it applies to the fluid is 20 N.

$$p = F/A = 20 \text{ N}/4 \text{ cm}^2 = 5 \text{ N}/\text{cm}^2$$

So the small piston creates a pressure of 5  $\rm N/cm^2$  in the hydraulic fluid.

From Pascal's law, we know that the pressure the small piston creates is the same everywhere in the fluid. So this is pressure at the large piston. The large piston has an area of  $100~\rm cm^2$ . What force is exerted on the large piston? This force will push the piston up, which will raise the 500-N load in our example.

Think of the force and area at each piston as ratios that have to be equal. They both have to equal the pressure of  $5~\rm N/cm^2$  in our example. So the force of the small piston divided by the area of the small piston must equal the force of the large piston divided by the area of the small piston. Here's how that looks:

$$\frac{Force\ of\ the\ small\ piston}{Area\ of\ the\ small\ piston}\ =\ \frac{Force\ of\ the\ large\ piston}{Area\ of\ the\ large\ piston}\ =\ 5\ N/cm^2$$

Our ratios are: 
$$\frac{F_{small}}{A_{small}} = \frac{F_{large}}{A_{large}}$$

$$\frac{20 \text{ N}}{4 \text{ cm}^2} = \frac{X}{100 \text{ cm}^2}$$

We solve the equation and find that X equals 500 N. So the force exerted on the large piston by the fluid is 500 N—much larger than the 20-N force that the small piston exerted on the fluid in the first place.

This example shows the difference in forces created within a hydraulic system. This difference provides the mechanical advantage in a hydraulic system. Their large mechanical advantages make hydraulic systems useful in many applications—from amusement park rides to pipelines.



**Figure 2.20** This ride uses a hydraulic system to create thrills. Hydraulics in the base of the ride lift and slant the platform as it spins.

#### LARGER FORCE - GREATER DISTANCE TO MOVE

You may recall from earlier in this unit that the mechanical advantage of simple machines came at a cost. For example, the mechanical advantage of a lever produced a larger output force. The shortcoming of the lever is that the input force has to move a greater distance than the output force. The mechanical advantage of hydraulic systems has a similar shortcoming. To increase the force on the output piston, the input piston has to move a greater distance.



#### Hydraulic and Pneumatic Devices

Use the Internet or your library to determine whether each device below is hydraulic or pneumatic. Where possible, try to determine the mechanical advantage of each device.

- · bicycle pump
- · front-end loader
- · flap controls on an airplane
- · air conditioner

## CHECK AND REFLECT

- 1. What is a pascal? What does it measure?
- 2. How do the sizes of the pistons affect the pressure in a hydraulic system?
- 3. Describe how forces are transferred in a fluid.
- 4. A hydraulic lift has 2000 N applied to an input piston that has an area of 50 cm $^2$ . The output piston has an area of 200 cm $^2$ .
  - a) What is the pressure on the liquid exerted by the input piston?
  - b) Will the force on the output piston be the same or less than the force exerted by the input piston? Explain your answer.



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Unit D: Mechanical Systems

# Experiment .....

# BUILD A WATER-DRIVEN DEVICE

#### Before You Start ...

One of the earliest methods of providing energy to a mill or factory was to use the force of falling water. Water was channelled to pass over the top of a large wheel. The water would catch on paddles or buckets on the wheel, which forced the wheel to turn. The axle for the wheel extended into the mill. Belts attached to this axle would transfer the wheel's force to turn saws or grind flour.

In this activity, your challenge is to build a device that can use energy from flowing water to lift the largest mass possible a vertical distance of 10 cm.

#### The Question

How can you construct a mechanical device driven by water that can lift a mass a vertical distance of 10 cm?

#### **Design and Conduct Your Experiment**

- 1 Your teacher will show you the lift mechanism that you will use for this activity. Notice that your device must connect to this spool or tube, which has a string attached to it. The other end of the string will be attached to the mass. The device must turn the spool or tube so the string winds around it enough to lift the mass 10 cm.
- 2 Working in a small group, determine what combinations of simple machines would be useful in building this device. You may find it helpful to review the information on simple machines on pages 261 to 265 and page 268 earlier in this unit.
- 3 Create a plan of how you will build your device. Include a diagram showing how you plan to connect the simple machines together. Also include a list of materials that you will need to create your device. Note: Your source of water will be a thin hose connected to a tap. The tap will only be turned on low—it will provide a source of gently flowing water, not water under pressure.

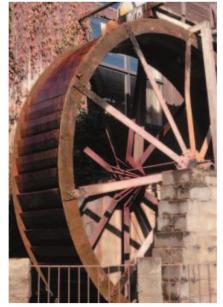


Figure 2.21 Flowing water causes this huge wheel to move. Linkages connect the moving wheel to mechanical systems that operate the mill.

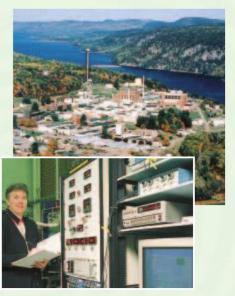
- 4 Build your device and test it. Remember: changes and modifications are part of the development process.
- 5 What was the largest mass your device could lift?
- 6 Be prepared to demonstrate your device to the class. Compare your device with others. How successful were the other devices?
- 7 After observing the other devices, describe one modification you would make to your device to improve how it functions.
- 8 How could you estimate the mechanical advantage of your device?

# Careers Profiles

#### PRACTICAL DESIGNERS

Mechanical engineers design engines and machines that extend our physical capabilities. These machines include automobiles, aircraft, ships, trains, spacecraft, robots, earth-moving equipment, harvesting machines, nuclear power plants—basically any object or device that moves. Colette E. Taylor is a mechanical engineer. Since 1988, she has worked at Chalk River Laboratories in Chalk River, Ontario. Here, she does research, along with other scientists and engineers, that supports and advances the development of CANDU nuclear reactor technology.

- **Q:** Why did you choose to become a mechanical engineer?
- A: When I was in high school, I had no idea what a mechanical engineer was, but I really enjoyed taking a wide range of science courses. I didn't want to specialize in any one thing. I wanted to use all of my science background. When I looked at the options for university, I discovered that mechanical engineering was one of the few career choices that required you to use a wide range of sciences. It was perfect!
- Q: Are there many women mechanical engineers?
- A: There were nine women in my graduating class of 135 students. And that was considered high! I think women have a distorted idea about what engineers really do. They think that you have to work with big, dirty, noisy equipment. Well, that's just not part of the job. I spend most of my day in meetings and working on new designs in my office.
- Q: What does it take to be a good mechanical engineer?
- A: Strong technical ability, communication skills, and high motivation are important characteristics for a successful engineer in today's competitive and demanding workplace.



Colette Taylor conducts research at the CANDU nuclear generating station in Chalk River, Ontario.

Colette says, "If you want a job that challenges you each and every day, and provides you with a wide variety of career opportunities, mechanical engineering is an excellent choice."

- Why do you think a career in mechanical engineering would give you "a job that challenges you each and every day"?
- 2. If you were a mechanical engineer, what kind of machines or systems would you like to work on?

# SECTION REVIEW

# **Assess Your Learning**

- Describe how to calculate the following aspects of a mechanical system:
  - a) mechanical advantage
  - b) efficiency
  - c) speed ratio
- Is it possible for a machine to be 100% efficient? Explain your answer.
- 3. Calculate the work done by a student doing 10 chin-ups. Assume that the student exerts a force of  $400~\mathrm{N}$  with arms that are  $0.5~\mathrm{m}$  long.
- 4. Describe how you could measure the efficiency of a bicycle.
- 5. A pulley system allows a load of 625 N to be lifted by a 90-N input force. What is the mechanical advantage of the pulley system?
- Imagine that you work in a company that builds robots. You are asked to design a robot with hydraulic arms that can help out in the home.
  - a) List some of the activities that this robot could use its hydraulic arms for.
  - b) Why would hydraulic arms be better for these activities than mechanical arms without hydraulics?



# SCIENCE AND TECHNOLOGY

Scientists and engineers always encounter new questions and problems in scientific research and technology development. Think about the information you learned and the activities you did in this section.

- 1. Describe one problem you encountered in this section and how you solved it.
- 2. Do you think there could be more than one way to solve the problem you described in question 1? Why or why not?
- 3. After learning about mechanical advantage, what two new questions do you have about it?



# 3.0

Science, society, and the environment are all important in the development of mechanical devices and other technology.

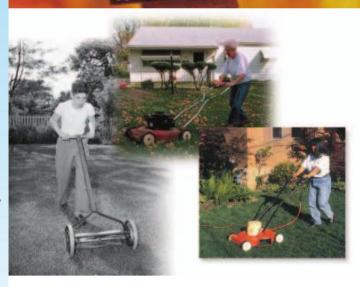
# Key Concepts In this section, you will learn

about the following key concepts:

- · design and function
- social and environmental impacts

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

- evaluate the design and function of a mechanical device in relation to efficiency and effectiveness
- identify the impacts of a mechanical device on humans and the environment
- develop and apply criteria for evaluating a mechanical device
- describe how the following factors affect technological development: advances in science, trial and error, and changes in society and the environment



Mechanical devices have evolved over time because of new developments in science and technology. The first lawn mowers, for example, were made of steel. They were powered by the person pushing the mower. Since then the lawn mower has been adapted to use first gasoline and later electricity as a source of energy. Most of the steel parts have been replaced by aluminum or plastic. The change in materials makes the mower lighter and easier to use. It also reduces its cost. Each change to the lawn mower was designed to make the machine more efficient, less expensive, and easier to use.

In this section, you will explore how the design and function of a mechanical device are related to its efficiency and effectiveness. You will also consider the effects that a device can have on the environment. Finally, you will look at how science and technology advance—through knowledge, trial and error, and changes in society and the environment.

# 3.1 Evaluating Mechanical Devices

Mechanical devices are constantly being evaluated. Manufacturers evaluate the devices they make to find ways to improve them. They want more people to buy their products so they want the devices to be better than, or different from, other brands. Inventors evaluate mechanical devices to find ways to make them easier to use or to find other ways of doing the same task. And you evaluate mechanical devices every time you use one or consider buying one.

#### USING CRITERIA TO EVALUATE A DEVICE

Your bicycle has broken down. You need to buy a new one, but there are many bike designs available. How do you decide which one to buy?

Working with a partner, list the features that you would like to have in a bicycle. Begin by thinking about what you use your bike for. Is it for riding on city streets? Is it for riding on trails out in the country? Is it for BMX riding? Will you ride it to school? If so, you need some method of carrying things. Will you be riding after dark? If so, you need to make sure you have good lights and plenty of reflectors.

The list of features you want are your criteria for evaluating a bike's design. That is, they are the features you will consider when you look at different bike designs to see if they meet your needs. Look at the bicycles shown in Figure 3.1. Do any of them fit your criteria?

Of course, the features in the list you made are not the only criteria you have to consider when you buy a mechanical device. A very important one is cost. You may find a bike that fits all your criteria exactly, but if it's out of your price range, you can't buy it. When you evaluate a mechanical device or anything else, it's important to be clear about all the criteria that you have to consider.

## infoBIT

#### **Bikes without Brakes**

Would you buy a bike without brakes? You would if you wanted it for track racing in a velodrome. You may have seen these bikes on television at the Olympics. They have no brakes and only one gear. The gear is sized according to the type of competition and the cyclist using the bike.









Figure 3.1 Do any of these bicycle designs meet your criteria?

#### **EFFICIENCY AND EFFECTIVENESS**

When you use a mechanical device, you want it to work efficiently. Earlier in this unit, you learned that efficiency could be calculated as a percentage by dividing the mechanical advantage by the speed ratio. That's a quantitative measure of efficiency because it gives you a number for a quantity or measurement. But efficiency can also be described qualitatively, just in words. For example, you can describe the efficiency of a mechanical device by saying how quickly and easily it helps you do a task. You also want a mechanical device to work effectively. It works effectively if it does its job well.

You can see the difference between efficiency and effectiveness by comparing different designs of bicycles. For example, a one-speed bicycle is effective in carrying you from one place to another. And it's more efficient than walking—you get there faster and use less energy to cover the same distance. A 21-speed bicycle is just as effective as a one-speed, but it's more efficient. By changing gears, you can increase your speed and climb hills more easily. You can cover the same distance more quickly and use less energy. That makes the 21-speed bike more efficient. So both designs are effective, but one is more efficient than the other. Usually, in evaluating a mechanical device, you are looking for the best combination of effectiveness and efficiency at a cost that you can afford.

Figure 3.2 The people in this photo use their bicycles as their main means of transportation for going to work, for visiting, and for shopping. Many of these are one-speed bicycles.



#### FUNCTION AND DESIGN

Scientists, engineers, and other inventors want to develop mechanical devices that work efficiently and effectively. To do that, they consider both the function and design of the device. The function is what the device is supposed to do. The design is the physical form of the device that makes it usable.





Figure 3.3 How do the designs of the mountain bike and the road racing bike show the different functions of the two kinds of bikes?

Think again about the bicycle. The basic function of a bicycle is to carry a person. But different types of bicycles have very specific functions, and their designs reflect these functions. Look at Figure 3.3. The two bicycles shown are both used for racing. However, the type of racing they do is so different that the designs are very different. They both have two wheels, handlebars, brakes, and seats, but even these look different. An important aspect of evaluating mechanical devices is ensuring that the design suits the function.

#### **EVALUATION FOR DEVELOPMENT**

If you are buying a mechanical device, you need to think about how to evaluate it. A thorough evaluation helps you make a better choice that suits your needs. Another reason for evaluating a device is to determine how it can be improved.

Earlier in this unit, you saw photos of how bicycles have changed from the early penny farthing to today's high-tech bikes. The design of bicycles is constantly being changed to improve how they function and to make them more comfortable and easier to use. The efficiency and effectiveness of bicycles as a means of transportation has greatly increased over the years.

Another factor that can be considered in evaluating mechanical devices is the environment. Sometimes the environment influences the design and function of a device. For example, mountain bikes are designed specifically for rough terrain. They have sturdier frames and larger tires than road-racing bikes do. Both these features help mountain bikes function more efficiently and effectively.

#### CONSIDERING THE ENVIRONMENT

The effect of a device on the environment should also be considered in evaluating it. For example, spikes in the tires on a mountain bike might make the bike more effective in climbing slopes. However, tires with spikes would tear up the soil and plants even more than ordinary bike tires do. To protect the local environment, tires with spikes should not be used. Other devices, such as cars, affect the environment by contributing to air pollution. This can affect you directly and can contribute to global warming.



Figure 3.4 Leaf blowers help people clean leaves off roadways and paths. Some people feel that these devices pollute the environment with their noise. What criteria would you use in trying to decide whether to buy a leaf blower?

#### EVALUATING A MECHANICAL DEVICE—A CASE STUDY

A good example of how evaluation leads to the development of better mechanical devices is a product that you use almost every day—the pop can opener. Its changes over the years show how evaluating a mechanical device can lead to improvements. These improvements made the product more convenient. They also affected the well-being of both people and the environment. The history of the pop can opener shows how trial and error can play a role in the development of even simple technology.

The development of an opening mechanism for the aluminum can went through four distinct designs:

- the church key
- the removable pull tab
- the buttons
- the non-removable tab

Each new design was the result of the previous device having some problem. Before you start reading about pop can openers, make a chart like the one below in your notebook. As you read, fill in the advantages and disadvantages of each design.

Opener Design	Advantages	Disadvantages
church key		

#### EVOLUTION OF A MECHANICAL DEVICE—THE POP CAN OPENER

To pour a liquid out of any container, you need two holes or one large hole. With two holes, the first hole allows the air into the can. The second hole lets the liquid out. The air flowing into the can replaces the liquid that is leaving the can. In fact, the air helps to create a smooth flow of liquid out of the second hole. One hole will work if it is large enough to let air flow into the can at the same time that liquid flows out of it. So one of the criteria for the design of an opener was that it could make either two small holes or one large one. Let's look at how pop can openers evolved.



Figure 3.5 The earliest cans were made of iron. They could be opened only by using a hammer and chisel!



Figure 3.6 The church key was the first practical design for a can opener.

Figure 3.8 The removable tab top made opening the cans much easier. It was a simple machine built right into the top of the can. But it too had problems.

#### **Church Key**

The first cans were completely sealed. They did not have an opener built into the lid. An opening device was needed to make two holes in the top of the can. This device was called a church key. A common church key is a piece of metal with a triangle end designed to punch into the can and open it. Figure 3.6 shows a church key being used to make two holes in the top of a can.

A church key is a simple machine—a lever. If you pressed on the top of the pop can with just your fingers, you would not have enough force to open it. The church key multiplies the force that you use. It also focusses it to a tiny point at the end of the triangle. Recall that pressure is the amount of force applied to a given area. So by using the church key lever to press on a tiny point on the top's surface, you can puncture the metal. The church key worked well, but it did have some drawbacks. Can you think of at least one problem with using a church key? Add the advantages and the disadvantages of the church key to your chart.



Figure 3.7 The church key is a lever that enables you to increase the pressure you can apply to the top of a can.

#### Removable Tab Top

One sunny summer day in the early 1960s, Ermal Fraze of Ohio was picnicking at the local lake. Unfortunately he forgot the church key to open his cans of soda pop. It was clear that this was a failure of the church-key can. If you didn't have a church key with you, you couldn't open the can. Fraze was determined to find a better solution. Making sketches, the metal engineer designed his solution on paper.

Fraze solved the problem by having a ringed tab that could be pulled off the top of the can. After much trial and error, he found the right design. When you wanted a drink, you would put a finger in the ring part of the mechanism and pull back the ring like a lever. The tab would "fail" and rip from the lid. Now you could have your drink. Not needing a church key was a big improvement, but an environmental problem arose from the new pull tab design. What do you think that was?

#### Buttons

With billions of cans being used every year, an environmental problem arose with the removable pull tab. What do you do with the tab after you take it off the can? Many people just threw their tabs onto the ground. The result was a litter problem and a safety hazard. A new solution was needed.

One solution was to have two holes with buttons pre-formed in the can's lid. One hole was smaller than the other. The directions on the can told the user to open the small hole first.

Recall from earlier lessons that pressure is force divided by area. By pushing on the small button, you exerted the same force as you would on the large one, but over a smaller area. You created more pressure at that point, so the smaller button was easier to open.

Opening the small button released the pressure in the can. This pressure came from the can's contents, usually carbonated pop. The bubbles in pop are carbon dioxide. In order to keep the bubbles in the pop, the can has to be sealed to contain this pressure. Once this pressure was released by opening the small hole, the large button was much easier to open.

While this solution solved the litter problem, many people didn't like having to push two buttons. Some found the small button difficult to press. A better solution was once again needed.

#### Non-Removable Tab Top

In 1976, the easy-to-open top with an attached tab was invented. It eliminated the environmental problems of the earlier pull tabs, so it is called the "ecology top."

The tab top opener is another example of a simple machine. Like the church key, the tab top is a lever. This mechanical device and its specially designed metal top provide an easy-to-open product. Figure 3.10 shows how the tab top exerts pressure on the top of the can to open it. However, the lever action alone of the tab would not be enough to open a hole in the can. The metal has weaker lines in it that outline the shape of the hole. When you exert pressure using the tab lever, you strain the metal along the weaker lines, and the hole pops open.

Both the removable tab top and the non-removable tab top are mechanical devices that act as levers. The only difference is that the non-removable tab top stays attached and so does not create a litter problem.

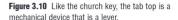




Figure 3.9 The buttons eliminated the litter problem, but consumers didn't like using them.



#### CRITERIA FOR EVALUATION

The changes to the pop can openers didn't happen accidentally. Can manufacturers evaluated each device and tried to improve it. To evaluate their can openers they probably asked questions such as:

- Is it efficient: does it open the can quickly and easily?
- Is it effective: does it allow air in so the liquid can flow out?
- Is it safe: does it create an opening that allows people to drink directly out of the can?
- Is it convenient: is it there when you need it?

These are just some of the questions they might have asked. After the problems with the removable pull tabs, they added questions about the environment. These included:

- Will the opener contribute to litter?
- Is the opener recyclable, along with the can?

As you were reading about pop can openers, you filled out a chart about their advantages and disadvantages. This is the type of information that is used in evaluating mechanical devices. However, in a real evaluation, you would begin with a list of things you want or are looking for in the device. The questions above are examples of how to start. This helps to ensure that you collect enough of the right kind of information to help you make your decision.

When you are buying, planning to use, or building a mechanical device, think of criteria that can help you evaluate your choices. These include: efficiency, effectiveness, design, function, and impacts on the environment and other people.

Figure 3.11 Today's aluminum cans are easy to open. Because the pull tabs stay attached to the cans, they don't contribute to litter.



#### **Making Sure That Consumer Products Are Safe**

Next time you use a mechanical device like a hair dryer or toaster, look on the outside casing for a symbol that looks like a large C with a smaller S and A inside it. This symbol stands for the Canadian Standards Association (CSA). The CSA is a non-government association that tests and approves a wide range of

products to make sure they are safe for consumer use. Other consumer product-testing organizations test for safety and value. Using the Internet or your library, find out how these organizations evaluate consumer products. Find out how they set the criteria they will use, and what kind of tests they do.

# **Making**Activity

#### EVALUATING A MECHANICAL DEVICE

#### The Issue

Every day you use a large variety of mechanical devices. Some are more efficient and effective than others. Some are better designed than others. You might notice how easy a device is to use, or how well it works in getting the job done. But do you notice whether it affects the environment? Or how it affects other people when you use it? What criteria should you use to evaluate a given mechanical device in a responsible way?

#### **Background Information**

- 1 When we think about buying a mechanical device, we usually have criteria to help us make a decision. Criteria are guidelines or standards that we use to gather information that we need for decision making. Usually these include only criteria directly related to our own use. But we should consider a wider range of criteria. That way, we can make sure that we buy and use mechanical devices and other technology more responsibly.
- 2 In any type of evaluation, you need to develop criteria. Depending on the situation, they may cover many aspects of a device, or only a few. Cost, energy efficiency, environmental impact, appearance, ease of use, comfort—these are just some of the criteria you might consider when you evaluate a mechanical device.
- 3 Imagine that the snowmobile was a new device about to be introduced onto the market. You are a member of an organization that tests consumer products. Your organization will be evaluating this new product to see if you should recommend its use. You are concerned not only about how the device meets the needs of individual consumers. You are also concerned about social and environmental factors.
  - Working with your group, develop a set of criteria that will help you evaluate the snowmobile. Remember to keep in mind the reason for your evaluation.
  - Evaluate the snowmobile. You will have to do some research to determine how well it fits your criteria.



- 4 When your evaluation is complete, design a presentation to summarize your group's findings so you can share them with the rest of the class.
- 5 Be prepared to defend how well your evaluation criteria address social and environmental needs.



Figure 3.12 What criteria would you use to evaluate this mechanical device?

#### **CHECK AND REFLECT**

- 1. What personal and societal factors influenced the changes in devices used to open aluminum cans?
- Do you think the design of the non-removable pull tab will change again or is this the final design? Explain your answer.
- 3. Your school wants to install a new bell. Which of the following are appropriate criteria for evaluating the bells available? Explain your answers.
  - a) How well does the device do its job?
  - b) How efficient is the device?
  - c) Is the device waterproof?
  - d) Are there any negative side effects to using the device?
  - e) How reliable is the device?
  - f) Is the device disposable?
  - g) Does the device come in a wide variety of colours?
- 4. What other criteria would you add to help your school choose a suitable bell? (Hint: Think about what the bell will be used for, and its possible effect on people who live near the school.)



#### ACTIVITY

#### CHOOSING A NEW SET OF WHEELS

You may have seen push scooters like this one—you may even have one of your own. Why do you think someone would choose to use one of these devices instead of a skateboard or roller blades?

- List the criteria someone might use to help her decide which device to buy
- If you had to choose a new skateboard, a pair of roller blades, or a scooter, which one would you choose? Why? If you already have a scooter, explain your reasons for buying one.
- Why do you think these scooters are available now and weren't available 10 years ago? List as many factors as you can think of. Do some research by visiting stores that sell these devices and by searching the Internet to find out what these devices are made of. Which items on your list do you think are good reasons for the scooters' availability?
- Interview some of your friends to find out how they would make a choice among skateboards, roller blades, and scooters. Do any of them have a set of criteria that they use to evaluate purchases?



Figure 3.13 A push scooter

# 3.2 Technology Develops through Change

In subsection 3.1, you saw how a simple mechanical device like a pop can opener can develop over time. The changes in the pop can opener resulted from both human and environmental needs. New materials and technology also contributed to its development. The original steel cans changed to more flexible and lighter-weight aluminum. As well, new methods of making the cans helped.

Another part of the development process for pop can openers was failure—not all changes succeeded. The button-top pop can did not succeed because people found it difficult to use. Trial and error are also part of technology development.

Look at Figure 3.14, which shows how the sewing machine has developed for home use since it was invented in the 1800s. What factors do you think contributed to the changes in sewing machines over the years? (Think about the factors that affected the development of the pop can opener.)

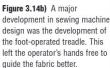


**Figure 3.14a)** Early sewing machines were operated by a hand crank. They could sew only simple stitches.

#### infoBIT

#### New Technology through Invention

In the winter of 1903, Mary Anderson was riding a streetcar in New York City. She noticed that the shivering driver had to keep getting out to wipe the snow and ice off the windshield. Mary had an idea, and made a quick sketch. Her device allowed the driver to operate a lever from the inside that moved a swinging arm on the outside that mechanically swept ice and snow off the windshield. By 1913, the windshield wiper was standard equipment on cars, trucks, and buses.





#### ADVANCES IN SCIENCE RESULT IN NEW TECHNOLOGY

Many of the devices we use today—from computers to hair dryers—are possible only because of electricity. Charles Coulomb first identified electric charges in the 1700s. However, it wasn't until the late 1800s that electricity was distributed widely in cities. And it wasn't until the 1940s that it became widely available outside Canadian cities and towns.

As scientists, engineers, and other inventors learned more about electricity, they saw how it could be used in new technologies, such as light bulbs. They also found that electricity helped them make new scientific discoveries. For example, we would not have electron microscopes without electricity. These microscopes opened up a whole world that had been invisible to human eyes.

#### FROM PARTICLES TO TRAINS

Sometimes new technology develops from scientific research that may not even seem to be related. One example is the MAGLEV trains in Japan, shown in Figure 3.15. These trains are powered by electricity and float on magnets so that they never touch the tracks. They can travel at speeds over 350 km/h! The technology for the MAGLEV train resulted from physics experiments using particle accelerators.



**Figure 3.15** Because they float on magnets, MAGLEV trains experience very little friction. This enables them to use more of their energy for increasing speed rather than opposing friction.

Particle accelerators are huge machines that break up atoms and other particles. To do this, they use large amounts of energy to create powerful magnetic and electric fields. Only a few particle accelerators exist in the world. It might seem that the specialized field of particle physics has very little to do with transportation. But scientists working in this field developed the technology that makes the MAGLEV train possible.

#### CHANGES IN SOCIETY RESULT IN NEW TECHNOLOGY

New technology can also result from changes to human society. An interesting example is the use of robots. Robots are widely used today, mainly in industry. But they don't look anything like the robots that were first popularized in movies and comic books in the mid-20th century. Those robots all looked like humans—with a head, torso, arms, and legs. The word "robot" comes from the Czech word *robotnik*, meaning "workers" or "slaves." It was first used in 1920 in a play in Czechoslovakia. In the play, human-like creatures were manufactured by the millions to work as slaves in factories

While movie makers were busy creating fictional robots, scientists and engineers were trying to build real ones. The first practical examples were developed in the 1960s. Today, robots perform tasks far more efficiently and quickly than humans are able to do. Robots weld car bodies together, diffuse bombs, perform surgery, help the handicapped, and even explore other planets.

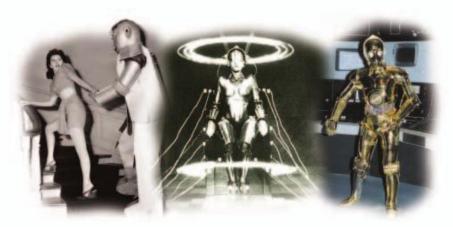


Figure 3.16 Some movie robots



Figure 3.17 Assembly-line robots weld car bodies together in an automobile factory.

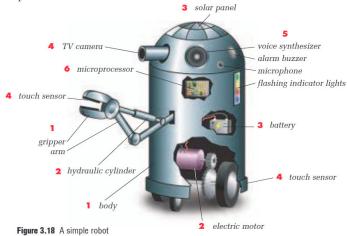
#### **Changing Society—Changing Technology**

The drive to develop more effective and efficient robots came from the need to replace humans in different tasks. In the past, people had been willing to work for low pay and carry out boring or dangerous tasks. However, by the middle of the 20th century, people were demanding better wages and better working conditions. As wages went up, industry looked for ways to replace humans in manufacturing and other applications. Robots were the answer.

An industrial robot that welds car parts together, for example, works faster and more efficiently than any human. But it doesn't look anything like a human. It doesn't need a head, torso, or legs to do its job. All it needs is an arm. In fact, most industrial robots today are nothing more than "smart" arms.

#### Anatomy of a Robot

Robots are extremely complex devices and vary widely in appearance, depending on the job they're designed to do. However, a very simple robot contains some or all of the following basic parts:



- 1 Body: steel, aluminum, or plastic. Metal rods are used for arms. Simple grippers that open and close are used for hands. Wheels are used for movement.
- 2 Motor Devices: electric motors and hydraulic or pneumatic cylinders. They move the robot's arms and wheels.

- 3 Power Source: battery or solar cells.
- 4 Sensors: detect light, sound, pressure, and heat. They tell the robot about the outside world.
- 5 Output Devices: buzzers, flashing lights, or synthesized speech. They enable the robot to communicate.
- 6 Microprocessor: minicomputer that acts as the robot's brain. It receives signals from the robot's sensors and decides what actions to take. It sends instructions to the robot's output devices or motor devices.

#### CHANGES IN THE ENVIRONMENT RESULT IN NEW TECHNOLOGY

Space exploration is a fascinating area of technology, but it does not affect very many people directly. The environment here on planet Earth does. Since the early 1960s, people have become more aware of their impact on the environment. The increasing human population and the use of certain technologies have damaged the environment. Chemicals have polluted water in lakes, rivers, and streams. Exhaust from cars and other vehicles has polluted the air.

People observed the changes in the environment and realized that new technologies were needed to prevent more damage. One example is the development of recycling technologies. These include new mechanical devices for processing materials so they can be used again or in a different form. Another example is the development of new materials, such as biodegradable plastic that breaks down much faster than ordinary plastic.

New technologies can help protect the environment from damage. Figure 3.19 shows a skimmer device used to clean up oil spills in water.



Figure 3.19 Oil floats on water, so clean-up crews can use skimmers such as this one to skim oil off the water's surface.

#### **PESEARCH**

#### Flying High

The first scheduled aircraft passenger service began in 1909. Passengers were carried by large, lighter-than-air craft called *zeppelins*. These lighter-than-air vehicles flew slowly but could travel long distances. So why are we not flying in zeppelins today? Use the Internet or your library to find out how passenger airplanes have developed through the years.

- How have new materials and other technologies affected the development of passenger airplanes?
- What role has the process of trial and error played in the development of passenger airplanes?



#### **CHECK AND REFLECT**

- 1. Look back at Figure 3.14 on page 315, which shows some of the stages in the development of the sewing machine. How do you think each of the following affected sewing machine development?
  - a) advances in science
  - b) advances in other technologies
  - c) changes in society
- Give an example of the role that trial and error can play in technology development. You can use an example from your reading in this section or any other example you know about.
- 3. Do you think cars will use the same kind of engine in the future as they do now? Why or why not?
- 4. Describe two ways that the environment could affect the development of new technology.

# Careers Profiles

Canadian Peter L. Robertson (1879–1951) invented the Robertson square-headed screw in Milton, Ontario. The new square design prevented screwdrivers from slipping off the screw head as easily as they did with other screws. In 1908, he set up the Recess Screws Limited factory to manufacture the new screw. Now known as Robertson Inc., the plant is still busy turning out Robertson screws.





Figure 3.20 Peter Robertson

#### INVENTOR

Most successful inventors will tell you that they started developing their natural curiosity at an early age. They took things apart to see what made them work. They constructed gadgets using toy building sets. They participated in science fairs. And in school, they took a variety of science, math, and engineering courses.

- Have you ever thought of inventing something? If so, what was it and did it work?
- 2. What do you think would be the most difficult part of being an inventor?
- 3. Why do you think both ordinary screws and Robertson screws are used—why not just one kind?

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#### SECTION REVIEW

#### **Assess Your Learning**

- Define in your own words the terms design and function as they are used to describe mechanical devices.
- If you were buying a blow dryer, you might use criteria such as the following to choose one:
  - It has to cost less than \$20.
  - It has to have at least two speed settings (high and low) and two temperature settings (hot and warm).
  - It has to have adjustable electrical settings so it can be used on other continents.
  - It has to be foldable for easy packing. Imagine that you are a professional hair stylist, buying a blow dryer to use at work. Would you use the same list of criteria? Explain your answer.
- Describe three reasons why people invent new machines or products.
- 4. What impact could the following discoveries have on a machine? Use an example of a machine in your answer.
  - a) the development of new types of materials
  - b) the development of new sources of energy



### SCIENCE AND TECHNOLOGY

The goal of technology is to provide solutions to practical problems. The development of good technology depends on solid scientific knowledge. It also depends on evaluating prototypes and designs to improve how they function. Think back to what you learned in this section.

- 1. What were some examples of the link between science and technology that you read about in this section?
- 2. What are some factors you would have to consider if you invented a new machine that you wanted people to use?
- 3. Why are machines and other products constantly being evaluated?



## Living with a Machine

#### The Issue

Imagine that a large new machine has been developed. It will transport up to six people in all kinds of weather for short or long distances. It will provide jobs for millions of people in everything from mining to manufacturing to servicing. However, it will also have the following impacts:

- · It will pollute the air wherever it is used.
- It will affect the entire Earth by contributing to the "greenhouse effect."
- It will kill thousands of people every year in accidents.
- Its operation will require that millions of square kilometres of the environment be paved over, destroying habitat for animals and plants.
- · It will kill thousands of animals every year.
- Its manufacturing and operation will require large amounts of non-renewable resources—metals and petroleum products.

Of course, this information describes the cars and other vehicles that we rely on today.

Now, when brand new technologies are developed, people try to identify such effects. They can then prevent the effects from happening or reduce the possible harm they could cause. But what do we do with existing technology such as the car?

Efforts are being made to reduce the harmful effects of cars. Research continues on ways to make cars more energy efficient and less polluting. In some areas, cars carrying more than two people are given special lanes to promote car pooling. Cars are being made safer with the use of airbags and other features.

What do you think should be done to reduce the harmful effects of cars? Use the following suggestions to find out more about what can be done about cars.



Cities such as Calgary have large areas covered in highways. This allows easy movement of cars. But the pavement destroys the natural environment, increases temperatures locally, and causes increased runoff of water polluted by oil and other chemicals.

#### 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 new car technology and how cities are dealing with cars.
- Ask the Experts: Try to find an expert, such as a city planner, a traffic engineer, or an engineer who works on car engines or design.
- Look It Up in Newspapers and Magazines: Look for articles about engine technology, car body design, and the environmental impact of cars.

#### **In Your Opinion**

- Where should new technology development for cars focus?
- Should the use of cars be restricted?
- Should we be concerned about the impact of new technology on people and the environment? Explain your answer.

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### UNIT SUMMARY: MECHANICAL SYSTEMS

#### **Key Concepts**

#### 1.0

- · systems and subsystems
- transmission of force and motion
- simple machines

#### 1.0 Machines are tools that help humans do work.

- A machine is a device that helps us do work. Machines use energy from animals, people, electricity, and fossil fuels to produce motion.
- There are six types of simple machines: the lever, inclined plane, wedge, screw, pulley, and wheel and axle.
- Complex machines are made up of two or more simple machines. Gears, linkages, and transmissions connect subsystems and help to transmit force in complex machines.

#### 2.0

- mechanical advantage, speed ratios, and force ratios
- mechanical advantage and hydraulics
- measurement of work in joules

## 2.0 An understanding of mechanical advantage and work helps in determining the efficiency of machines.

- Mechanical advantage is a measure of how much a machine can increase an applied force. The speed ratio describes how the speed of an object is affected by a machine.
- Work is done when a force acts on an object to make the object move.
   Machines help us do work by transferring energy. Work input and work output are not equal in the real world because of friction.
- Efficiency is a measurement of how well a machine or device uses energy. It
  is usually given as a percentage. It can be calculated by dividing the
  mechanical advantage by the speed ratio and multiplying by 100. This is a
  quantitative description of efficiency. No machine can be 100% efficient.
- Hydraulic systems use a liquid to transmit force in a closed system of tubes.
   They work because of Pascal's law. These systems can have a large mechanical advantage because of the difference in the sizes of the pistons used.

#### 3.0

- design and function
- social and environmental impacts

## 3.0 Science, society, and the environment are all important in the development of mechanical devices and other technology.

- Function and design are two important aspects of mechanical devices.
   Function is what the device is supposed to do. Design is the physical form of the device that makes it usable.
- The main factors that should be included in an evaluation of a mechanical device are: efficiency, effectiveness, and impact on humans and the environment.
- Efficiency can also be described qualitatively. A machine or device is efficient when it helps you do a task quickly and easily.
- Technology development is influenced by scientific knowledge, trial and error, and changes in society and the environment.

Unit Summary

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#### **Getting Started**

At the beginning of this unit, you drew a design for a device to solve the problem of retrieving a robotic explorer that had become wedged in a drainage pit. After you designed the device, you studied simple machines, gears, and hydraulic systems. Now it's time to put all that information to use.

If you did not design a mechanical device to remove a robotic explorer from a drainage pit earlier in this unit, you should do that activity now. If you have completed this activity, collect your notes and designs and organize them in a manner that makes sense to you.

Review your results with your partner or group.

#### Your Goal

Redesign the gripper device you designed earlier, and construct a working model of it.

#### What You Need to Know

Your teacher will show you the model of the drainage pit where the robotic explorer is located. It will look something like the picture on page 256. Note that in the earlier activity you assumed that the robotic explorer had a mass of 100 kg. For this activity, you can choose the mass of load that will work with your model.

#### BUILDING A MECHANICAL HAND



Place gripper device at A and load to be lifted

#### Steps to Success

- Review your original design drawings and make modifications to improve your design.
- 2 Create a plan that describes how you will build your gripper device. Include in your plan a list of the materials you will need.
- 3 Show your plan to your teacher for approval. Revise your plan based on your teacher's comments.
- 4 Build your device and test it.
- 5 Demonstrate your device to the class.
- 6 Observe how your classmates' devices work. Record any ideas you think you could incorporate into your device.

#### How Did It Go?

- 7 What worked well in your gripper device?
- 8 What would you modify so your device would work better next time?
- 9 What were some of the limitations you faced when you built your device? For example, did you have enough time?
- 10 Which device out of all of those made by your class do you think worked best? Explain your answer.
- 11 What are some possible applications of your gripper device?

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Unit D: Mechanical Systems



### **Unit Vocabulary**

 Create a concept map that illustrates the relationships between the following terms. Begin your concept map with the phrase mechanical systems.

simple machine friction
complex machine work
subsystem efficiency
mechanical advantage hydraulic
speed ratio pressure

### **Check Your Knowledge**

1.0

- 2. Why are machines useful?
- 3. What is the difference between a simple machine and a complex machine?
- 4. Identify four simple machines, and describe the advantages of each one.
- 5. a) What is a subsystem in a complex machine?
  - b) Identify as many subsystems as you can in the robotic dog shown in the drawing below. For each one, explain why it is a subsystem.

- **6.** What is the purpose of the transmission in a car?
- 7. What type of simple machine is in each item below?

bottle opener hammer your jaw roller blades shovel screwdriver

2.0

- Describe three effects of simple machines and give one example for each
- 9. A lever is made out of a long pole and a rock, as shown in the diagram here. How would you change the location of the rock to increase the lever's mechanical advantage?



- 10. A sailor uses a force of 600 N to pull on a pulley system to raise sails on a boat. The maximum weight of sails that the sailor can raise with this system is 2400 N. What is the mechanical advantage of the pulley system? (Hint: The weight of the sails is the same as the pulley's output force.)
- 11. Heavy equipment operators use a joystick to control the hydraulic arms on front-end loaders. When the joystick is moved forward 3 cm, the hydraulic arms move 4 m. What is the speed ratio of the front-end loader?
- **12.** What is the difference between force and work?

Question 5b) Sparko, the robot dog

Unit Review

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- 13. Three students have built a prototype of a mechanical device to move gym equipment from the storeroom into the gym. They test their prototype and measure the forces and distances. They use their measurements to calculate the work done. They find that the work input and work output are equal. Is their calculation correct? Explain your answer.
- 14. Engineers are working to develop new car engines that are up to 60% efficient. What does "efficiency" mean in this example?
- 15. Why do hydraulic systems usually have large mechanical advantages?

#### 3.0

- 16. The development of new technology can be a process of trial and error. Explain the meaning of this statement. Use an example to support your explanation.
- 17. Why is it important to know how to evaluate mechanical devices? Use the following words in your answer: efficiency, effectiveness, impacts on people and the environment.
- 18. We often see the words "science" and "technology" used together. Describe in your own words the relationship between the two terms.
- 19. A new type of one-person motorized vehicle has been developed. It is about the size of a motorcycle but you sit in it like a car. List some of the social and environmental issues that should be considered when this machine is evaluated.

#### **Connect Your Understanding**

- 20. The food at the grocery where your family shops arrived there by truck. But it may have arrived in your community—before it got to the store by truck or train or air.
  - a) Describe two ways in the past that people transported goods.
  - b) Why do you think so many different ways of transporting goods have been developed?
- 21. What do you think would happen to a car's braking system if a hole developed in one of the brake lines? Use the words "force" and "pressure" in your answer.
- 22. List two examples of machines that use both hydraulic systems and levers. Why do you think hydraulic systems are used in each example?
- 23. You are delivering a large box of erasers to the back of a store. At the loading dock, you can lift the box a distance of 1 m onto the dock. This requires a force of 10 N. Or you could push the box up a ramp 4 m long. This requires a force of 2.5 N.
  - a) Which method of raising the box requires more work? Include your work calculations in your answer.
  - b) Which method do you think would be easier? Why?

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- 24. The ride-on lawn mower like the one in the photo is a small tractor.
  - a) Make a list of criteria that could be used by a family trying to decide whether to buy one of these mowers.
  - b) What factors, other than cost, might affect a family's decision to choose this type of mower instead of another type of lawn mower? (Other types of lawn mowers include the push mower without any motor, the electric mower, and the gasoline mower.)
- 25. Imagine you were listening to an inventor in the 1800s describe his development of the internal combustion engine. (This is the type of engine used in cars and other vehicles today.) During the discussion, you realize he hasn't considered any of the social or environmental issues associated with the engine. Why do you think the inventor ignored those aspects of his invention?

#### **Practise Your Skills**

- 26. Draw a design for a catapult device that could launch a golf ball over a small tree. The catapult should include at least two simple machines and a hydraulic system.
- 27. Plan an experiment to measure the mechanical advantage and speed ratio for a stapler.
  - a) What materials would you need?
  - b) What procedure would you use?
  - c) What variables would you need to control?

#### **Self Assessment**

- 28. Describe what you found most interesting about studying mechanical systems in this unit.
- Describe one issue or idea in this unit that you would like to explore in more detail.
- 30. What part of the unit did you find most difficult? What could you do to improve your understanding of that part?
- 31. What major factors will you consider the next time you want to buy a mechanical device of some kind?

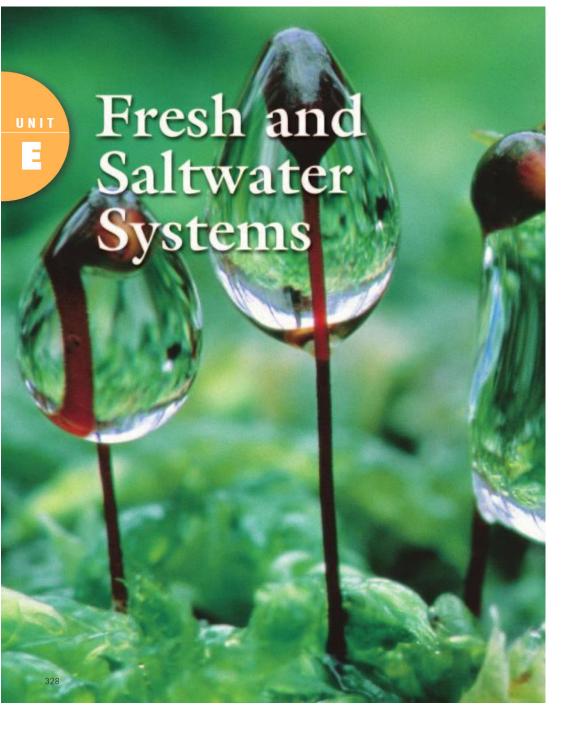
#### Focus On

#### SCIENCE AND TECHNOLOGY

In this unit, you have investigated science and technology related to mechanical systems. Consider the following questions.

- 32. Reread the four questions on page 257 about the science and technology of mechanical systems. Use a creative way to demonstrate your understanding of one of the questions.
- 33. Describe a situation where a machine was invented to meet a specific human need
- 34. Describe an example of how advances in science contributed to the development of new technology.
- 35. Describe two ways that the environment can affect the development of mechanical devices.

Unit Review





#### In this unit, you will cover the following sections:

Humans depend on water supply and quality.

- 1.1 The Distribution of Water on Earth
- 1.2 Water Quality

## Water in its various states affects Earth's landforms and climate.

- 2.1 Waves and Tides
- 2.2 Erosion and Deposition
- 2.3 Processes That Shape Ocean Basins and Continental Drainage
- 2.4 Water and Climate

## Living things in aquatic environments are affected by many factors.

- 3.1 The Diversity of Organisms in Salt and Freshwater Systems
- 3.2 Populations in Fresh and Salt Water
- 3.3 Water Quality and Living Things

#### Human activities affect aquatic environments.

- 4.1 How Humans Use Water
- 4.2 Measuring Impacts

# Exploring



Rain is just one of the ways that we experience Earth's water systems.

When you think of water, what comes to mind? Perhaps you think of drinking it, cooking with it, or washing in it. You might think of sailing on a lake, or skiing down a snow-covered hill. Water is all that and more. Living systems—including you—need it to survive. Ecosystems depend on it. The land is changed by it. Industry uses large amounts of it. Climate and weather are determined by it.

In this unit, you will explore fresh and saltwater systems. You will investigate how water quality influences living things, and how water affects landforms and climate. You will discover how human activities and needs have changed our planet's water supplies and the environments that depend on them.

Because you live in Canada, you see water in the environment all the time—in lakes, rivers, and streams, and falling from the sky. Canada is a water-rich country. Most countries in the world have much less fresh water than we do. In fact, in some areas of the world, it hasn't rained in years! But even in Canada, water isn't always where we need it when we need it.



#### COPING WITH A DRY CLIMATE

In the 1930s, much of Alberta and Saskatchewan was in the grip of a long drought. Lake and river levels dropped significantly. Small streams, sloughs, and ponds simply dried up. The water in the soil evaporated into the dry air. Topsoil turned to dust and blew away. Farming became almost impossible.

Today, southern Alberta is a very different place from the "dust bowl" of the 1930s. Large irrigation projects have brought water from the foothills of the Rockies to these dry areas. Crops can now be grown in areas where only grasses and cacti once lived. Such irrigation projects have also changed parts of southern Saskatchewan and British Columbia. In the 1930s, farmers in Alberta struggled to keep their farms going during the severe drought.



The rich crops of southern Alberta today rely on irrigation to ensure a steady supply of water.

#### HUMAN WATER USE

Irrigation is only one of the many ways that humans use Earth's water supply. In agriculture, in industry, and in our personal uses, we use water every day. And in our many uses, we affect the other organisms on Earth that depend on water as well. Can you think of any living thing on this planet that does not require water in some way to survive?

#### Give it a TRY

#### ACTIVITY

#### YOUR WATER USE

Water is essential to life—your life as well as that of all other organisms on the planet. Fresh water is especially important to humans. We think we have lots of water, but even in our water-rich country, the amount of clean, fresh water we want isn't always available. As you saw from the effect of a severe drought on Alberta, lack of water can be a serious problem. Can individuals like you help to conserve water?

- In what ways do you use precious water? With a partner, brainstorm all
  of the ways you can think of that you use water. Look over the items on
  your list, and identify the ones where you might be wasting water. For
  example, do you leave the tap running while you brush your teeth?
- For each item on your list, suggest a way that you could reduce your water use. Add your ideas to a class suggestion board on how to reduce water consumption at home.



#### USING WATER INDIRECTLY

When you use water for brushing your teeth or drinking or washing dishes, you are using water directly. But all day long, you're also using water indirectly. Every food you eat, every item of clothing you wear, every vehicle that you travel in—everything you use involves water in some part of its production. Water for irrigation is important in growing fruit and other crops. In manufacturing jeans, water is used for washing fabrics and dyeing. In making soft drinks, water is an ingredient, as well as part of the cleaning process for bottles.

All of these uses can have negative impacts on Earth's water. It's up to all of us to understand Earth's water system—what it is, how it works, and how we affect it—so we can keep our planet healthy.



### SOCIAL AND ENVIRONMENTAL CONTEXT

As you work through this unit, you will learn about the science of water systems and the social and environmental importance of water. Think about the focusing questions below as you perform activities and answer questions throughout the unit.

- 1. What are the characteristics of fresh and saltwater systems?
- 2. How do these water systems function?
- 3. How do fresh and saltwater systems interact with Earth and its atmosphere?
- 4. How do the actions of humans affect these water systems?

Thinking about these questions will help you understand the importance of water to all life on Earth—including our own. They will also help you understand how science and technology help us meet our needs for water.

In the project at the end of this unit, you will consider the effect of human activity on the water we drink. This project will give you an opportunity to use the research, thinking, and decision-making skills you practise in this unit. You will also be able to use the scientific knowledge about water systems that you learn here.



# 1.0

# Humans depend on water supply and quality.

#### **Key Concepts**

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

- · water quality
- · human impact

#### **Learning Outcomes**

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

- describe the distribution of water on Earth
- recognize that fresh and salt water contain other materials
- define water quality
- describe tests for water quality
- describe methods for making fresh water from salt water



When astronauts first viewed Earth from space, they were impressed by its beautiful blue and white colour. Earth is unique among the planets because 74% of its surface is covered with water. It is often called the "water planet" or the "blue planet." Yet, parts of Earth are so dry that they are deserts. In other areas, there is enough water, but people may not be able to drink it because of minerals that give it an unpleasant taste and odour. These are all natural variations in Earth's water supply.

The water supply can also be affected by human activities. Industries might pollute the water in lakes and rivers. Overuse by people in cities might reduce the amount of water available in an area.

An important first step in managing our water supplies is to understand how and where water occurs on Earth and what water quality means to humans and other living things. Let's begin by exploring fresh water, salt water, and water quality.

## 1.1 The Distribution of Water on Earth

Our planet has more water than any other planet in the solar system. Our water also exists in different forms. It isn't all frozen the way water on Mars is. But is it evenly distributed all over Earth? Where is the water on Earth, and what kind of water is it?

Think about a map of the world and what you know about water already. Draw a circle. The whole circle represents the total amount of water on Earth. If the circle was a pie, how big a piece of this pie do you think would represent all the drinking water available in the whole world? Draw that slice of pie on your circle. Keep your prediction handy so you can refer to it later in this subsection.

#### DRINKING WATER FOR HUMANS

Humans, and many other animals, would die if they had only salt water to drink. Drinking water must be fresh water, not salt water. However, not all fresh water is drinkable. Think about the water that collects in puddles on the street after a summer rainstorm. Would you drink that? Why not? Or the water that runs in ditches along country roads in the spring—would you drink that? Both of these are examples of fresh water, but you shouldn't drink them. Water that humans can drink safely is called **potable water**. Only a tiny amount of water on Earth is potable.



Figure 1.1 How many different states of water can you see at this lake?

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#### Water in Alberta

Alberta is fortunate to be a water-rich province with large rivers, huge lakes, and gleaming glaciers. However, most of our major rivers are far from the large urban centres of Edmonton and Calgary, which need a lot of water. Some of Alberta's largest rivers, such as the Hay, Peace, and Athabasca, drain to the north. The Bow and Elbow rivers, and the North Saskatchewan River all have reservoirs for water storage and management. A reservoir is an artificial lake. A reservoir may be used for drinking water, irrigation, or generation of hydro-electricity.



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# **Inquiry**Activity

#### Materials & Equipment

Part A

- 1000-mL graduated cylinder or beaker
- 100-mL graduated cylinder
- salt
- balance
- · 10-mL graduated cylinder
- freezer
- eyedropper

Part R

graph paper or graphing software

Figure 1.2 In this activity, you are creating a model of the distribution and characteristics of water on Earth.

### WATER, WATER EVERYWHERE

#### The Question

How much water on Earth is available for humans to drink?

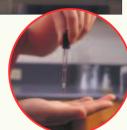
#### Procedure 📀 🧂

Part A Using a Model of Earth's Water

- fill a 1000-mL graduated cylinder with water. This represents all the water on Earth.
- 2 Predict the amount of this 1000 mL that you will use to represent the amount of drinkable water on Earth.
- Our 30 mL of this into a 100-mL graduated cylinder. This 30 mL represents the total amount of fresh water on Earth.
- Use the balance to measure out 29 g of salt. Dissolve the salt in the 970 mL of water remaining in the 1000-mL graduated cylinder. This represents the amount of water in all the oceans. It is too salty to be drinkable. Put it aside.



Sow pick up the 100-mL graduated cylinder containing the 30 mL of fresh water. Pour 6 mL into the 10-mL graduated cylinder. Take the 100-mL graduated cylinder that now contains only 24 mL of water, and put it in the freezer. This represents the amount of fresh water that is frozen in glaciers and icecaps.



You now have 6 mL of water left in the 10-mL graduated cylinder. Use an eyedropper to remove a small amount of water. Let one single drop fall into your palm. This one drop represents all the fresh water on Earth that is available for people to drink! It is about 0.003% of the total amount of water on Earth.

Here's what you've learned about the distribution of water on Earth:

- Of all the water on Earth, 97% is salt water in the oceans, and 3% is fresh water.
- Of the fresh water (3% of the total water), 77% is ice, 22% is groundwater, and 1% is in lakes, rivers, and wetlands.

#### Part B Graphing the Distribution of Water on Earth

- Another way to represent Earth's water supply is to graph it. Either by hand or using graphing software, draw two separate circle graphs, one for each of the statements about water shown in the box.
  - Remember to be accurate when graphing. If you are doing it by hand, make sure to convert the percentages to degrees, and use a protractor to measure the angles accurately.
  - · Colour your graphs, and give each one a title and a legend.

#### Analyzing and Interpreting

8 In this activity, you used two different methods of presenting information about the distribution of water on Earth. What were the two methods? What were the benefits of using each method? What were the drawbacks to each method?

#### Forming Conclusions

9 Using words, pictures, or both, describe how much water is available to humans as drinking water, compared with the rest of the water on Earth.

#### Applying and Connecting

While you were doing this activity, water was evaporating from your samples into the air. About 0.0009% of all the water on Earth is a gas in the atmosphere at any one time. In some places in the world, water in the atmosphere is the only fresh water that's available for people to drink. How can they drink water from the air? A village in the desert on the north coast of Chile uses special web collectors to gather water from the fog that forms early every morning. In Peru, Ecuador, Namibia, and Oman, people are also using this technology.

#### **PESEARCH**

#### Canada's Water Riches

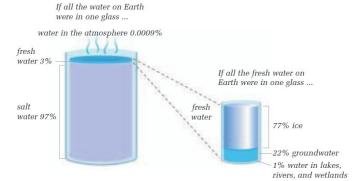
Canada is awash with water. We are bounded on three sides by oceans. We have 9% of all the world's fresh water. We have over 2 million lakes. And we have large reserves underground as well. Should we share our fresh-water riches with the United States and other countries? Use the Internet to learn more about this issue. Decide for yourself what Canada's policy on water exports should be.

**Figure 1.3** Most of the water on Earth is in the salty oceans. Most fresh water is frozen solid.

#### WATER ON EARTH

Earlier in this subsection, you learned that humans can drink only fresh water. From the information above, it looks as if there's plenty of water for us to drink. But most of the fresh water is locked in icecaps and sea ice in the Arctic and the Antarctic far from population centres. And not all of the water underground, and in lakes, rivers, and wetlands is accessible. In fact, only about 0.003% of all the water on Earth is available for humans to drink. The remaining fresh water may be too far below Earth's surface or in places where humans don't live.

Imagine that you had 1000 glasses of water in front of you, representing all the water on Earth. You would be able to drink less than one-third of one glass! Figure 1.3 is another way of illustrating the amounts of salt water and fresh water on Earth.



#### CHECK AND REFLECT

- 1. a) Where is most of the fresh water on Earth?
  - b) Is it readily available for humans to use? Why or why not?
- 2. a) How much of all the water on Earth is available for humans to drink?
  - b) Find the circle graph that you drew at the beginning of this subsection predicting the amount of drinking water compared with the total amount of water on Earth. Was your prediction close? Why or why not?
- 3. We know that Earth's population is increasing. Do you think enough drinking water will be available for future generations? Why or why not?

# 1.2 Water Quality

When you turn on your tap, you expect your glass to fill up with clear water that has no unpleasant odour or taste. In Canada, we expect the quality of our water to be good all the time. Water quality describes how pure the water is. You can determine water quality by measuring the amount of substances besides water that are in a water sample.

Water in nature is never pure—it always contains organisms, organic material, minerals, and other chemicals. You are about to explore water quality in more detail. To prepare for your exploration, start a concept map with the phrase water quality in the centre. Build your concept map as you read about and investigate water quality. See Toolbox 9 for information on creating concept maps.

#### SUBSTANCES DISSOLVED IN WATER

Many different substances are dissolved in both fresh and salt water. Most of these substances are called *salts*. The most common salt dissolved in water is sodium chloride—the same mineral we use for table salt. The total amount of all salts dissolved in water is called its *salinity*. Seawater (water in the oceans) has a much higher salinity than fresh water. Seawater's average salinity is 3.5%. Seawater also contains many other substances in much smaller amounts. It even contains gold and silver! But you would have to process an enormous amount of seawater to obtain even a small amount of gold.

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#### **Unsafe Water**

Over I billion people drink dirty water every day because they can't get clean water. Worldwide, 3 to 5 million people die each year from unsafe water. Most of them die from diseases carried by the local water supply. The diseases may be caused by bacteria, viruses, or small parasites in water. Most of these diseases are spread by drinking water contaminated by feces of infected animals or people.



Why is this water unsafe for human use?

### math Link

Seawater is a solution containing 96.5% water and 3.5% dissolved salts. The following substances make up these salts:

sodium 30.6% chloride 55.0% sulphate 7.7% magnesium 3.7% calcium 1.2% potassium 1.1% other 0.7% Which substance makes up the largest percentage of dissolved salts? What

percentage of seawater is this substance?

#### HARD WATER

Fresh water can be found both on Earth's surface and underground. As it flows, it dissolves minerals from the soil and rocks it passes through. One of these minerals is salt. Fresh water contains much less salt than seawater does. But in some places, the salinity of fresh water is high enough that you can taste it. In Canada, salty fresh water can be a problem in places on the Prairies. Other substances can also be a problem. In some places in Ontario, water contains so much iron that it affects the taste.

Many areas across the country have hard water. Hard water contains a high concentration of the minerals calcium and magnesium. You can tell that you have hard water if soap doesn't lather properly. Hard water also leaves mineral deposits in appliances such as kettles and hot water heaters.



**Figure 1.4** Hard water causes mineral deposits called *scale* to form on the inside of pipes. The scale clogs up the pipes.

#### ORGANISMS IN DRINKING WATER

Fresh water also contains organisms and other organic matter. Some of the substances and organisms that may be found in water are harmful and some are not. Most minerals are not a serious health problem, but some organisms that may be found in fresh water can be. For example, *Escherichia coli*, known as *E. coli*, is a type of bacteria that can cause sickness and even death. Usually, our water treatment processes prevent these organisms from becoming a problem.

#### WATER QUALITY TESTING

If you get your water from a well, your family probably doesn't have the water tested very often. Because the water comes from deep underground, it is protected from most pollutants—both natural and human-made. But most cities and towns get their drinking water from surface sources, either lakes or rivers. They then filter this water and treat it with chemicals. This processing brings it to a level of quality that is safe for human use. Such water must be tested regularly to make sure that it is potable.





## Community Water Processing

Getting good quality water to people, businesses, and other users is a big effort. Water from a source such as a lake, river, or groundwater is pumped into a treatment plant. There it passes through a series of stages that gradually make it cleaner and cleaner until it is safe to drink. Find out how water treatment is done in your community.

## Inquiry

## Activity

#### Materials & Equipment

- · 1 500-mL sample of tap water in a beaker
- · 2 500-mL samples of untreated water from 2 different sources (provided by your teacher)
- · filter paper (or white paper coffee filters)
- funnel
- 250-mL beaker
- · graduated cylinder
- 3 test tubes
- silver nitrate 🥘
- (1% solution)
- 3 Erlenmeyer flasks
- soap flakes (not detergent)
- · 1-mL measuring spoon
- · 3 stoppers for flasks
- bromothymol blue



#### Caution!

Do **not** taste any of the water samples at any time during this activity.

#### Caution!

Always follow your teacher's instructions in handling and disposing of chemicals.

#### TESTING THE WATERS

#### The Question

Are there physical and chemical differences between treated water and untreated water?

#### The Hypothesis



Write a hypothesis about the differences you would expect to find between treated and untreated water.

Hint: Think about their appearance and what substances they might contain.

#### Procedure 🕲 🧔



#### **Checking for Clarity**

- 1 Observe the samples in their beakers. Record their appearance, including
- Read the next step and predict what you will see after filtering each water sample.
- Place a filter paper cone in a funnel and place the funnel in the empty beaker. Using the graduated cylinder, pour 100 mL of one water sample through the filter paper. Wait until the water has drained through the filter entirely. Observe the filter paper and the water in the beaker. Record your observations.
- 4 Repeat step 3 for each of the other two water samples.

#### Testing for Chlorine

- 5 Predict which water sample will contain the most chlorine.
- 6 Pour a small amount from each water sample into separate test tubes. Add 5 drops of silver nitrate solution to each test tube. Record any changes you see in the water in the flasks. Wash your hands.

#### Testing for Hardness

- 7 Use the graduated cylinder to measure 100 mL of each sample into 3 separate Erlenmeyer flasks. Label each flask.
- 8 Add 1 mL of soap flakes to each flask and put the stoppers in the flasks. Shake each flask vigorously for 30 s. Observe the soap froth in each flask. Record your observations.

#### Testing for Living Organisms

9 Thoroughly wash out, rinse, and dry the 3 Erlenmeyer flasks and rubber stoppers. Pour 125 mL of the tap water into a clean Erlenmeyer flask. Put the same amount of each of the other samples in separate flasks. After you measure each sample, make sure to clean the measuring container thoroughly with soap and water. Then rinse and dry it carefully before using it for the next sample.

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- Add 5 drops of bromothymol blue to each flask. Tightly stopper the flasks and label them. Record the colour of the solution in each flask. Place all the flasks in a warm, dark place where they won't be disturbed for 24 h. Wash your hands. After 24 h, remove the flasks from the dark and record the colour of the solution in each one.
- Wash your hands after you have completed all the tests and cleaned up your equipment.

#### **Collecting Data**

12 Record your observations in a table similar to the one below.

Purpose of Test	Appearance of Sample before Test	Appearance of Sample after Test	What the Test Indicated

#### Analyzing and Interpreting

- 13 Explain any differences you observed in the appearance of the filter papers used for the water samples.
- 14 Which sample contained the largest amount of chlorine? Why?
- 15 Which sample contained the hardest water? How do you know?
- 16 When you were preparing the test for living organisms, you had to clean the graduated cylinder between water measurements. You also had to make sure the Erlenmeyer flasks were clean. Why did you have to be so careful?
- 17 Which sample contained the most living organisms? Do you think it would be safe to drink? Remember: Do **not** taste any of the water samples.
- 18 Which sample had the least number of living organisms? Why?

#### Forming Conclusions

19 Are there differences between treated water and untreated water? Summarize the results of your tests to support your conclusion.

#### Applying and Connecting

For years, the Cree community of Split Lake, Manitoba, had suffered health problems because of poor water quality. They went to Environment Canada for help and then linked up with the International Development Research Centre (IDRC) in Ottawa. IDRC had been working on low-cost water-testing kits for developing countries. The Split Lake community used the IDRC technology to prove that people in isolated areas could do their own water testing and take action to improve their water quality.



**Figure 1.6** Step 3. Pour 100 mL of one water sample through the filter.



**Figure 1.7** Step 6. Add 5 drops of silver nitrate solution to each test tube.



**Figure 1.8** Which glass of water is safe to drink? Maybe neither of them is!

#### WATER TESTING CRITERIA

One of the first things that a technician does when testing water is to look at it. Look at the two glasses of water in Figure 1.8. Which one of these glasses of water would you be more likely to drink? Another step in water quality testing is smelling the water. Does it have any unpleasant odours? For example, in some areas, dissolved hydrogen sulphide gas can give water a rotten egg smell. And it's not only the smell that is bad. Hydrogen sulphide is unsafe for human consumption.

Always remember, however, that clear water is not a sign of clean water. Ocean water can be very clear, but we can't drink it because of the high salt content. Similarly, a stream in the woods may look clear, but it may contain organisms or chemicals that are dangerous to humans. In order for us to be sure that our water is safe to drink, it must be tested regularly. After testing, the water is filtered and treated with chemicals, such as chlorine, to kill any dangerous organisms.

These are some of the items that drinking water is tested for:

- taste and odour
- turbidity (cloudiness) and colour
- toxic substances and other pollutants
- bacteria
- hardness or mineral content
- pH (how acidic or basic the water is)
- dissolved oxygen
- solids, including floating materials
- dissolved solids

#### CHANGING SALT WATER TO FRESH WATER

As you learned in subsection 1.1, most of the water on Earth is in the salty oceans. Much of the fresh water is locked up in icecaps and glaciers. Only a small percentage of liquid fresh water is available for drinking. In some areas of the world, very little fresh water is available, but there is lots of salty water. Is there a way to use salty water for drinking? Salt water must be processed to remove the salt to make the water potable. The two most common processes used for producing fresh water from salt water are distillation and reverse osmosis.

#### Distillation

Distillation equipment produces pure water (distilled water) from water that may contain minerals, such as salt, and other substances. In **distillation**, the solution is boiled so that the water evaporates and leaves the salt behind. Liquid fresh water is then formed from the water vapour.

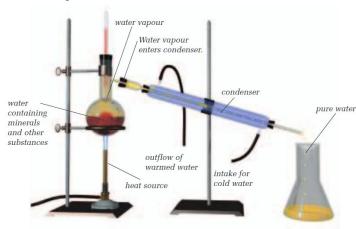


Figure 1.9 This simple lab apparatus can create pure water.

#### **Reverse Osmosis**

Reverse osmosis operates by forcing salt water through a filter or membrane with holes too small for the salts to pass through. Osmosis is the movement of water particles through a membrane. The particles move from an area of higher water concentration to one with a lower water concentration. In reverse osmosis, the water moves from an area of lower water concentration to one of higher water concentration. In this way, the water leaves behind the unwanted dissolved substances.



**Figure 1.10** This reverse osmosis set-up can also create pure water from salty or polluted water.

#### CHECK AND REFLECT



- You are walking along a dry, dusty road in summer. Feeling really thirsty, you stop by a clear, running stream. Would you drink the water? Why or why not?
- 2. Some cities and towns take their drinking water from rivers and lakes. Sometimes their water quality changes during the year. What do you think might cause these changes? Suggest an example of the difference in water from a lake between summer and winter.
- 3. Saudi Arabia is a desert country with very little fresh water. However, it has a long coastline along the Red Sea and the Persian Gulf. Large commercial desalination operations in Saudi Arabia produce fresh water from salt water. The availability of inexpensive fuel in the form of oil makes these huge operations possible. One of the reasons Canada does not have huge desalination operations is the high cost of fuel to heat the water. Can you think of any other reasons why we don't use distilled water?



#### ACTIVITY

#### SALT WATER INTO FRESH WATER

You can turn salty or dirty water into drinkable fresh water simply by using the sun. After all, it's the sun's energy that converts the salty water of the oceans into the fresh water of the rain. All you need is a clean, clear plastic bag, a twist-tie to close the bag, some table salt, and a cereal bowl of water.

- Dissolve a tablespoon of salt in the bowl of water. Taste the water by touching it and tasting it off your fingertip. It should taste very salty.
- Place the bowl inside the plastic bag and close the top of the bag tightly with the twist-tie.
- Set the bag and bowl next to a sunny window, and leave it there for 24 h.
- After 24 h, open the bag, and touch the liquid collected on the inside of the bag. Taste it. Is it still salty?
- · Explain what happened to the salty water.



Figure 1.11 Set-up for activity

#### SECTION REVIEW

#### **Assess Your Learning**

- 1. Explain what potable water is. If all the water on Earth is represented by a 1000-L tank, how many millilitres of that would represent potable water?
- 2. Do you think there are reserves of fresh water that have yet to be used by humans? Explain your answer.
- 3. What chemical is usually added to water that will be piped to households? Why?
- 4. What is hard water? What do you think soft water is?
- 5. If you haven't already done so, add information on water quality and testing to your concept map. Keep your concept map so you can add to it later in this unit when you learn how water quality can affect organisms.



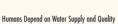
### SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology have contributed to human well-being. Think about what you learned in this section.

- 1. How have water quality testing techniques improved people's
- 2. Why do you think more and better water desalination technology is being developed?
- 3. What did you learn about water quality in this section that helped you understand the importance of protecting our sources of drinking water?



Desalination plant







## <u>2.</u>[

# Water in its various states affects Earth's landforms and climate.

#### **Key Concepts**

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

- · water-borne materials
- · erosion and deposition
- · stream characteristics
- · continental drainage systems
- ocean basins
- climate
- glaciers and icecaps

#### **Learning Outcomes**

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

- describe the causes of waves and tides
- describe erosion and deposition and their causes
- identify stream characteristics
- describe processes that shape ocean basins and continental drainage
- identify factors that affect glaciers
- recognize evidence of glacial action
- describe the link between water and climate



Water exists in many different forms on Earth. You can find it in all three states—solid, liquid, and gas. You can find it underground, on the surface, and in the air. Because there is so much of it, water affects both the living and non-living parts of Earth's environment. Waves and tides erode shorelines and influence the kinds of animals and plants that live there. On land, moving water in streams and rivers, and moving ice in glaciers change the geography of continents. And water—or the lack of it—determines climate and weather around the world. In this section, you will learn more about how fresh and saltwater systems interact with the atmosphere and Earth's surface.

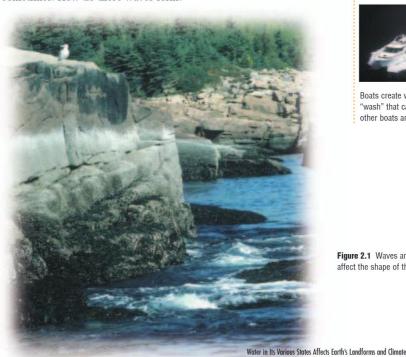
## 2.1 Waves and Tides

In Figure 2.1, waves splash onto the ocean's shore at low tide. Above the line of waves, you can see another line on the shore where the waves hit at high tide. Waves and tides are two examples of ways in which water moves.

Waves are movements on the surface of the water. Tides are the regular rising and falling of very large bodies of water. You can also see in Figure 2.1 evidence of erosion caused by the waves. Make a sketch of what you see in Figure 2.1. Label it to show where the waves are coming from, the effect they have had on the shore, high tide level, and low tide level. As you read through this subsection, add information on waves and tides to your diagram.

#### WHAT IS A WAVE?

If you have ever been to the ocean or a lake, you know that the water's surface is constantly moving. On calm days, waves lap along the shore. On stormy days, they crash against it. But even small bodies of water—right down to puddles—have waves sometimes. How do these waves form?



#### infoBIT

#### **Boats and Shore Erosion**

A large cruiser travelling at 8 knots (14.8 km/h) will cause a wash big enough to sink small boats. damage moored ones, and contribute to shore erosion. In waterways where major bank erosion is occurring, you may see "NO WASH" signs displayed. This means that boat drivers must slow down so that no waves are created that could damage the shore.



Boats create waves called "wash" that can affect other boats and the shore.

Figure 2.1 Waves and tides both affect the shape of the shoreline.

## Inquiry

### Activity

#### Materials & Equipment

- · deep, flat baking pan
- water
- 1 cork

#### MAKING WAVES

#### The Question

How does the movement of waves affect objects floating on the water?

#### The Hypothesis

Write a hypothesis to explain how the movement of waves affects objects floating on the water.

#### Procedure

1 Fill the baking pan three-quarters full of water, and place it on a desk or table. Wait for the surface to be calm.



Figure 2.2 Set-up for making waves

- 2 Create waves by blowing across the water's surface.
- 3 Take turns trying to produce different kinds of waves. See if you can change the height of the waves.
- 4 Place a cork on the water, and wait for the water to calm. Predict what will happen if you blow on the water and not on the cork. Blow on the water to make waves, but do not blow directly on the cork.

#### **Collecting Data**

5 Draw labelled diagrams of the different waves you make and the cork's movement.

#### Analyzing and Interpreting

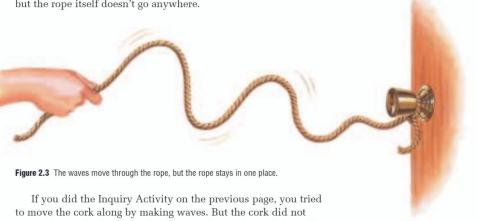
- 6 Were you able to change the heights of the waves you created? If so, how did you do it?
- 7 Were you able to move the cork across the pan? Explain why or why not.

#### Forming Conclusions

 ${\bf 8}$   $\,$  Using words and pictures, create a summary of what you know about waves.

#### THE MOVEMENT OF WATER WAVES

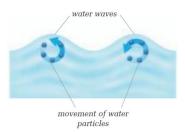
Waves are changes in patterns that move along the water's surface. The water itself does not move very far, but waves can move thousands of kilometres across the surface of the ocean. You can use a rope as a model of wave motion. In Figure 2.3, a student is shaking a rope to create waves. The waves move through the rope, but the rope itself doesn't go anywhere.



If you did the Inquiry Activity on the previous page, you tried to move the cork along by making waves. But the cork did not move along, only the wave did. You may have observed the cork moving in a small circle. Within the wave, the water particles move in a circular motion as shown in Figure 2.4. But the water particles themselves do not move long distances.

#### CAUSES OF WATER WAVES

Most waves are caused by the wind. The stronger the wind, the bigger the waves. Out in open water, waves appear as up-and-down water movements. If you were in a boat, you would feel this up-and-down movement as the waves passed under your boat. Near the shore, the water becomes shallower, and the lower part of the waves drags on the bottom of the ocean or lake. This slows the waves down, and the tops of the waves rise up and eventually break, crashing onto the shore. This is where waves do the most damage.



**Figure 2.4** A wave moves along the surface of the water, but the water itself moves only in a tiny circle in one place.

#### reSEARCH

#### **Tsunamis**

Earthquakes can create huge ocean waves, called tsunamis. Although these waves are large, they are spread out over a long distance. Because of this, they are not very noticeable in the open ocean. Once they begin to slow down in shallow water, however, they can grow as high as a 15-storey building. Find out how an earthquake causes a tsunami.

- Why do we hear of tsunamis in the Pacific Ocean more than anywhere else?
- How does the tsunami warning system in the Pacific Ocean work?

#### EFFECTS OF WAVES ON SHORELINES

The force of waves crashing against a shoreline can change the shape of the shore, whether it's hard rock or soft sand. Large waves erode away the shore. But small waves move gently onto the shore. They can deposit sand or other materials near the shore. Figures 2.5 and 2.6 show some examples of the effects of waves on coastlines.



Figure 2.5 Percé Rock is the most famous landmark on the Gaspé Peninsula in Quebec. Wave erosion has pierced a hole through the rock and is gradually eroding away the whole rock.



Figure 2.6 Waves are eroding and depositing gravel along these beaches in Nova Scotia. Gravel ridges are being deposited out in the water, as gravel is being eroded from the land.

#### WHAT ARE TIDES?





Figure 2.7 Why does the water level change in this bay?

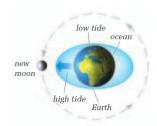
The two photos in Figure 2.7 were taken at the same spot about 6 hours apart on the New Brunswick coast. What happened to the water in the bay? Where did it go? If you waited another 6 hours, how much water would be in the bay?

Because New Brunswick is on the shore of the ocean, the water level along its coast changes regularly every day. This change in water level is called the tide. People who live beside the ocean are used to seeing and working around high and low tide. High tide is the highest water level along the coast, and low tide is the lowest water level. In most places, there are two high tides and two low tides a day.

#### THE CAUSES OF TIDES

The main cause of tides is the gravitational force of the moon. Figure 2.8 shows how tides occur. The side of Earth that is closest to the moon feels the strongest pull from the moon's gravity. This is where the bulge of water is the largest. But other forces are also at work, resulting from Earth's and moon's rotations. These forces cause another, smaller bulge on the other side of Earth at the same time. The two large bulges, on either side of Earth, are the high tides.

As the moon orbits Earth, it pulls the large bulge of water along. At the same time, Earth is spinning in its rotation, and orbiting around the sun. All of these movements combine to create two low tides and two high tides every 24 hours and 50 minutes. Because every day is 24 hours, this means that low tide or high tide is 50 minutes later every day. People who live along the ocean use guides called tide tables to tell them when the tides occur, and how high or low they will be that day.



**Figure 2.8** The gravitational force of the moon is the main reason for ocean tides on Earth.

#### CHECK AND REFLECT

- 1. Describe the movement of water in a wave.
- 2. What happens to waves in a lake as they get closer to shore?
- 3. We usually think of waves on lakes and oceans. Can rivers have waves? If so, what causes them?
- 4. What causes tides?
- 5. Look at your drawing of the shoreline that you started at the beginning of this subsection. If you haven't already done so, add information from this subsection to it. Did you learn anything in this subsection that surprised you? What was surprising about it? How would you explain this new idea to another student?



**G**laciologists are scientists who would rather spend a summer cooling their heels on ice than soaking up the sun on a southern beach. They study glaciers, investigating how glaciers move and their connection to world climate.



Glaciologists exploring an ice cave

#### GLACIOLOGIST

Glaciologists use radar to find out what the ground is like under a glacier. When they have gathered enough data, they design computer programs that describe the movement of glaciers and predict how and why glaciers change.

- 1. Why is it important to understand the natural environment?
- 2. What do you think would be the most interesting part of a glaciologist's job? Why?
- 3. List three important skills a person would need to be a successful glaciologist.

## 2.2 Erosion and Deposition

Think about a river or stream in or near your community. How fast does it flow? Is the water clear or muddy? Does it flow straight or does it wind its way through the area? The answers to these questions would describe some of the characteristics of your stream or river. Scientists use these characteristics to help them understand where different types of organisms might live in a river and how they might be affected by human activities. Engineers use these characteristics in building dams and bridges.

#### STREAM CHARACTERISTICS

To learn more about a stream or river, you would develop a *profile* of it. A stream's profile is a description of its characteristics. How fast does it flow? How steep is the stream's channel? How is it eroding its banks? Each stream has a pattern of flow that is shaped by its characteristics. **Stream characteristics** include the rate of water flow and the slope of the stream's bed. Rivers can be described with these same characteristics. Figure 2.10, after the next Inquiry Activity, is an example of a river's profile.

#### infoBIT

#### **Hot Springs**

Rivers and streams carry and deposit sediments on Earth's surface. Hot springs bring dissolved sediments up from within Earth and deposit them on the surface. The water of the hot springs comes from deep underground, where the temperature of the rocks is higher than at the surface. From earlier studies, you know that warm or hot water can dissolve more solute than cold water. As the hot water passes through rocks and soil, it dissolves more and more minerals. But once it reaches the surface, it cools down. As it cools, it can no longer keep so much solute in solution, so it deposits the sediment near where it emerges from the ground.



These terraces of calcium carbonate are deposited by the hot water from hot springs in Nahanni National Park.

## Inquiry

## Activity

#### Materials & Equipment

- · gravel and sand mixture
- · buckets or pails
- · stream table or roof gutter
- · mixing spoon
- · 2 lengths of plastic tubing
- books
- · paper towels, sponges

#### STREAM FLOW

#### The Question

What is the relationship between the slope of a stream bed and the erosion of the material in the stream bed?

#### The Hypothesis



Form your own hypothesis to test the relationships between stream-bed slope and the erosion of stream-bed material.

#### Procedure 🕲 🗂





- a depth of 3 to 5 cm. Use the mixing spoon to spread the mixture evenly. Connect one piece of plastic tubing to the drain port at one end of the stream table. Place the other end of the tubing in an empty bucket.
- 2 Connect a second length of plastic tubing to your water source, if it is a faucet. If it's not a faucet, place one end of the tubing in a clean bucket full of
- With the help of another student, raise the stream table or roof gutter 1 cm at the end opposite the drain port. A third person then places a 1-cm pile of books under the raised end. Lower the stream table onto the books and make sure it is steady before you let go.
- 4 Read the next three steps. Predict what will happen to the stream-bed material and the water's flow each time.
- Check the drain port and remove any sand and gravel mixture that is blocking it. Allow the water to flow at a slow trickle onto the raised part of the stream bed or roof gutter. Squeeze the end of the tubing until you get the flow you want. Observe the direction and speed of the water's flow. Observe its effect on the stream-bed material. Make sure to keep the flow rate of the water the same for each trial.
- 6 With the help of another student, increase the slope of the stream table by lifting the end opposite the drain port to 5 cm. A third person places a 5-cm stack of books under the raised end. Make sure the gravel and sand mixture is evenly spread on the bottom of the stream table. Empty the water in the outlet bucket, and check all tubing connections. Use the same flow of water as in step 5. Observe the direction and speed of the flow of water. Observe its effect on the stream-bed material.
- Use the same procedure as in steps 5 and 6 to raise one end of the stream table to 20 cm. Make sure the gravel and sand mixture is evenly spread on the bottom of the stream table. Empty the water in the outlet bucket, and check all tubing connections. Use the same flow of water as in steps 5 and 6. Observe the direction and speed of the flow of water. Observe its effect on the stream-bed material.

## Caution!

At least two people must be used to lift the stream table.

With the help of another student, lift the stream table off the pile of books. A third person removes the books. Place the stream table flat on the desk, and let any remaining water drain from it. Use the paper towels and sponges to clean up any spills.

#### Collecting Data

9 Design a data table to record your observations in your notebook. Draw diagrams to illustrate changes to the gravel and sand mixture.

#### Analyzing and Interpreting

- 10 What happened to the stream-bed material as the water flowed over it?
- 11 How did the stream flow behave on the shallow slope? Did this change as the slope was increased?
- 12 Why was it important to keep the water flow rate constant for all the trials?
- 13 Was your hypothesis correct or would you have to restate it? Would you have to change any of the variables in the set-up before you could verify your hypothesis?

#### Forming Conclusions

14 Using a written summary and labelled diagrams, describe the relationship you discovered between the slope of the stream bed and the erosion of material on the stream bed. Include observations of the speed of the water in the stream in your summary.

#### Applying and Connecting

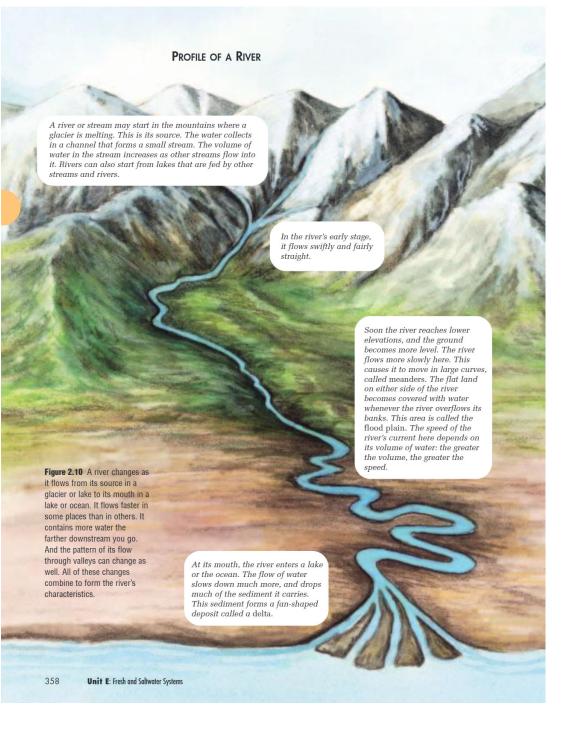
Operators of river rafting companies have to know every twist and turn of the rivers they use. Before they determine a suitable course on a river, they must understand the river's characteristics. This helps them choose the route that is both the safest and the most exciting. It also helps them identify places where they can come ashore easily, if necessary.

#### Extendina

During this activity, you observed the flow of water when the stream bed was at different heights. You probably described the water as moving faster or slower, depending on how high the stream bed was placed. This type of information is called *qualitative data*. It describes events without using exact measurements. Suppose you had measured the speed of the water in metres per second for each height of the stream bed. This type of information is called *quantitative data*. It describes events in measurements or quantities. In this activity, the quantitative data would be the measurement of speed. In another activity, it might be temperature or amount of solute. Design a procedure to collect quantitative data on the rate of water flow in your stream bed. Test your procedure. Compare the speeds at different heights of the stream bed.



Figure 2.9 Setting up the stream table



#### **EROSION AND DEPOSITION**

Moving water is one of the most powerful forces on Earth. It can tear away pieces of rock and lift and carry sand and soil long distances. Earlier in this section, you saw how waves can affect shorelines by eroding in some places and depositing sediment in others. Streams and rivers also shape the land as they flow through it.

Recall from your earlier studies that erosion is the wearing away and transporting of rock fragments and soil. These are called sediments. Deposition is the laying down or depositing of sediments. A river's sediment load is the amount of water-borne materials, such as soil, rocks, and organic matter that it carries. Water-borne means "carried by water." Remember that as long as water is flowing, it can carry sediment. But the slower it flows, the less load it can carry. As it slows down, it deposits some of its sediment load. Once it stops flowing, it can't carry any load. It deposits all the sediment it still carries.

#### CHEMICAL WEATHERING

Erosion can also occur because of chemical weathering. Caves form when rainwater and streams dissolve limestone and other rocks. The water collects in cracks and holes in the rock. As it sits there, it gradually dissolves more and more of the rock until large caverns form. Streams and rivers flowing through these caverns cause even more erosion.



#### **I'ESEARCH**

#### Karst Landscapes

The formations shown below form part of what is called a karst landscape. Such a landscape typically has caves, sinkholes, natural stone bridges, sinking streams, and other features. Find out how karst landscape forms. What are sinkholes and sinking streams?



These karst formations are in the Mackenzie Mountains in the Northwest Territories.

Figure 2.11 Streams and rivers flowing through caves carry dissolved sediments.

#### WHAT MAKES A WATERSHED?

A watershed is all the area of land that drains into one main lake or river. It can contain many smaller rivers and lakes, which all eventually drain into a larger one. Even your neighbourhood is part of a watershed.

Most watersheds drain into lakes and rivers that drain into other lakes and rivers, which finally drain into an ocean. The location of the highest land on the continent determines the direction that a watershed drains. This high land is called the Continental Divide. In North America, the major divide is in the Rocky Mountains. To the west of the Continental Divide, rivers flow into the Pacific Ocean. To the east of the Continental Divide, rivers flow into either the Arctic Ocean or the Atlantic Ocean. The borders between British Columbia and Alberta, and Yukon and the Northwest Territories follow the Continental Divide.

#### **CHECK AND REFLECT**

- 1. List two characteristics you would want to know about a stream if you were planning to wade across it. Why would you want to know these?
- Do you think that all hot springs deposit the same kinds of minerals? Explain your answer.
- a) Describe some natural factors that might cause erosion along riverbanks.
  - b) Describe some human activities that might cause erosion along riverbanks.
- 4. Using maps and references, create a map to show the streams, rivers, and lakes that are part of the watershed you live in.
  - a) Find out how your watershed is connected to the Continental Divide.
  - b) Mark on your map the direction to the Continental Divide from your community and the direction to the ocean that your watershed eventually drains into.

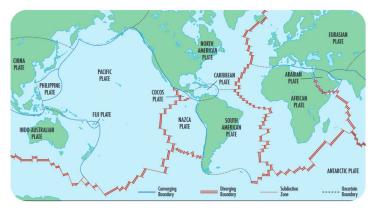


This sign marks the Continental Divide in the Rocky Mountains.

## 2.3 Processes That Shape Ocean Basins and Continental Drainage

In your short lifetime, Earth has been a stable place. Familiar places—rivers, mountains, continents, and oceans—have not changed very much. We may forget that Earth is very old and much of what we see now is not the way it appeared in the past. Earth is in a constant state of change.

#### PROCESSES THAT FORM OCEAN BASINS



**Figure 2.12** The Theory of Plate Tectonics states that the surface of Earth is divided into huge moving plates.

In earlier grades, you learned that the solid outer part of Earth is called the *lithosphere*. The lithosphere is made of rock that is broken into huge plates. The map in Figure 2.12 shows the shape and position of these plates today, but these plates are not fixed in these positions. They are moving very slowly over Earth's surface because of convection currents within Earth. Some plates are moving toward each other. Others are moving apart. And some are moving alongside each other in opposite directions. These movements have shaped the geological features on the ocean floors and many of those on the continents. Figure 2.13 shows the major features on the ocean floors and how they formed.

#### infoBIT

## What Is the World's Tallest Mountain?

If you said Mount
Everest, you're right—
sort of! Mount Everest
is the tallest mountain
on dry land (8850 m).
But Mauna Kea in
Hawaii starts on the
ocean floor. If it's
measured from its base
underwater, it's taller
than Mount Everest.
Mauna Kea is about
10 023 m tall.



The continental shelves are shallow areas around the edges of the continents. They are mainly sedimentary deposits of materials eroded off the continents. They are largest on the edges of oceans that are opening up (e.g., the Atlantic), where plates are moving away from each other.

Volcanic islands are formed by volcanoes that grow up all the way from the ocean's floor. Trenches form where two plates are moving toward each other. The thinner oceanic plate is pushed down below the thicker continental plate.



Figure 2.13 The geological features on the ocean floor are the result of plate tectonics. Where plates move toward each other, trenches form. Where they move apart, ridges and faults form. Ridges are a sign that new crust is forming.

Seamounts are underwater volcanoes that do not come all the way to the ocean's surface.

Mid-ocean ridges form where molten rock pushes up from the interior of Earth. On either side of the ridge are two different plates. They are slowly moving away from each other as the molten rock hardens into new crust.

#### CONTINENTAL DRAINAGE SYSTEMS

The changing lithosphere also affects the major drainage patterns of our continents. Changes have occurred over millions of years. Earlier, you learned that the Continental Divide sets the pattern for the directions in which rivers flow. That divide in Canada follows the ridge of the Rocky Mountains. But how did the Rocky Mountains form?

The same forces that shaped the ocean basins built the Rockies. Look again at the map of the plates that form Earth's surface in Figure 2.12. At the edge of the continent, two plates meet. As they push against each other, the continent's surface wrinkles and pushes up. The Rockies and other folded mountains were created this way.

Plate tectonics have formed many mountain ranges. These mountains have helped to shape continental drainage systems. But another major force has carved much of North America's surface to create the lakes and river valleys we see today. This force is ice.



**Figure 2.14** Notice where the Rocky Mountains are located. They were formed by plate movements. How are the major river systems related to the mountain ranges?

#### **GLACIERS**

Glaciers are large moving bodies of ice. Glaciers that cover vast areas of land are called *continental glaciers* or *icecaps*. They form in Earth's coldest regions. Antarctica and Greenland are covered by continental glaciers. Glaciers also form high up in mountain ranges. Here the temperature is so cold that snow and ice melt very little. More and more snow and ice build up and begin to move. These glaciers, called *valley glaciers*, flow down through the high valleys between mountain peaks.

As glaciers move, pieces of rock become imbedded in the ice. These pieces range in size from tiny fragments to huge boulders. It is these pieces combined with the massive glacier that grind down and shape the land they pass over.

The movement of glaciers depends on the climate. In a cooler climate, little melting occurs. The snow and ice continue to build up, and the glacier continues to move forward or advance. If the climate becomes warmer, more melting occurs. Snow continues to fall in the highest parts of the glacier. But now more melting than build-up occurs. The ice that already forms the glacier melts more and more. The glacier melts back or retreats. It leaves behind the soil, rock, and boulders it once contained.



#### Frozen History

Since 1900, glaciers all over the world have been retreating faster than ever before. In 1991, a man who died 5000 years ago was found preserved in a glacier in the Alps. The glacier had retreated as far back as it was 5000 years ago. It is still retreating. Who was this man? What have scientists learned about him and the world in which he lived?



This man died as he was travelling through the Alps 5000 years ago.

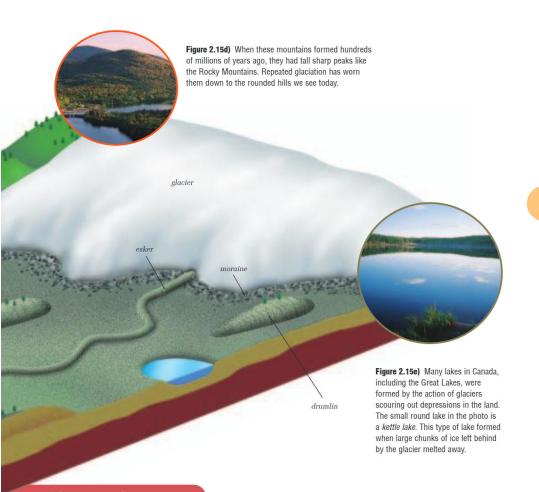
#### RECOGNIZING GLACIAL FEATURES

Today we have continental and valley glaciers only in certain areas. But many times over Earth's history, large areas were covered with glaciers. This was the time of the Ice Ages. Much of Canada's geography was shaped by these huge sheets of ice. See if you recognize any of the glacial landforms in the photos below. Are there any of these features in the area where you live? Have you seen any of these features in other areas you have visited? Glacier Landforms Figure 2.15a) Moraines form from rocks and gravel that build up along the sides and at the end of the glacier. As the edges of the glacier melt, large deposits form. kettle lake Figure 2.15b) Eskers form when parts of the glacier melt. This meltwater flows in tunnels under the ice. The melting releases sand and gravel from the glacier. These sediments are deposited Figure 2.15c) Drumlins are small hills with a by the meltwater in the pattern distinctive teardrop shape. They form when a glacier of a winding river. moves over moraines that had formed earlier. The tip of the drumlin points in the direction that the

glacier was moving.

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#### CHECK AND REFLECT

- Describe one of the processes that shaped the continental drainage system we have today in Canada.
- 2. The Athabasca Glacier is part of the Columbia Ice Fields between Banff and Jasper. It once extended much farther across the valley than it does now. Is the glacier advancing or retreating? Why do you think this is happening?
- Find out how glaciers have formed the landscape where you live. Using reference books, maps, the Internet, and your own observations, identify glacial features in your area.

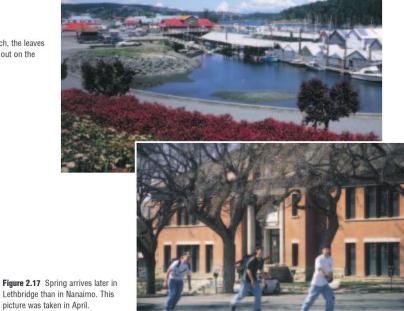
## 2.4 Water and Climate

Lethbridge, Alberta, and Nanaimo, British Columbia, are both located at almost the same latitude. This means that they are both about the same distance north of the equator. But the climates in the two cities are very different. The two pictures below were taken in the spring. What differences do you notice in the way the trees, grasses, and flowers look in the two places? Find the two cities on a map of Canada. Suggest reasons why there might be such major differences in their climates.

#### CLIMATE

Climate is the average weather measured over a long period of time. On some days in summer, Lethbridge and Nanaimo may have the same amount of sun and the same temperatures. But over a whole year, their weather varies in different patterns. The two cities have different climates.

Figure 2.16 In March, the leaves are already coming out on the trees in Nanaimo.



Lethbridge than in Nanaimo. This picture was taken in April.

#### THE EFFECT OF LARGE BODIES OF WATER ON CLIMATE

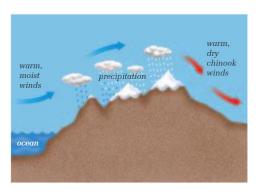
Large bodies of water, like the oceans and the Great Lakes, influence the weather and climate in their regions. In earlier studies, you learned that water has a higher heat capacity than most other substances. This means that it can hold onto the heat longer than other substances do. It takes a very long time to raise the temperature of a large body of water, and a long time to lower it. Even with small lakes, it takes many hot days and warm nights in a row to raise the temperature of just the few centimetres of water near the surface.

The main effect that this has on the climate in an area is to prevent extremes in temperature. For example, Nanaimo is beside the ocean, so temperature differences between day and night, or between winter and summer are not as great as they are in Lethbridge. Lethbridge has few lakes in the area, and it is surrounded mainly by land. Land heats up and cools down quickly compared with water. It is affected much more rapidly by changes in the amount of sunlight and the air temperature.

#### infoBIT

#### **Mountain Weather Effects**

The Rocky Mountains have a major influence on Lethbridge's climate. Southern Alberta, where Lethbridge is located, has a very dry climate because it's in a rain shadow. The winds coming in from the Pacific Ocean are loaded with moisture. When they hit the west side of the mountains, they have to rise higher where the air temperature is colder. The cold air causes the water to condense and fall as rain or snow. By the time these winds cross the Rockies, they have lost much of their moisture, so the air on the east side of the mountains remains dry. These same Pacific winds are responsible for chinooks. The Pacific air warms as it moves down the east side of the Rockies. The warm air becomes the chinook wind. A chinook can raise air temperatures more than 25°C in one hour.



The Rocky Mountains create a rain shadow that affects southern Alberta

#### CHOOSING A WINTER VACATION

#### The Issue

Throughout Canada and the rest of North America, there are major differences in climate from place to place. When deciding on a winter vacation, you could easily find places that would have snow for skiing. Or you could go somewhere for a snow-free holiday. In this activity, you will investigate factors that influence climate, and gather data to design travel promotional material for a winter holiday.

#### **Background Information**

Mean Temperature and Precipitation



When you're packing for a holiday, it's important to know what kinds of temperatures and how much precipitation to expect. Your teacher will give you an information sheet about the climate in some Canadian cities. Using a map of Canada, plot the locations of the cities listed on the information sheet. With a partner, and based on your own experiences, predict what a typical January day might look like in each place. Now choose a latitude where you will find at least two cities from your list on or near that latitude. Make a bar graph to compare their mean temperatures. Make another bar graph to compare their total precipitation.

#### Influences on Climate

Large bodies of water and landforms, such as mountains, can influence the climate of an area. Using your bar graphs and your maps, try to explain how these two factors may have led to the differences that you see in your bar graphs.

#### **Support Your Opinion**

Now choose one Canadian city of interest to you and your partner. Design a travel brochure or a radio commercial for a winter vacation there. The following topics should be included:

- mean annual temperature and precipitation for the area
- · factors that contribute to local weather patterns
- · water-related recreational activities for winter Remember, you are supposed to be "selling" your area for a winter vacation. Your brochure or commercial must grab the interest of a potential vacationer. If you choose a brochure, it should be illustrated and should highlight the major points that you want to get across. If you choose a radio commercial, you can use sound effects to help you sell your ideas.



Figure 2.18 Winter vacation

#### **CURRENT EVENTS**

You have learned that you can make some predictions about climate for a location if it is next to a large body of water or far from one. But what if two places at the same latitude on the same ocean have very different climates? Look at the map below. Labrador, on Canada's east coast, and Scotland are at about the same latitude. Labrador has very cold winters and short, cool summers. Scotland has a mild climate with little snow. Yet they are both beside the Atlantic Ocean.

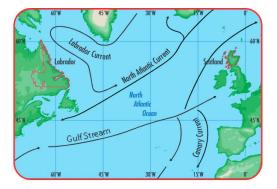


Figure 2.19
Why are the climates of Labrador and Scotland so different?

The difference between the two areas is the effect of ocean currents. **Currents** are streams of water that move within a larger body of water. They can be caused by any of the following:

- wind
- temperature differences in the water
- salinity differences in the water
- Earth's rotation

#### **CURRENTS AND CLIMATE**

Currents are different from waves because the water in currents actually moves from place to place. Surface currents are caused mainly by steady winds. The currents that affect the climates of Labrador and Scotland are both surface currents. These currents move water thousands of kilometres through the ocean. If they start near the equator, they may carry warm water far into the northern hemisphere, like the North Atlantic Current does. If they start closer to the North Pole, they may carry very cold water down into more southerly areas, like the Labrador Current does. When these currents flow close to shore, they can influence the climate of the land there.



#### El Niño and La Niña

A change in ocean currents is one of the key indicators of the climate event known as El Niño. Using the Internet and other research sources, find out:

- · What causes El Niño?
- How does it affect climates around the world?
- · What is La Niña?
- How can scientists predict when these events will occur and how strong they will be?



#### OCEAN CURRENTS AND PRECIPITATION

The temperature of an ocean current affects more than just the air temperature. It also affects the amount of precipitation that a location receives. Warm air can hold more moisture than cold air can. As a result, wind blowing over a warm ocean current will carry moisture. Wind blowing over cold ocean currents will be relatively dry. Figures 2.20 and 2.21 show the effects of this difference.



Figure 2.20 The winds that blow in from the north Pacific Ocean pass over the warm North Pacific current. They carry so much moisture that the coast of British Columbia is a rain forest.



Figure 2.21 The cold Peruvian current flows northward along the coast of Chile and Peru. The winds off the current are cold and carry so little moisture that desert covers the entire coast

#### CHECK AND REFLECT

City	Mean January Temperature (°C)	Mean July Temperature (°C)
A	-4	+22
В	-7	+18
С	-11	+17
D	-15	+18

Figure 2.22 Question 1. Which cities does this information represent?

- Look at the temperature data for the four cities given in Figure 2.22. Match each pair of temperatures to one of the following cities: Calgary, Toronto, Edmonton, Charlottetown. Give reasons for your matching.
- 2. Do you think that large bodies of water are able to influence the kinds of plants that people can grow in an area? Why or why not?
- 3. What is the difference between weather and climate?

#### SECTION REVIEW

#### **Assess Your Learning**

- Describe how a wave forms in a lake. Explain what would happen to the speed and direction of a small boat when a wave passes underneath it.
- 2. Why do many inland waterways have speed limits for boats?
- 3. When camping in the mountains near the border between Alberta and British Columbia, you noticed one stream flowing west and the other flowing east. What is the area or geological feature called where you are camping? Where will the water in these rivers eventually end up?
- 4. How do caves form?
- 5. Why do hot springs have more minerals deposited around them than cold springs do?
- 6. What geological evidence do we have here in Alberta that glaciers once covered this province?



### SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology are developed to meet human needs and expand human capability. Think about what you learned in this section.

- A frontier is an area that hasn't yet been fully explored or developed. You may have heard outer space called "the final frontier." But we have a huge frontier right here on Earth. Working with a partner, discuss why the oceans can be called a "frontier."
  - Why do we still have so much to learn about the oceans?
  - What role do you think technology plays in helping us explore the oceans?
  - In what ways is oceanic exploration similar to space exploration?
- 2. How do you think understanding a stream's characteristics could help us protect our water supply?



3.0

Living things in aquatic environments are affected by many factors.

#### **Key Concepts**

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

- · water quality
- adaptations to aquatic ecosystems
- · human impact

#### **Learning Outcomes**

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

- describe the diversity of organisms in salt and freshwater systems
- recognize that some common characteristics allow species to live in water
- identify factors that contribute to development of adaptations in aquatic species
- describe populations in fresh and salt water
- identify seasonal, short-term, and long-term changes in populations
- explain the relationship between water quality and living things



Think about the view of Earth from space at the beginning of section 1.0. What was Earth's major surface feature? Most of Earth is covered in a salty water solution that we call the *oceans*. This water is home to a wide range of living things from microscopic organisms to the largest animals on Earth, whales.

Some of the same organisms that live in salt water can also live in fresh water, but most cannot. Each is adapted to its own environment. In what ways do you think animals that live in salt water might be different from those in fresh water? In what ways would they be the same? In this section, you will learn some of the ways that aquatic organisms are adapted to their environments. You'll also discover how they interact with their environment and each other.

## 3.1 The Diversity of Organisms in Salt and Freshwater Systems

When we think of a variety of organisms living in water, we might think of the organisms in a large lake or in a tidal pool of the ocean. But even in a small pond or slough, you would find a variety of species, each adapted to its own small part of the pond ecosystem. Such variety is often used as an indicator of a healthy environment. The more species in a pond, lake, or river, the more nutrients, light, and oxygen you are likely to find there. Figure 3.1 shows some of the organisms you might find in a pond.

#### infoBIT

#### **Greatest Diversity**

The most diverse ecosystems in the world are the tropical rain forests of South America, Asia, and Africa. Coral reefs are the second most diverse ecosystems.

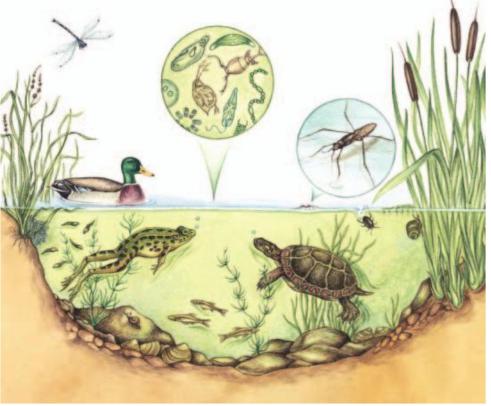


Figure 3.1 Even a small pond can support many different kinds of living things.

#### Give it a TRY

#### ACTIVITY

#### POND DIVERSITY

A pond near you is in an area that will soon be developed for housing. A local environmental group wants to make the pond part of a small park in the development. But some people in the area say the pond isn't worth saving because it's probably already so polluted that nothing lives in it. As a member of the environmental group, you want to prove that the pond has a diverse group of organisms living in it.

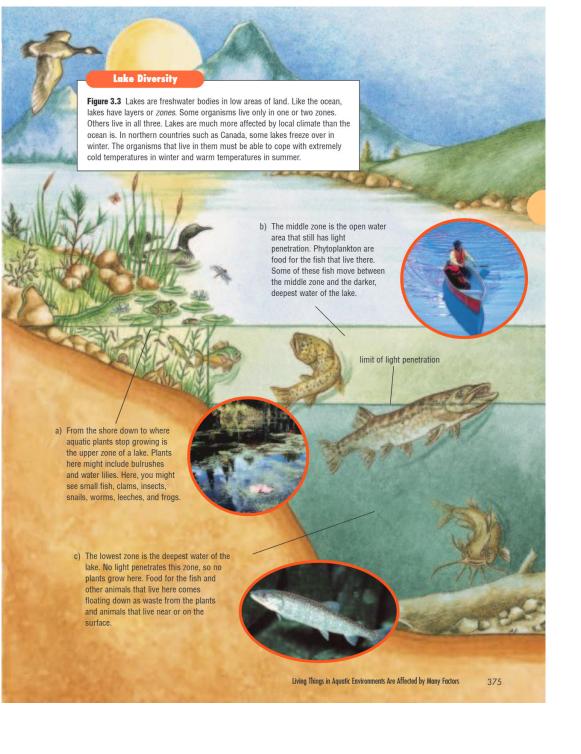
- Look at the pond and its inhabitants shown in Figure 3.1 on the previous page.
   List as many different kinds of living things as you can see.
- Beside each one in your list, briefly describe where it lives in the pond.
   Describe any features it has that allow it to live there. (For example, fish have fins that help them swim through the water.)
- · Do you think the pond is worth saving? Give reasons for your answer.



#### DIVERSITY IN FRESH AND SALT WATER

In earlier grades, you learned that an *ecosystem* is any place on Earth where living things interact with other living things and non-living things. **Diversity** in an ecosystem refers to the variety of different kinds of species living there. Many different kinds of organisms live in freshwater lakes and rivers. But the salt water of the oceans supports a greater diversity of living things. Many more, different kinds of organisms live in salt water because the oceans have more, different kinds of environments. Two-thirds of all the major types of organisms in the world live all or part of their lives in salt water. Figures 3.3 and 3.4 will help you compare the diversity of freshwater and saltwater ecosystems.





#### Ocean Diversity

Figure 3.4 The ocean is similar to a huge lake because it has a shoreline, shallow areas, and deep areas. But in the oceans, there are greater differences in water motion, salinity, and depth than in a lake. The deepest part of the ocean is about 11 000 m. The deepest lake in the world is Lake Baikal in Russia at about 1700 m.



#### Intertidal Zone

Animals and plants that live along the shoreline of the ocean have to be able to withstand the pounding of the waves. They also have to be able to live out of the water for some time every day at low tide. This shoreline area they live in is called the *intertidal zone*.

- Different ecosystems form in intertidal zones, depending on whether the shore is rocky, sandy, or muddy.
- Animal species have developed special adaptations to live in this zone.

#### Estuary

One of the most diverse and richest ecosystems is an *estuary*. Here fresh water from rivers and streams mixes with the salt water of the ocean to form *brackish* water.

- · Marshes often grow in or around estuaries.
- Many different kinds of plants, animals, and insects that can tolerate the brackish water live here.
- Estuaries are rich in bird life, because of all the food and shelter available.

#### **Continental Shelf**

The *continental shelf* is a shelf of land that extends out from the edge of a continent below the ocean's surface.

- Canada's largest continental shelf is on the east coast.
- The water here is warmer than in the open ocean, and light penetrates almost all the way to the hottom.
- The combination of warm water, light, and nutrients make this a very rich area for both plants and animals.

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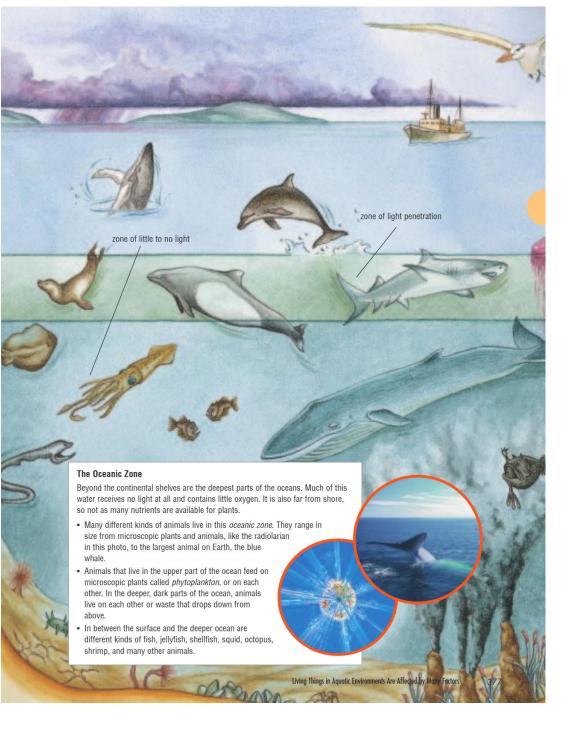


Figure 3.5 What special conditions do these fish need to survive?

#### ADAPTATIONS OF ORGANISMS IN AQUATIC ENVIRONMENTS

An adaptation is a physical characteristic or behaviour of a species. An adaptation increases the species' chances of survival in a particular environment. All living things have adaptations that are specific for the environment they live in. And living things continue to adapt if their environment changes. Aquatic species have adaptations that help them to breathe, feed, move, and reproduce in water. For example, fish have gills to enable them to remove oxygen from the water.

When you go into a pet store, you can see tanks full of brightly coloured tropical fish. Do you think these fish would survive in your local lake or river? These fish are adapted to warmer waters than those we have in Canada. The only way we can keep these fish here is indoors. Water temperature is just one of many factors that organisms have adapted to in aquatic environments. Here's a summary of the main environmental factors that lead to the development of adaptations by species.

#### **Temperature**

The fish in Figure 3.5 can't survive in cold water. And fish that live in very cold water can't survive in warm temperatures because their bodies overheat. There are fish in the Arctic that have a natural antifreeze that keeps their blood and body tissues from freezing in the frigid water temperatures.

#### Light

Most organisms thrive in light. Plants need light to photosynthesize. In the deepest parts of the deepest lakes and oceans, animals survive without light. Look at the animal in Figure 3.6. How do you think it has adapted to the lack of light?



Figure 3.6 This dragonfish manages to survive in an environment without light. It produces its own light from spots on its body called *photophores*.

#### Pressure

The animal in Figure 3.6 must also survive under very high pressure. The weight of the water above it is many times greater than at sea level. These animals cannot survive when brought into shallower water because their bodies can't function at lower pressures.

#### **Salinity**

The salt content of water can be very high in some inland seas like the Dead Sea. The organisms that live there cannot survive in fresh water. Most freshwater organisms cannot live in salt water. The salt in the water actually draws fluid out of their organs. For that reason, humans and many other animals can't drink salt water.



**Figure 3.7** Salmon are unusual because they can survive in both fresh and salt water. They are born in fresh water, then migrate out to sea. They live in the ocean until it's time to come back up the rivers to lay eggs.

#### **PESEARCH**

#### Game Fis

A variety of game fish inhabit lakes, streams, and rivers. The temperature of the water, the amount of oxygen dissolved in the water, and the availability of food all determine the types of fish that can be found in each habitat. Talk to fishers and do research to answer the following questions.

- What water conditions would you look for if you wanted to catch trout?
- Sturgeon are a very primitive, ancient type of fish.
   Some sturgeon weigh more than 50 kg. Where would you go to fish for sturgeon? In what type of water conditions would you find them?
- Which fish species can tolerate poor oxygen and high temperature conditions?



**Figure 3.8** Barnacles grow on rocks at the tide line, so they are constantly battered by waves. They attach themselves firmly to rocks so the waves can't take them away. Their hard shells also protect their bodies from the waves.

#### **Water Movement**

Some animals and plants live in areas where the water moves strongly. Like the barnacles shown in Figure 3.8, they have to be able to withstand the water's movement and the debris that the water carries. They may have adaptations for attaching themselves to rocks and other fixed objects. Or they may be adapted to digging into sand for protection.

## CHECK AND REFLECT



- 1. Why is the diversity of living things in salt water greater than in fresh water? Give as many reasons as you can think of.
- 2. Describe three characteristics that enable fish to live in aquatic environments.
- 3. Some water plants thrive in our lakes. Every summer they grow up but every winter they die back. How have they adapted to seasonal changes in their environment?
- 4. What might happen to the fish in a lake if a factory discharged a large amount of hot water into the lake?
- 5. What did you find the most interesting about the factors that aquatic organisms have to adapt to? Why?

# 3.2 Populations in Fresh and Salt Water

Something has happened between the time of John Cabot 500 years ago and now. Why are there so few fish now compared with even 100 years ago? Natural changes in animal populations are not unusual, but the rapid decrease of one species of fish from plenty to so few is unusual. Is the decrease a result of overfishing only, or are other factors involved? Hypothesize what factor or factors you think could have caused the decrease in the number of cod. Write down your hypothesis so you can look at it again later.

#### UNDERSTANDING POPULATIONS

In this section, you have learned about the diversity of organisms in fresh and saltwater environments. You have also seen the adaptations that some of these species have to enable them to live in these environments. Another important aspect of understanding ecosystems is the study of populations.

When we looked at diversity, we were looking at how many different species there are in fresh and saltwater environments. When we looked at adaptations, we were looking at how species have adapted to their environments. The study of populations looks at groups within species. A **population** is a group of organisms of the same species that live in a particular area. For example, perch are common in the lakes in Alberta. But the perch that live in Sullivan Lake form a separate population from the ones in Lesser Slave Lake.

Figure 3.9 When John Cabot arrived in the waters of Newfoundland, he wrote that there were so many fish in the water that the boat could only move

# math Link

A researcher is estimating the population of mussels in an intertidal zone. She marks out an area 50 m long by 5 m wide. She counts the number of mussels in five  $1-m^2$  squares along one end of the area. Here are the amounts she found: 22, 26, 20, 18, and 16. What is the average number of mussels she found in a  $1-m^2$  square? Use this number to estimate the total number of mussels in the whole marked area. (Hint: Draw a diagram to help with your calculation.)

# Decision Making Activity

## CAN THE COD FISHERY BE SAVED?

#### The Issue

The cod population off Canada's east coast was once so huge that ships came from all over the world to fish there. Today, there are so few cod that fishing for them in Canadian waters is carefully controlled. Is overfishing entirely to blame for the large reduction in the cod population? Can anything be done to restore the cod stocks?

#### **Background Information**

- 1 You know that aquatic organisms have adapted to specific environmental conditions. You may also know that different changes can occur in populations of aquatic organisms. You will now develop your opinion about the main reason for the large decrease in the cod population off Newfoundland. Was it caused by humans' fishing? Have each member of your group research information on one of the following:
  - a) where cod are found and what temperatures and depths they prefer
  - b) what cod feed on and where and when they breed
  - c) the opinion of the Department of Fisheries and Oceans scientists on the reasons for the cod's disappearance and on the possibility of the stock growing back
  - d) other opinions, including those of fishers, on the reasons for the cod's disappearance and on alternatives to the ban on fishing
- 2 When you have gathered your information, share it 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.

#### **Support Your Opinion**

- 3 Was the hypothesis you made at the beginning of this subsection correct? Do you think that overfishing is the only reason for the decline in the cod population?
- 4 Can anything be done to allow more fishing? What recommendations would you make to the government on how to deal with the cod problem in a fair way for fishing families?
- 5 Share and compare your group's opinion with those of other groups.

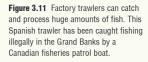


Figure 3.10 The Grand

Banks off Newfoundland is a rich fishing area.



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#### CHANGES IN POPULATIONS

A change in a population may mean an increase or decrease in the number of individuals. Or it may mean a change in the number of females compared with males. Or it may mean a change in the number of young compared with the number of old individuals. A population changes because something in its ecosystem has changed. There are three major types of changes to populations: seasonal, short-term, and long-term changes.

#### **Seasonal Changes**

In Canada, we can observe dramatic seasonal changes in populations of freshwater organisms. Because of the extremes of temperatures between summer and winter, populations swell during the warm summer months, and then disappear during the winter. This does not mean they are all dead. Some are dormant and hibernating. Another seasonal change is connected with breeding stages of some organisms, as shown in Figure 3.12. Can you think of other seasonal changes in aquatic populations that you've observed?



**Figure 3.12** Mosquitoes lay their eggs in water. When the eggs hatch, the larvae live in the water for a couple of weeks before becoming adults and flying away. So in a very short time, the population of mosquito larvae in a pond can change dramatically.



#### **Plunging Populations**

On Canada's west coast, another important fish population is decreasing dramatically. The population of wild salmon off British Columbia may be as little as half of what it was 100 years ago. The decrease in salmon population is mainly due to overfishing. But loss of streams for egg-laying and warming of the ocean may also be affecting these fish.





**Figure 3.13** An oil spill can cause short-term changes in populations of aquatic organisms. Toxic chemicals can kill fish and other organisms. In this aerial photo, you can see large, floating barriers called *booms*. They are used to keep the oil from spreading.

### reSEARCH

# The Effect of El Niño on Fish

An example of a short-term natural event is the effect of El Niño on fish populations off the coast of South America. Find out what fish are affected and why. How does this change affect fishers?

#### **Short-Term Changes**

Short-term changes in populations are those that take place over a relatively short period and don't last very long. Unlike seasonal changes, they don't happen every year. A short-term change might be part of a natural event, or it might be caused by human activities. A population of salamanders might disappear because a drought dries up its pond. But a few months later, the rain begins, the pond fills up, and a new population of salamanders develops. Where do you think the new salamanders came from?

#### **Long-Term Changes**

Long-term changes in populations may also result from natural causes or human activities. A natural landslide might change the course of a stream. All the mosses and plants that lived in the old stream bed below the slide die off because water no longer flows there. An example of long-term human effects on populations is the introduction of zebra mussels to the Great Lakes. Zebra mussels are a European species that was first noticed in the Great Lakes in 1988. They probably came over in the ballast tanks of ships. The ships emptied the water from their tanks, and the mussels were in this water. By 1994, there were about 93 000 mussels per square metre in some areas of the Great Lakes. Many native shellfish populations were reduced because of competition with this species.

## **CHECK AND REFLECT**

- When populations or species die off, or when they're unhealthy, it's a sign that something in the ecosystem has changed. Do you agree or disagree with this statement? Explain your reasons.
- 2. Look at Figure 3.14. Does it show a single population or several populations? Explain your answer.



Figure 3.14 Question 2. Is there more than one population shown here?

- 3. The zebra mussel population in the Great Lakes has exploded. Do you think that this population growth will continue in the same way? Why or why not?
- The following table shows the cod catch off Canada's east coast over 21 years. Make a bar graph of this data to help you answer the questions below.

	Cod Catch	Catch in Tonnes				
1972	1979	1988	1993			
219 000	378 000	400 000	50 000			



- a) What trend do you see in the cod fishery over the years shown here?
- b) Why do you think this happened?
- c) From the information you have here, what do you predict will happen to the cod stocks over the next five years?
- Look again at the hypothesis you made about cod at the beginning of this subsection.
  - a) Did any of the information in this subsection support your hypothesis? Explain your answer.
  - b) What other information would you need to confirm or change your hypothesis?



Figure 3.15 What is happening to Twin Lake?

#### infoBIT

#### Alkali Lakes

Some Prairie lakes have a white material coating the rocks around the shore. These are deposits of natural chemicals called carbonates and bicarbonates. The water has dissolved them out of the soil and rocks in the area. When water has a high concentration of these chemicals, it is said to be alkaline. The chemicals are essential for plant life. But in very alkaline lakes, not many different types of organisms can survive.

# 3.3 Water Quality and Living Things

The fishing at Twin Lake was always good when you first started going there with your family. During the last few years, however, you have noticed that people are catching fewer and fewer fish. When you go swimming, you have noticed that fewer young fish seem to be darting in the shallows. Someone commented that the fish seemed to be all small and of one species, whereas they used to be a variety of sizes and species.

The lake itself did not seem different—the water was still clear, and its temperature seemed to be the same. The loons still raised their young on the lake, and the heron family still fished in the shallows. But there seemed to be fewer of them as well. Was something happening to the lake?

After discussing this possibility, you and your friends decide to investigate the apparent changes in the lake. What type of information would you want to include in your investigation? Where would you find this information? Are there professionals you might contact? Make a list of the information you would need before you could decide if there is a problem with the lake.

#### CHANGES IN WATER QUALITY

At the beginning of this unit, in section 1.0, you learned that humans depend on a high level of water quality for safe drinking water. Other living things also have water quality requirements, but they can be very different from human ones. Living things, such as fish and water plants, do not need water as pure as humans do. Water that we could not drink can support a large number of different species that are adapted to those water conditions.

A lake like the one described at the beginning of this subsection contains many different species. Your local lake or pond probably has different types of insects, algae, microscopic plants and animals, and fish. As you learned earlier in this unit, they are all adapted to survive in that environment. But some species are more specialized than others. That means they are adapted to a narrow range of conditions. Even slight changes in the water quality or its temperature can affect them.

# Inquiry

# Activity

#### Materials & Equipment

- 4 600-mL beakers
- · masking tape
- pen
- 2 L room-temperature bottled water (nonchlorinated)
- · 25 g sea salt
- · stirrers
- 1 mL measuring spoon
- · brine shrimp eggs
- · 4 squares of paper, each large enough to cover the top of a beaker
- hand lens (optional)



Figure 3.16 Brine shrimp are microscopic animals that live in salt lakes and brine ponds. These environments are so salty that few other organisms can live there. Brine is a salt and water solution that contains a high concentration of salt.

### CHANGING WATER QUALITY

What effect could changing water quality have on an organism?

#### The Hypothesis

Write a hypothesis to explain how changing the salt concentration in water could affect the hatching of brine shrimp eggs.

#### Procedure 😢



- 1 Fill each beaker with 500 mL of room-temperature bottled water. Label the beakers A. B. C. and D.
- 2 Set beaker A aside. It contains fresh water only. To beaker B, add 2.5 g of sea salt. To beaker C, add 7.5 g of sea salt. To beaker D, add 15 g of sea salt. Stir beakers B, C, and D to dissolve the salt.
- 3 Predict what will happen to the brine shrimp eggs in each beaker within 3 days after adding them. Add about 0.5 mL of brine shrimp eggs to each
- 4 Put the beakers in a place where they won't be disturbed, away from direct light and heat. Cover each beaker with a square of paper. Wash your hands.
- Observe the beakers daily for 3 days.

#### Collecting Data

6 Record the appearance of the beakers on the day that you set them up. Record their appearance after 3 days.

#### Analyzing and Interpreting

- 7 In which beakers did the brine shrimp eggs hatch?
- 8 What can you conclude about the amount of salt in the brine shrimp's natural habitat?

#### Forming Conclusions

9 Describe how the differences in water quality affected the brine shrimp eggs.

#### Applying and Connecting

Adult brine shrimp have been used for many years as fish food for fish kept in aquariums. Brine shrimp eggs are also used now in large quantities in commercial aquaculture. Aquaculture is the growing of fish and other seafood in "farms" for human consumption. Brine shrimp eggs are used to feed commercially grown shrimp, prawns, and some types of fish.



Figure 3.17 This lake has been affected by acid rain.

#### **EXAMPLES OF WATER QUALITY CHANGES**

How many different species of plants and animals do you think live in the beautiful, clear lake in Figure 3.17? The water may look clean and pure, but this is a "dead" lake. Acid rain, caused by air pollution from factories, has changed the lake's water. The water is now too acidic to support most life. Fish and other organisms can no longer survive in it. This is one example of what can happen to living things when water quality changes.

While we often think of organisms disappearing because of water pollution, sometimes the opposite effect occurs. In Figure 3.18, the green slime is called *algal bloom*. This rapid and large increase in the growth of algae in a body of water is caused by too much fertilizer entering the water from farmers' fields. This abundant algal growth soon covers the surface, blocking out light to the plants below. The underwater plants no longer have light for photosynthesis, so they die. Because there are no more plants producing oxygen, other organisms soon die as well. So, although one organism (the algae) thrives, others die.

These are just a couple of examples of how water quality can affect aquatic organisms. You will learn more about human impacts on aquatic ecosystems in the next section.



Figure 3.18 Algal bloom forms when the amount of the dissolved nutrients in the water increases greatly. This is usually caused by fertilizer runoff from farmers' fields.



#### When Is Water Too Warm?

Thermo-electric plants generate electricity by burning coal. Much of Alberta's electricity is generated this way. These types of plants use a great deal of cooling water from nearby lakes to condense the steam from their turbines. Once this water is used, it is much warmer than the water in the lake it came from. Some plants use cooling ponds to let the water cool down before it is released back into the lake. Think about what might happen if the warm water is released directly from a plant into a lake.

- How would this warm water affect the growth of aquatic plants in a northern climate such as Edmonton has?
- How would populations of aquatic organisms be affected if the plant reduced production or shut down boilers for repairs and maintenance?
- What effect might the exhaust gases from the furnaces and boilers have on aquatic environments downwind from the plant?

#### CHECK AND REFLECT

- 1. Acid rain affects the survival of young fish and the eggs and larvae of other aquatic organisms. It does not seem to affect the adults. How do you think acid rain would affect the growth of the fish populations over time?
- 2. All throughout the months of our long, cold winter, snow and ice build up on the streets and sidewalks of Calgary and Edmonton. Animal waste, oil, antifreeze, and road salt collect in this snow. When spring finally arrives, snow and ice rapidly melt. How might this meltwater affect populations of aquatic organisms downstream from these cities?
- 3. At the beginning of this subsection, you listed some information you would need to help you decide if there is a problem with Twin Lake. What would you add to that list after reading this subsection? Why?
- 4. Find your concept map on water quality that you began earlier in this unit. Add information from this subsection on how aquatic organisms interact with their environment.



# Experiment .....

# CREATING YOUR OWN AQUARIUM

#### Before You Start ...

You are now familiar with the differences between fresh and salt water as well as with some of the methods that can be used to determine water quality. You also have a general understanding of the many factors that can affect aquatic organisms in both salt and freshwater systems. Now you have a chance to use some of this knowledge to design and set up a freshwater aquarium.

#### The Question

How can you set up a freshwater aquarium with the proper water quality and environmental factors to support living organisms?

#### **Design and Conduct Your Experiment**

- 1 Decide what organisms, materials, and equipment you will need to set up your aquarium. For example:
  - a) How big will your aquarium be or, in other words, how many litres of water will it hold?
  - b) What type of container will you use for your aquarium?
  - c) What types of aquatic plants and animals are appropriate for the size of your aquarium?
  - d) How will you control the temperature and light?
- 2 Design a procedure for testing water quality.
  - a) What types of equipment and materials will you need to test water quality?
  - b) Where can you find inexpensive water-testing materials?
- 3 Write up your procedure and design. Show it to your teacher for approval.
- 4 Set up your aquarium. (Remember that you have to do tests before and after the living organisms have been added.)



**Figure 3.19** This is an example of how one group of students set up their aquarium.

- 5 Now perform the water quality tests before you add living organisms. Repeat these tests after the living organisms have been added. Always wash your hands after working on your aquarium.
- 6 Share and compare your design and findings with your classmates. Be prepared to explain:
  - · why you chose the organisms you did
  - what the results of your water quality tests were (both before and after)
  - any adjustments you made as a result of the tests
- 7 How would you improve your design?
- 8 Would the same procedures that you used in setting up a freshwater system also apply to setting up a saltwater system? Why or why not?

## SECTION REVIEW

#### **Assess Your Learning**

- 1. a) What does the term diversity in an ecosystem mean?
  - b) Would a puddle have as much diversity as a pond? Why or why not?
- Draw a sketch showing the three levels in a lake. Briefly describe each level.
- 3. In Figure 3.20, why do all these animals have gills? What is the purpose of gills?







Figure 3.20 Question 3



- 5. Give an example of some event that might cause a population of aquatic organisms to change. Describe the change. Is your example a seasonal, short-term, or long-term change? How do you know?
- 6. Is water quality important to fish? Explain your answer.



# SOCIAL AND ENVIRONMENTAL CONTEXT

Decisions regarding science and technology involve a variety of considerations. These include social, environmental, ethical, and economic considerations. Think about what you learned in this section.

- 1. A community beside a large lake has been using a ferry boat system for crossing. Now it is deciding what kind of crossing to build on the lake. Residents can choose between two different technologies: a bridge or a causeway. (A causeway is a roadway built by placing rocks and gravel on the bottom of the lake. More material is added until the road is above the water surface.) What environmental considerations do you think might affect this technology decision?
- 2. What social and economic considerations do you think might affect the decision the community has to make in question 1?
- Suggest some science questions that the community might want to have answered before making their decision.



# 4.0

# Human activities affect aquatic environments.

#### **Key Concepts**

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

- · water quality
- · human impact

## **Learning Outcomes**

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

- describe how humans use
   water and the impacts of this
   use
   identify practices and
- technologies that affect water quality
   recognize that these practices
- and technologies have costs and benefits
- describe how scientific research helps to measure environmental impacts
- recognize that scientific and technological knowledge alone can't solve all environmental problems

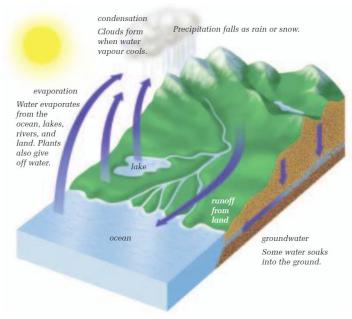


Figure 4.1 The water cycle. Water on Earth passes through many stages. The water you drink now could have been used by the builders of the pyramids.

In earlier studies, you may have learned how water cycles through the environment over and over again. The total amount of water is renewable on a world scale. However, the same amount of water isn't always available in any one place year after year. In some places, there may be droughts. In other places, there may be floods. And in some places, the water may be so polluted that it's not drinkable. All of these situations could be caused by natural events, or they could be caused by people using water.

# 4.1 How Humans Use Water

In the Exploring section at the beginning of this unit, you may have identified ways that you use water directly. You may also have suggested ways that you could reduce this water use. Look back at that list now. How many of your ideas for reducing water use have you been able to carry out? Your direct uses, like those on your list, are all called domestic or personal uses. But recall that you also use water indirectly. Your indirect uses reflect other uses such as those by industry and agriculture.

Many indirect uses have negative effects on Earth's water supply. These negative effects can include polluting lakes and reducing groundwater supplies. Why do we let this happen? As with many situations, there are both benefits and costs to the way we use water. Some of these are economic (for example, jobs) and some are environmental. A "+/-" (plus-minus) chart is one way of keeping track of benefits and costs. The "+" refers to the benefits, and the "-" refers to the costs. Make your own "+/-" chart as you read through this subsection. In the benefits (+) column, describe the ways in which that water use benefits people or the environment. In the costs (-) column, describe the ways in which that use is harmful or costly. After you have finished reading, work with a partner to add any other benefits or costs connected with water uses that you can think of.

Human Uses of Water				
Water Use	Benefits (+)	Costs (-)		
Water Use	Benefits (+)	Costs (-		

## infoBIT

#### The Disappearing Sea

The Aral sea was once one of the largest bodies of fresh water in Central Asia. Russian water diversion projects for growing cotton drained more water from the sea than was being replaced by rivers flowing into it. A strong commercial fishery no longer exists. Docks that were once right on the shore are now many kilometres away from the water's edge. Agriculture is an important source of income but so is fishing. And what kind of value can we place on all the plants and animals that can no longer live in the Aral Sea because of the lack of water?



Fifty years ago, the Aral Sea was much larger than it is today.

#### reSEARCH

#### Irrigation in Alberta

Because of Alberta's dry climate, much of its agriculture depends on irrigation. Find out what the benefits and costs of irrigation are to farmers, the environment, and the province's economy.

#### THE MAJOR USES OF WATER

All life on Earth depends on water, but humans make the greatest use of it in the greatest number of ways. And the more people there are, the greater the amount of water that gets used. Figures 4.2 to 4.8 show the three major types of water use worldwide.

#### Agriculture

Of all the water used by people around the world, 73% is used in agriculture for irrigation to grow crops. Irrigation is important to the economy of many countries. It helps to provide food for the people who live there. Agricultural products grown on irrigated land can be exported to bring in money from other countries. Irrigation also helps to provide jobs for people in agriculture.





Figure 4.2 Irrigation ditch, India

Figure 4.3 Irrigation, Alberta

Irrigation is important in food production in many places in the world. But it can also cause problems. Over-irrigation of the soil can dissolve salts in the soil and cause them to deposit on the soil's surface, as shown in Figure 4.4. Most plants won't grow in salty soils, so this reduces the ability to grow crops. Irrigation can also deplete groundwater supplies.



**Figure 4.4** Salt deposits from irrigation. Irrigation must be carefully managed to prevent these.

### Industry

The next biggest use of water worldwide is in industry, about 22%. Industry uses water as a coolant, as a solvent, for washing, and for diluting pollutants when releasing them into the environment. Many industrial activities can affect water in the environment if the used water isn't cleaned or diluted before it is discharged.



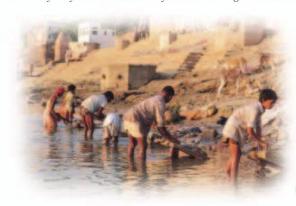
Figure 4.5 Amount of water used in producing 1 t of different products

Different products require different amounts of water in their production. As you can see from Figure 4.5, the plastics industry is a huge user of water. This is a good example of your own indirect water use. How many items do you use that are made of plastic? Each of these products requires water in its production.

Governments control industry's water use through environmental and other regulations. They do not prevent industry from using water because industry is essential to a country's economy. It provides jobs, products, and services.

#### Domestic

Domestic use, or use in the home, is about 5% of total water use worldwide. Water for domestic use in developed countries like Canada is purified and piped into homes. In many developing countries, people do not have clean water piped into their homes. This may be because the distribution system doesn't exist. Or it may be because the family can't afford to pay for the pipes to bring it in. They may have to walk many kilometres to get safe water.



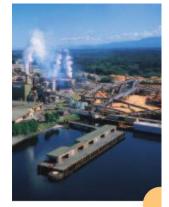


Figure 4.6 Pulp mill in British Columbia



**Figure 4.7** In Canada, we have clean water piped into our homes.

Figure 4.8 In developing countries like India, clean water isn't available for all domestic chores.

**Human Activities Affect Aquatic Environments** 

395

# **Making**Activity

## HOLDING BACK THE WATER

#### The Issue

Do dams have a positive or negative effect on water-system resources?

#### **Background Information**

Dams built across rivers are the oldest means of controlling water flow. Rainwater and water from melting snow that would otherwise be lost can be captured and stored in large reservoirs behind dams. It can then be released in a controlled manner as it's needed. Unfortunately, the damming of rivers, while providing many benefits, has wide-ranging environmental effects.

#### Advantages of Dams



Figure 4.9 The 362-km-long reservoir created by the Bennett Dam, Williston Lake, is the largest human-made lake in Canada.

**Recreation.** The large lake that forms behind a dam can provide many facilities for recreational activities.

**Hydro-Electricity.** The controlled release of water can be used to generate electricity.

Flood Protection. During times of high rainfall or heavy melting snow, water can be held back to eliminate or reduce costly flooding.

**Irrigation.** During periods of low rainfall, water can be released to irrigate crops.

**Employment.** The construction and operation of a dam provides many local jobs.

**Shipping.** Dams, in combination with locks, can make a once-treacherous river safe for boats to travel on.

#### Disadvantages of Dams



Figure 4.10
The PeaceAthabasca River delta began to shrink when the Bennett Dam was built 1200 km upstream.

Water Flow. Dams decrease the flow of water, which can shrink the size of rivers, lakes, and wetlands downstream.

Salinity. As less fresh water flows downstream, more salt water from the ocean can enter the river's mouth. This harms species that cannot tolerate higher salt levels.

**Habitat.** Reservoirs displace people and wildlife. They also destroy natural habitat and valuable farmland.

**Migration.** Migrating and spawning fish need special fish ladders to swim upstream past dams.

Sedimentation. Sediment in the river is trapped behind the dam. This sediment normally collects in river deltas and flood plains, providing important plant nutrients.

#### Canadian Facts about Dams

- · Canada is one of the world's top 10 dam builders.
- Most of the major river systems in Canada have been dammed.
- We have over 600 large dams and thousands of small dams.
- · Most large dams in Canada are built to provide hydro-electricity.
- · Most of Canada's dams are in Quebec and British Columbia.
- If you combined all of the area flooded by dams in Canada, it would cover an area the size of Lake Ontario.

#### **Support Your Opinion**

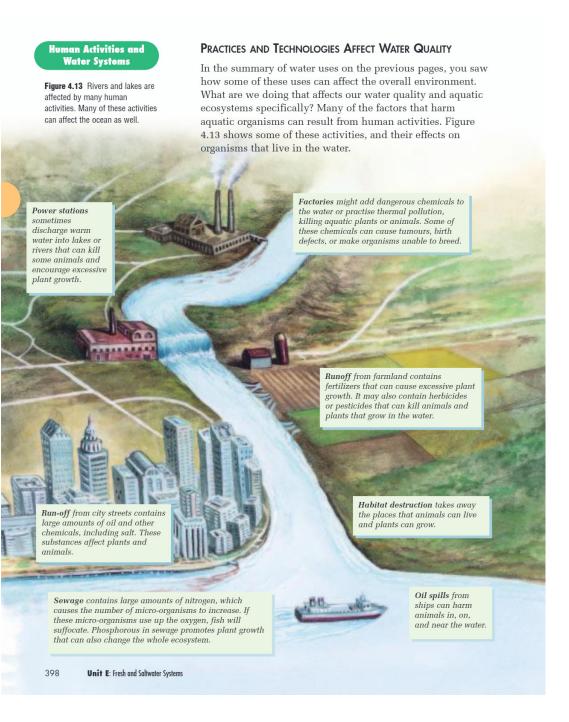
- 1 Imagine that a large electrical utility has proposed to build a dam at the site shown in the drawing at the bottom of the page. Draw a map to show what you think the area will look like after construction is complete.
- 2 a) What benefits will the dam provide?
  - b) What possible problems might it create? Can you think of ways to reduce the problems?
  - c) After you've examined the benefits and the problems, state whether you think the dam should be built or not.



Figure 4.11 In the 1950s, a series of dams was built on the St. Lawrence River. The reservoir that was formed left the sites of six villages underwater. The above photo shows a house being moved away from the area about to be flooded.



Figure 4.12 What will this area look like after the dam's construction is completed?



# CHECK AND REFLECT

- The chart below shows how much water is used in selected countries per person per day in three categories: domestic use, agricultural use, and industrial use.
  - a) Which countries are most likely to rely on irrigation to grow their crops? Which countries are least likely to do so?
  - b) In which countries is agriculture probably the main source of commercial income?
  - c) What type of water systems are people in countries like Cambodia and Gambia likely to have in their homes?
  - d) What kind of climate do you think Turkmenistan has during its growing season?
  - e) Which countries probably receive the most rain during their growing seasons?
  - f) Why do you think there are such large differences in water use among the countries in this chart?

Freshwater Use (litres per person per day)					
Country	Domestic Use	Agricultural Use	Industrial Use		
Cambodia	6	118	1		
Canada	431	313	3136		
Egypt	132	1906	177		
Gambia	3	39	1		
Mexico	129	1849	172		
Swaziland	36	1754	36		
Turkmenistan	145	14 254	145		
United Kingdom	110	16	424		
U.S.A.	554	1942	2127		
Uruguay	32	496	16		

Source: The World's Water 1998–1999: The Biennial Report on Freshwater Resources, by Peter H. Gleick, published by Island Press, Washington, DC.

- 2. Describe two effects that chemical pollution could have on aquatic animals.
- You use water directly every day at home—for example, for drinking and washing. Home use is one of the three major ways people use water.
  - a) What are the other two main types of water use by people?
  - b) Give two examples of how you use water indirectly every day. For each one, explain how you are using water indirectly.

#### infoBIT

#### Technology for Monitoring

The Canadian Wildlife Service uses gull eggs to monitor toxic pollutants around the Great Lakes. Mussels, a shellfish, are used to monitor toxic substances in sediments on the east coast of the U.S. Pollutants in the water collect in these organisms. Scientists then analyze the animals' tissues. This type of monitoring helps scientists better understand how pollution is affecting organisms.

# 4.2 Measuring Impacts

GIARDIA PARASITE STRIKES COMMUNITY

# BOIL YOUR WATER! Giardia can make you sick

A micro-organism called *Giardia* causes giardiasis or "beaver fever." From time to time, the population of *Giardia* organisms increases rapidly. This parasite is usually controlled by proper chlorination and filtration of drinking water, but outbreaks can occur. A small number of people get sick, and everyone is suddenly made aware of how important safe drinking water is.

One way to help guard against problems with water quality is to monitor the water supply regularly. **Monitor** means to observe, check, or keep track of something for a specific purpose. For example, when you put water in the sink to wash your face, you monitor the water level to make sure it doesn't overflow.

### Give it a TRY

#### ACTIVITY

#### KEEPING OUR WATER SAFE

How can we keep our water quality levels high enough to protect ourselves? One of the ways is by constantly checking or monitoring our water to make sure no dangerous substances or organisms affect it.

- Suggest a monitoring program that you think should be in place to prevent outbreaks of giardiasis like the ones mentioned in the headlines above.
- List the tests that you think should be done, and how often they should be carried out.
- · Be prepared to share your plan with your class.



#### MONITORING TO PROTECT WATER QUALITY

Town and city water supplies have to be monitored regularly to ensure that the quality of the water remains high. Water technicians regularly measure the chemicals and organisms in the water and observe how it looks and smells. In this way, they can identify possible problems and adjust the water treatment to eliminate them.

Similarly, research scientists use monitoring techniques to protect the environment. Monitoring also helps them develop appropriate technologies to help protect the environment. Think back over what you have learned about aquatic environments. You can probably list several things that scientists would monitor in a lake, slough, river, or stream. The presence of toxic chemicals in the water is one of these. Another one is the diversity of organisms in the environment.

#### **ONGOING MONITORING**

Ongoing monitoring of a site helps scientists observe change. As you saw earlier, a change in the number of species in a lake indicates that the environment has changed. This, in turn, would be compared with other monitoring information to see what else might have changed. For example, the amount of sediment in the water might have changed because of road-building along the water's edge. The water becomes cloudy. Animals and plants that cannot tolerate this condition disappear from the lake. In turn, those animals that fed on them no longer have enough food. The information from this kind of monitoring can then be used to develop regulations and technology to protect the environment.



**Figure 4.15** To develop effective clean-up technology, scientists must monitor the environment. They need information on how oil affects the shoreline and how long these effects last.



Figure 4.14 Logging roads built in wilderness areas can threaten streams. Scientists monitor the quality of the water to make sure no damage is done to the stream or its inhabitants. What do you think should be done if a logging company's activities affect a stream?

# Decision Making Activity

### CHLORINE AND THE ENVIRONMENT

#### The Issue

Spring runoff is a problem for many Canadian cities. Large amounts of organic material, such as leaves, collect in their watersheds during the winter and enter the waterways when the ice and snow melt. Organic matter can affect the colour and the taste of water. Additional chlorine is usually required in the spring to ensure that the water is safe from bacteria and other disease agents. Should the amount of chlorine in our water be increased at certain times of the year?



Figure 4.16 By monitoring water throughout the year, technicians in this water treatment plant know when they have to add more chlorine.

#### **Background Information**

- Scientists have studied the influence of chlorine on organic materials in water supplies. Some of the chlorine reacts with this organic material to form chloroform and other chlorine-containing chemicals. Research has shown that some chlorine-containing chemicals can increase the risk of cancer.
- 2 Working with your group, find out more about the benefits and costs of using chlorine in the water supply. Have each member of your group research information on one of the following:
  - a) the risk to health of not treating water supplies with chlorine
  - b) the risk to health of using chlorine in water treatment
  - c) alternatives to using chlorine for water treatment
  - d) scientific research underway on chlorine use
  - e) what (if anything) is used to treat your local water supply

#### **Support Your Opinion**

- 3 When you have finished your research, share your information 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 that the amount of chlorine in our water should be increased at certain times of the year? Give reasons to support your opinion.

#### PROBLEM SOLVING NEEDS MORE THAN SCIENCE AND TECHNOLOGY

In the *infoBIT* at the beginning of subsection 4.1, you read about the changes to the Aral Sea in Russia. Over the years, human uses have drained a huge amount of water from the sea. Docks that once lined the shore are now far from the water's edge as the sea shrinks. A once rich fishing industry has been destroyed. The problems with the Aral Sea cannot be solved by science and technology alone. Scientists have studied the effects of the human impact on the sea. The technology exists to solve many of these problems. What more is needed?

Problem solving requires a strong commitment from people. People must decide what needs to be done and how to do it. In many cases, they must find the money to help carry out the solutions.

# Protecting Watersheds Contact the

**PRSEARCH** 

Contact the environment ministry to find out what kind of monitoring they do in your local watershed. See if you can arrange to go with a scientist on a monitoring field trip. Prepare a field trip report for presentation to your class.

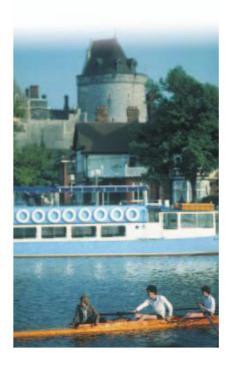


#### A SUCCESS STORY

Can huge problems in aquatic environments be solved? A good example of a success story is the famous Thames River in England. In London, the Thames used to be an open sewer. For hundreds of years, the city dumped sewage into it. Industry along its shores dumped toxic waste directly into it. Dead animals floated in it. Just the smell of the water made people sick.

Today, the Thames is so clean and clear that types of fish that had disappeared from it years ago are starting to reappear. Scientists knew for years what was wrong with the river—pollution. They also knew how to fix it—stop the pollution. The river only started to become cleaner in the 20th century. In this case, science and technology alone could not fix the problem. People finally organized and became committed to creating a solution. In this case, the reason was public health. The Thames was a hazard to people's health.

Figure 4.17 The Thames River was once so polluted that the smell of it could make you sick.



#### PEOPLE WORKING TOGETHER

Think about environmental problems in water systems in your area or elsewhere. It's likely that scientific studies have been done on these problems. The technology may exist to help solve these problems. Or perhaps the technology does not exist or is too expensive. Science and technology alone cannot do what is necessary. People have to work together and look at different ways to approach problem solving.

### CHECK AND REFLECT

- 1. Why is monitoring an important technique in environmental protection?
- 2. Why can't science and technology alone solve all our environmental problems?



#### ACTIVITY

## POLLUTION DILUTION

Many years ago, there was a slogan that said, "The solution to pollution is dilution." Some people thought that if you diluted a pollutant enough, it would no longer be harmful to the environment. You will use a non-toxic substance to represent a pollutant such as oil. Follow the instructions here, and see if that old slogan is true.

- Arrange the cups in a row on a table or counter. Put 50 mL or 1/4 cup of water into each cup. Add 1 drop of food colouring to the first cup and mix it well.
- Take 1 tsp. (5 mL) of this solution and pour it into the second cup. Mix it well.
- Take 1 tsp (5 mL) of this solution and pour it into the third cup. Mix it well.
- . Continue this process up to the last cup.
- Put the 5 samples on the sheets of paper so you can see their colour more easily.
- How many dilutions did you have to do before you could no longer see any colour difference?
- Do you think the first colourless sample would be safe to drink if the food colouring was oil?
- Is it a good idea to depend on the dilution of pollution when we dispose of wastes?

#### Materials & Equipment

- 5 small clear containers (cups or glasses)
- measuring cupwater
- food colouring
- stirrer
- teaspoon
- · plain white paper

#### Caution!

Never taste water that you use in science experiments.



## SECTION REVIEW

#### **Assess Your Learning**

- 1. Think about the different ways that water is used in your community. Describe two uses other than water use in the home. Do you think less water could be used in the situations you describe? How?
- 2. Most treatment facilities add chlorine to their water. Explain why this is a necessary step in water treatment.
- Describe two types of water pollution that can result from industrial development.
- 4. Scientific research has helped us understand what causes pollution and how it affects Earth's water systems. Through technology development, devices and techniques exist to prevent polluting activities. Use your "+/-" chart from this section (page 393) to help you explain why pollution continues to occur. Think of as many reasons as you can.
- 5. How can ongoing monitoring of a river help scientists determine if a change in a population of fish is caused by natural events or human activities?



# SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology have both intended and unintended consequences for humans and the environment. ("Intended" means "planned.") Think back to what you learned in this section.

- In this section, you learned that the largest use of water worldwide is in irrigation. Why do farmers use irrigation technology? (This is an intended consequence or result of the technology.) Describe two unintended consequences (results) of using irrigation technology.
- 2. If you did the Decision Making Activity on chlorine, did you have any difficulty finding reliable information? Do you think some of the publications or Web sites were biassed (supported one side more than another)? How do you know? Does that mean that their information is not usable?
- 3. Think ahead to your water e-zine/magazine project on logging in community watersheds. What did you learn in this section that you could use in advising a community on how to identify possible unintended consequences of logging?



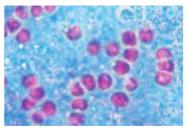


# Chemicals in Our Water Supply

#### The Issue

The town of Retaw is debating whether to stop adding watersoftening chemicals to its water supply. Dissolved calcium and magnesium minerals are normally found in most water supplies. In some areas, like Retaw, the concentration of these minerals is so high that the water is hard. Retaw uses lime (calcium hydroxide) to soften its water. The lime reacts with the calcium and magnesium minerals so that they settle out. They can then be easily removed.

Should Retaw continue to add chemicals to soften its water supply? Look at the arguments below for and against adding chemicals to soften water.



The micro-organism *Cryptosporidium*. Water softening can make it more difficult to remove this organism from the water supply.

Retaw should continue to add
chemicals to soften its water
supply.

# Soap works better in soft water.

It creates suds more easily.

# Soft water eliminates the problem of mineral deposits called *scale* in equipment.

Kettles, hot water heaters, and other equipment can be seriously damaged by mineral buildup from hard water.

#### Soft water protects us from possible health problems associated with hard water. High levels of calcium in hard water may contribute to the

development of kidney stones.

needed to kill organisms.

Adding more alum and chlorine may be harmful to human health. Aluminum in drinking water may be related to Alzheimer's disease. Chlorine compounds have been linked to increased risk of cancer.

Retaw should not add

chemicals to soften its water

Some soaps work in hard

Treating water with lime to

treating it with other

chemicals More alum

soften it increases the cost of

(aluminum sulphate) is needed

alum's effectiveness. Alum helps

because the lime reduces the

remove small particles and organisms. So more chlorine is

water.

#### Go Further

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

- Look on the Web: Check out water softening on the Internet.
- Ask the Experts: Try to find an expert on water softening. Experts can be found in all sorts of places: your community's water department, universities, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about water softening or chemicals in our water supplies.

#### **In Your Opinion**

Write up your point of view on water softening as one of the following:

- a letter to the editor of the Retaw newspaper
- a letter of concern to the Retaw town council
- a statement that you could read at a public forum on this issue

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# UNIT SUMMARY: FRESH AND SALTWATER SYSTEMS

#### **Key Concepts**

#### 1.0

- · water quality
- human impact

#### 2.0

- water-borne materials
- · erosion and deposition
- stream characteristics
- continental drainage systems
- · ocean basins
- climate
- · glaciers and icecaps

#### 3.0

- water quality
- adaptations to aquatic ecosystems
- · human impact

#### 4.0

- · water quality
- human impact

#### **Section Summaries**

#### 1.0 Humans depend on water supply and quality.

- Most of Earth's water is in the salty oceans that cover much of the planet's surface. Of
  the remaining fresh water, most of it is locked in icecaps and glaciers all over the world.
  Our drinking water comes from groundwater and rivers and lakes.
- Water in nature contains a wide range of materials including minerals, microscopic organisms, and other organic material. Water quality testing ensures that the water we use from nature is safe to drink.

#### 2.0 Water in its various states affects Earth's landforms and climate.

- Waves and tides are different types of water movement that interact with the shoreline of bodies of waters, eroding and depositing sediment.
- Understanding stream and river characteristics helps us understand how erosion and deposition shape Earth's surface.
- Two other important processes that shape Earth's surface are plate tectonics and glaciers. Plate tectonics resulted in the ocean basins and helped to shape the continental drainage system of North America. Glaciers have further eroded that drainage system into the distinctive pattern we see today.
- Water interacts with Earth to produce the great variations in climate we experience, from desert climates to rainy ones.

#### 3.0 Living things in aquatic environments are affected by many factors.

- In the same way that we are affected by the air around us, living things in aquatic environments are affected by the water they live in.
- The variety of organisms found in an aquatic environment depends on the water conditions of light, temperature, and depth of the water. Oceans support a greater diversity of life than freshwater systems because they contain a greater range of environments.
- A population is a group of individuals of one species living in a particular area. A change in a population indicates that something in its environment has changed.
- Each aquatic species is adapted to a certain quality of water. Some need very clean
  water with a high level of oxygen. Others can survive in murky water. No matter what
  their preference, a change in that quality can seriously affect them.

#### 4.0 Human activities affect aquatic environments.

- Humans use water in many ways—for work, for play, for survival. Even when we aren't using water directly, we can have an effect on aquatic environments.
- Our greatest use of water is in irrigation for agriculture. The next largest use is for industry. Domestic use (in the home) is third. All these uses have both intended and unintended results. Many of the unintended results are harmful to aquatic environments.
- Monitoring aquatic environments helps us to understand the effects of human activities.
   It also helps us to develop technologies that will make our activities less harmful.
- Science and technology alone cannot solve problems. People must take action and be committed to solutions.



#### **Getting Started**

You have learned in this unit that water is one of our most important resources. Here in Canada, as in other places in the world, we depend on a continual supply of fresh water. We expect clean, safe drinking water, and our agriculture and other industries depend on having large amounts of fresh water.

Our natural environment also depends on water. Our forests act as reservoirs that purify and store water. When the snow and rain fall on our watersheds, they are trapped by this ecosystem. Over time, they are slowly released into the streams and rivers that supply us with water. The trees and other organisms in these environments are affected by many factors including wastes and pollutants.

You learned that our activities directly influence water quality and availability. It is important to understand the impact that technological development has on them.

# To Log or Not to Log



Clear cutting is the most common forestry technology used in Canadian logging.

Logging is one such activity that often stirs controversy. Wood and wood fibre are important components of many things we use. Much of northern Alberta and the eastern slope of the Rocky Mountains are heavily forested. The trees they contain are a valued source of lumber and a potential source of wood pulp for paper manufacture. But many people object to clear-cut logging, the most common logging technology. It is unsightly and can have environmental consequences, such as excessive erosion. Some people would prefer to see logging greatly reduced, but the forest industry is a major employer in Canada. In certain areas, it is almost the only employer.

In some communities, the debate about logging focusses on water quality. Should logging be allowed at all near any body of water (lake or river) that is the source for a community's drinking water? Is there some way to balance employment, environmental, and human safety considerations?

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How do we protect our water supplies?

Valuable timber surrounds this community's water supply.



#### Your Goal

Your class will work together to design and publish a water e-zine electronically or a paper magazine that presents information and points of view about logging in a community watershed.

#### What You Need to Know

For the purpose of this project, assume that your community takes its drinking water from a lake surrounded by commercially valuable forests, like the one in the photograph. One of the main industries in your community and the surrounding area is forestry.

#### Steps to Success

- 1 Your class will divide up into groups to collect information, prepare articles and photos, and design and publish your e-zine/magazine. Publishing will mean either putting up a Web site or putting together a printed paper document. Articles could include news items, human interest stories, poems, fictional stories, or photo essays. Some of the topics you should cover include:
  - · where your drinking water comes from
  - · why water quality is important
  - · how logging might affect your drinking water
  - logging technologies—clearcutting and alternatives
  - · watershed protection activities
  - how logging might affect watershed ecosystems
  - importance of logging to the community's economy
  - how logging and environmental protection may be able to co-exist
  - · any other related topic you think is important
- Have other students in the school read your e-zine/magazine. If it's an e-zine, they can post their comments electronically. If it's a paper magazine, you could set up space on a bulletin board where they could post their comments on the issue.

#### How Did It Go?

- 3 Summarize the types of comments you received from other students about your e-zine/magazine. Which comments would help you improve your publication? Why?
- 4 If you were to produce an e-zine/magazine on another issue, what would you do differently?

Project

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# UNIT REVIEW: FRESH AND SALTWATER SYSTEMS

### **Unit Vocabulary**

 Write a short story about Earth's fresh and saltwater systems using the following terms:

potable water
water quality
salinity
waves
tides
stream characteristics
watershed
glaciers
climate
diversity
populations
monitor

## **Check Your Knowledge**

1.0

- 2. a) Where is most of the water on Earth located?
  - b) Is this water useful to humans? Explain your answer.
  - c) Describe the differences between the water in a lake and the water in the ocean.
- 3. What is the difference between salinity and hardness in water?
- Even when water appears to be clear and clean, it may not be safe enough to drink.
   Describe two things that could make it unsafe for human use.

5. A friend of yours has moved out to the country but she doesn't like the well water there because it has a salty taste. What would you suggest your friend's family do to improve the quality of their water?

#### 2.0

- 6. How do waves affect a coastline?
- 7. A wave is travelling at 50 km per hour across the ocean. As the wave passes your sailboat, you drop a toy boat onto it. How far will the toy boat travel in a day? Explain your answer.
- 8. What is the difference between a current and a tide?
- 9. a) What is the Continental Divide?
  - b) How is it related to the watershed that you live in?
- 10. a) What is a glacier?
  - b) How do glaciers affect the environment?
- 11. What effects does a large body of water have on the climate of a city on its shore?

3.0

- 12. Which water environment would you go to if you wanted to study as many different types of aquatic organisms as possible? Why does it have so many different types of organisms?
- 13. Define the term adaptation in your own words. Give two examples of adaptations that fish have to living in water.
- 14. Describe three types of human activities that can affect aquatic organisms.

- **15.** a) Describe three major ways that people use water worldwide.
  - b) For each one, give an example of how this use might affect water in the natural environment.
- **16.** What is indirect water use? Give some examples to support your explanation.
- Agree or disagree with the following statements. Give evidence to support your decisions.
  - a) Because water is recycling itself all the time, we don't have to conserve it.
  - b) Only human activities can have negative effects on aquatic animals.

## **Connect Your Understanding**

- 18. Look around your community. What evidence do you see that human activities might be harming the local water supply? What evidence do you see that efforts are being made to conserve or protect water in your area?
- 19. A new oceanside resort trucks in tonnes of fine, clean sand to create a beach along a rocky shoreline. In what ways could this change to the rocky shore affect the animals that live there? How do you think the wave action on the ocean's shore might affect the new beach?
- 20. You are out for a drive in the country, and you notice some unusual-looking hills. They are rounded and tapered at one end. You also notice snake-like

- ridges of gravel and sand. What is each feature called? Explain the relationship between these geological features and glaciers that covered the province in the past.
- 21. Imagine a glacier high up in the mountains. What do you think would happen to the glacier in each of the following situations?
  - a) Winter temperatures are higher than normal for 10 years.
  - b) Winter temperatures are lower than normal for 10 years.
  - c) Two winters where the same amount of snow and ice melts from the front of the glacier as falls on it farther up.
- 22. Ten years ago, there was only one house beside a lake. Today, there is a small community, including a marina and a campground. (A marina is a place on the waterfront where people can park their boats in the water.) Ten years ago the fishing was good here, but now very few fish are caught.
  - a) What factors do you think affected the fish population? (Think about factors other than overfishing.)
  - b) What effect do you think the change in the fish population might have on the other animals in the lake? Hint: Think about micro-organisms as well as other, large animals.

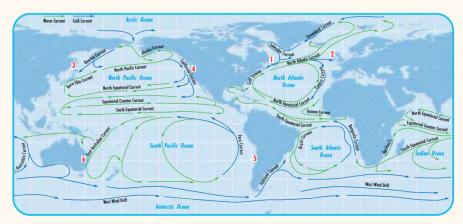
#### **Practise Your Skills**

23. Imagine that you are a journalist who will be interviewing the head of a mining company that is about to develop

### UNIT REVIEW: FRESH AND SALTWATER SYSTEMS

- a mine in a wilderness area of the province. Make a list of questions you will ask about how the development will affect water in that area.
- 24. Plan an experiment to determine which of three water samples is safest to drink. Hint: Limit your testing to suspended solids and organisms.
  - a) What are your major variables?
  - b) What materials would you need?
  - c) What procedure would you use?
- 25. On the map shown below, six cities are shown and the ocean currents that pass near them. Compare the following pairs of cities:
  - (1) St. John's, Newfoundland, and (2) Dublin, Ireland
  - (3) Sapporo, Japan, and
    - (4) Vancouver, British Columbia
  - ullet (5) Santiago, Chile, and
    - (6) Sydney, Australia

For each pair, predict which one will have a warmer climate and which one will have more rain. Explain your predictions for each one. Check your predictions by using reference books and the Internet.



Question 25. Which cities have warmer climates? Which cities have more rain?



#### SAFETY IN THE LABORATORY

## **Safety Wins**

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.





Flammable Hazard: Materials could ignite (catch on fire) if exposed to flames, sparks, or friction.



Explosive Hazard: The materials or equipment could explode.



Toxic Hazard: The material is very poisonous and could have immediate and serious effects.

Corrosive Hazard: The material may corrode ("eat away at") clothing, skin, or other materials.



Biological Hazard: Be alert to the possibility of poisoning or infection from microscopic and other organisms.



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.



compressed das



dangerously reactive material



oxidizing material



poisonous and infectious causing immediate and serious toxic effects



flammable and combustible material



biohazardous infectious material



corrosive materia



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 →

Toolbox 1



#### 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 shown on 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.
- 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

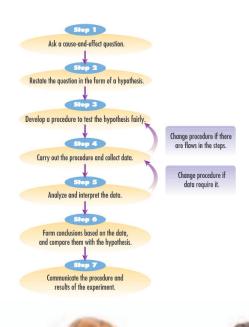
Are you willing to

- 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  $\rightarrow$ 

Toolhox 2

### **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.

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 experimentplanning 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 will you need for the experiment? For the seedling experiment, the materials would include 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.

### **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 tables 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.)

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 guestion.

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 don't support your hypothesis, there are two possible reasons why.

- Perhaps your experimental plan was flawed and needs to be re-assessed and possibly planned again.
- Perhaps your hypothesis was incorrect and needs to be re-assessed and modified.

For example, 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 flaws. 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.

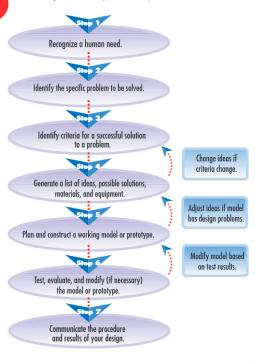
Scientists always share the results of their experiments with other people. They do this by summarizing how they performed the first six steps. Sometimes, they will write out a formal laboratory report stating their purpose, hypothesis, procedure, observations, and conclusions. Other times, they share 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.

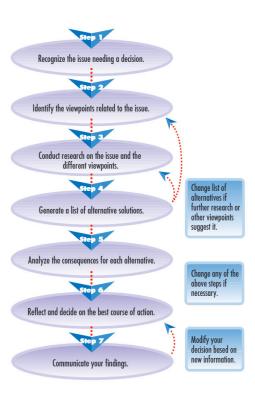
Inventors and engineers create things to meet people's needs. When they make something new, they like to show it to other people and explain to them how it works. Sometimes they will use a carefully drawn diagram of the new device and write about how they performed the first six steps. Other times, they 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 wellbeing
- 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	1
Run-off	3	3	S
Birds move	2 to 1	3	1
Playing field well used	2	2	possibly 1
Development and maintenance cost	2 to 1	3	1

### **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. Here are some types of measurements you might come across every day.

#### Length

Length tells you

- · how long or short something is
- · how far or near something is
- · how high or low something is
- · how large or small something is

Common units used to measure length include millimetres (mm), centimetres (cm), metres (m), and kilometres (km). All these units are based on a single standard: the metre.

#### 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 Kitchener, Ontario, to Kamloops, British Columbia
- · the distance from Earth's core to its surface



When you use a measuring tool such as a ruler, look directly in line with the measurement point, not from an angle.

#### Volume

The volume of something tells you the amount of space that it takes up (occupies). Common units used to measure volume include litres (L) and millilitres (mL). Remember, 1 mL equals 1 cm<sup>3</sup>.

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.



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.

#### CHECK IT YOURSELF

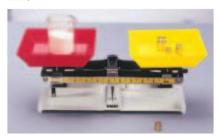
- 1 Which of the following tools could you use to measure volume? Why?
  - a spoon
  - · a test tube
  - a balance
- How could you transform an empty can into a volume measuring tool? Describe, step-by-step, how you would do it.

#### Mass and Weight

In science, the mass of an object and its weight mean different things. The mass of something tells you the amount of matter it has. The weight of an object is the measure of the force of gravity acting on it. We use mass more often in science. Common units used to measure mass include grams (g) and kilograms (kg).

You usually measure mass with a balance. Your classroom probably has an equal arm balance or a triple beam balance like the ones shown here.

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 heam)



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.

You can use a spring scale to measure weight, which is the force of gravity acting on an object. A spring scale is sometimes called a force meter. A spring scale measures force in newtons.

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.

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.



spring scale

#### 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?

Continued on next page →

Toolbox 5

#### Estimating

When you estimate, you use your mind to guess the length, volume, or mass of an object. 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's 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

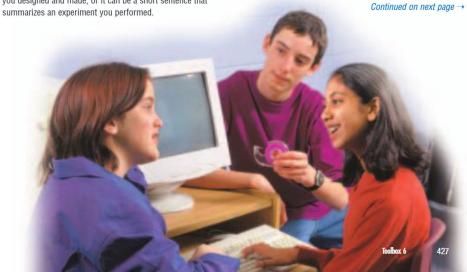
#### Tell readers why you did the work.

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. 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.

This last section of your report can be called "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.

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

Science and technology often involve collecting a lot of numerical data. This data may be recorded in tables or charts. 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.

#### **Creating Line Graphs**

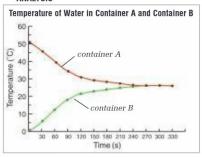
Line graphs are good for exploring data collected for many types of experiments. Using line graphs is a good way to analyze the data of an experiment that are continually changing. For example, here are some data collected by a group of students investigating temperature changes. They poured hot water 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.

Here are the data they collected shown as a chart and 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.

#### EVIDENCE

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

#### ANALYSIS



#### 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?

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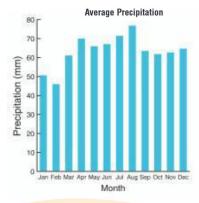
Toolbox 7



#### **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



#### 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 this circle graph, the "whole" is Earth's total land area. The "parts" are the approximate percentages of land made up by each continent.

#### Percentage of Earth's Land Area

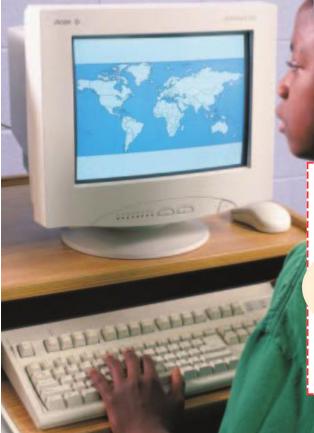


#### Hints

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  $360^\circ$  is. 10% is the same as 10/100, which is the same as 0.1. So  $0.1 \times 360^\circ = 36^\circ$ .
- 2 How could you use this information to hand-draw your own circle graph?

Toolbox 7

#### 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.

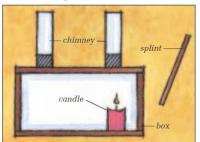
Four types of diagrams you can use include: a Simple Sketch, a Technical or Scientific Diagram, an Orthographic (Perspective) Diagram, and a Computer-Assisted Diagram (CAD). Examples of each type of diagram are shown. A side view and a top view for a simple sketch are also shown. These different views 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

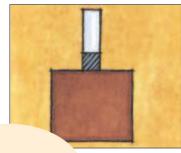
#### For technical and orthographic diagrams

· blank graph paper

#### For computer-assisted diagrams

- · blank diskette
- · access to computer and software

#### A Simple Sketch (Side View)



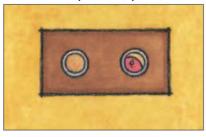
#### Hints

If you're going to use your diagram to help you design a structure, include a top, side, and front view.

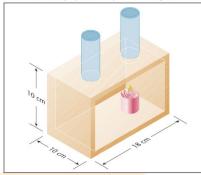
#### REMEMBER!

- 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 Simple Sketch (Top View)



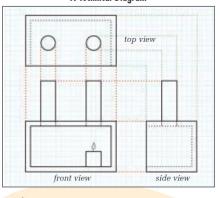
#### An Orthographic (Perspective) Diagram



#### Hints

Use graph paper to help you with the details of your diagram if you don't have a ruler handy.

#### A 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 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.

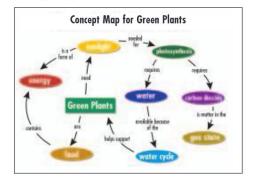
#### Venn Diagram



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?

#### **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

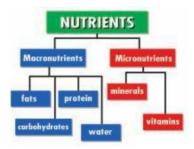
To use a concept map, ask yourself questions such as:

- · 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



#### 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**

		Characteristics			
		can move	needs food	can communicate	can breathe
are	goat	Х	X	Х	X
inings to compare	tree		Х		
	rock				
	person	X	Х	Х	Х

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.

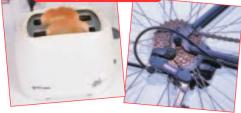
#### Hint

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

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	1	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.

Continued on next page →

Toolbox 10

#### 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:

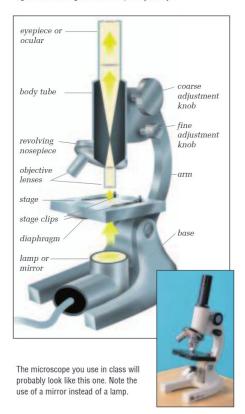
- title or name of the source (e.g., if you read a chapter of a book, you would write down the book's title; for a Web site, you would include the address)
- · author's name, if known
- publisher (e.g., for a Web site, this would be the name of person or organization who has put up the site)
- date of 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.



#### How to Use the Microscope

- 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.





Continued on next page →

Toolbox 11

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.

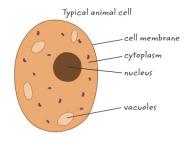
#### **Drawing Hints**

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 Using a mathematical compass, draw a circle with a diameter of 10 cm to 12 cm. This represents the view you see through the eyepiece. Scientists call it a *field of view*, or just *field* for short.



- 3 Draw only what you see. Keep your details simple and straightforward. (You don't need to add colouring or shading.)
- 4 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. Record which objective lens you used to observe the image.
- 5 Give your drawing a title at the top of the page.



#### GLOSSARY



adaptation physical characteristic or behaviour of a species that increases the species' chances of survival in a particular environment

alveoli tiny air-filled sacs in the lungs; the site of gas exchange (singular alveolus)

amplitude height of the wave from its middle
rest position to its highest point

**angle of incidence** angle between the incident ray and the normal

**angle of reflection** angle between the reflected ray and the normal

aorta large artery carrying blood from the left ventricle to the body

aperture hole or opening in a camera that lets in light

aqueous solution solution in which water is the
solvent

arteries thick-walled blood vessels that take blood away from the heart to the rest of the body

atherosclerosis cholesterol build-up on the walls
 of arteries

atria upper chambers of the heart that receive blood from the body and lungs (singular atrium)

autonomic nervous system division of the peripheral nervous system that controls automatic responses in the body, such as heart rate

axon long extension of a neuron's cell body that transmits information to neighbouring cells

#### B

binoculars device for viewing distant objects; made up of two short refracting telescopes fitted together

bioluminescence the ability of certain organisms to produce light by a chemical reaction

bronchi two main branches of the trachea that
 lead into the lungs (singular bronchus)

**bronchioles** tubes that connect the bronchi to the air sacs in the lungs

**bronchitis** disease in which mucus builds up in the bronchi and causes them to become narrower

buoyancy tendency of an object to float when placed in a fluid

buoyant force upward force that a fluid exerts on an object; opposite to the pull of gravity on an object in a fluid



camera eyes eyes that are round and have a cornea, a lens, and a retina

capillaries tiny blood vessels that connect arteries to veins; one cell layer thick and extremely narrow

carbon monoxide colourless, odourless gas that is released when a cigarette burns

cell the basic unit of life

cell membrane thin structure that encloses all the contents of plant and animal cells; has tiny openings that allow particles of some substances, but not others, to pass through

cell wall outer covering of a cell that provides strength and support; found only in plant cells

central nervous system division of the nervous system composed of the brain and spinal chord

charge-coupled device device that converts light into electrical energy; used in digital cameras

chemical digestion breakdown of large food particles into smaller particles by enzymes

**chloroplasts** organelles that convert sunlight into food; found only in some plant cells

cilia hair-like extensions that protrude from the surface of some unicellular organisms and from some cells in multicellular organisms

circulatory system transport system reaching every cell in the body; delivers nutrients absorbed by the digestive system and oxygen absorbed by the respiratory system to every cell; transports waste products from cells for removal by the excretory system; defends the body against disease; connects all organ systems climate average weather measured over a long period of time

colloid cloudy mixture in which the droplets or tiny particles are too small to separate out

complex machines system in which simple machines all work together; parts of a complex machine that have just one function are called subsystems and often contain a simple machine

compound eyes eyes that are made up of many smaller units; found in insects and crustaceans

compound light microscope microscope that has two or more lenses and has a light source

compressibility extent to which a substance (solid, liquid, or gas) can be compressed; objects under compression tend to deform in shape

concave lens piece of transparent material that is thinner in the middle than at the edges; light rays passing through it diverge or spread out

concave mirror reflecting surface that is curved inward like the inside of a bowl or a spoon; light rays reflected from it converge (come together)

concentration the amount of solute (usually in grams or kilograms) dissolved in a specific amount of solvent (usually in millilitres or litres) in a solution; written g/mL or kg/L

cones specialized cells in the retina that detect colour; there are three types of cones, each sensitive to different colours: red, green, and blue.

**connective tissue** supports and connects different parts of the body

Continental Divide highest point of land on a continent; rivers flow into different oceans depending on which side of the divide they start

convex lens piece of transparent material that is thicker in the middle than at the edges; light rays passing through it converge or come together

convex mirror reflecting surface that bulges out like the back of a spoon; light rays reflected from it diverge (spread out)

crest highest point of a wave

**current** stream of water that moves within a larger body of water

cytoplasm contents of the cell inside the cell membrane excluding the nucleus; contains nutrients the cell needs to survive



dendrites small branches of a neuron that receive information from neighbouring cells

density mass per unit of volume; calculated by dividing the mass of a substance by its volume

dialysis removal of waste products from the blood using a machine that functions as a kidney

diaphragm large muscle below the lungs that helps move air in and out of the lungs; part that changes the size of a camera's aperture; it varies the amount of light that reaches the film

diffuse reflection reflection that happens when parallel rays hit a rough surface; all rays reflect at different angles

diffusion the movement of particles of a substance from an area of higher concentration to an area of lower concentration

digestive system breaks down the food you eat into parts small enough to be absorbed and transported throughout the body

digital imaging process of creating an image using a computer

distillation technique for separating solutions that involves boiling and condensation

diversity description of the variety of different species in an ecosystem; may also be used to describe variety in a population or species



efficiency measurement of how well a machine or device uses energy; can be calculated by dividing mechanical advantage by speed ratio or by dividing work output by work input

electromagnetic radiation all forms of radiant energy: visible light, infrared radiation, ultraviolet radiation, radio waves, X-rays etc.

electromagnetic spectrum refers to the whole range of wavelengths of visible and invisible electromagnetic radiation emphysema disease that causes damage to lung tissue, causing shortness of breath

enzyme substance created by the body to carry out chemical digestion

epithelial tissue covers the surface of the body and internal organs and lines the inside of some organs

excretion waste removal

excretory system removes chemical and gaseous wastes from the body; involves organs from other bodily systems

eyepiece lens or set of lenses in a microscope or telescope that is closest to the user's eye



field of view the area that you can see when looking through a microscope

film material that is sensitive to light; used in cameras to record images

fluid any matter that has no fixed shape, can flow, and takes the shape of its container; any substance in a gas or liquid state

fluorescent form of artificial light; uses ultraviolet light waves to make the coating inside an opaque tube glow white

focal point point at which light rays meet, or appear to meet, after being reflected by a mirror, or refracted by a lens

 $\begin{tabular}{ll} \textbf{friction} & force that opposes motion \\ \textbf{function} & purpose or task \\ \end{tabular}$ 



gamma rays high-energy electromagnetic radiation with the shortest wavelength; used to treat some types of cancer

gastric juice liquid in stomach made of mucus, hydrochloric acid, enzymes, and water; chemically digests food

gears pair of wheels with teeth that interlink; when they rotate together, one gearwheel transfers turning motion and force to the other glacier large moving body of ice; glaciers can be many metres or even kilometres thick



hard water water containing a high concentration of calcium and magnesium

hazard symbol warning symbol on hazardous materials; made up of a safety warning enclosed in a yellow triangle (which means "caution"), orange diamond (which means "warning"), or red octagon (which means "danger")

heterogeneous mixture mixture in which the different substances can be seen

homogeneous mixture mixture in which the different substances cannot be seen; a mixture that looks as if it is all one substance

hydraulic system system that uses a liquid under pressure to move loads; device that uses liquids in a confined space to transfer forces; works according to Pascal's law

 $\begin{array}{ll} \textbf{hydrometer} & \text{device used to measure the density} \\ \text{of liquid} & \end{array}$ 



incandescent form of artificial light; uses electrical energy to heat a thin wire thread that glows white hot

incident ray ray of light that arrives at a mirror or other substance

inclined plane simple machine made up of a flat surface, such as a board, at an angle to another flat surface, such as the ground or a table top; ramp

incompressible not capable of being compressed; liquids are said to be incompressible

infrared rays electromagnetic waves that have less energy than visible light; they are invisible but can be felt as heat

input force force applied to operate a machine
integumentary system protects body's internal
environment from the external environment

intensity brightness of light; amount of light arriving per unit area at a place

interact work together

interneurons neurons in the central nervous system that connect sensory neurons to motor neurons

invisible spectrum parts of the electromagnetic spectrum that the human eye cannot see

iris band of muscle in the eye that controls the size of the pupil and the amount of light entering the eye



laser acronym for light amplification by the stimulated emission of radiation; beam of light whose waves all have the same frequency and move in step and in the same direction; able to travel long distances without spreading out

law of reflection angle of incidence of a wave hitting a surface equals the angle of reflection

lens curved piece of glass or other transparent material that refracts light in a predictable way

lever simple machine made up of a rigid bar or plank that rotates on a fixed object called a pivot or fulcrum

linkage belt or chain to transfer energy from an energy source to an object (e.g., a bicycle chain)

**luminous** describes objects that produce light; for example, the sun, light bulb, fire, etc.

lung cancer growth of tumours, which take up space in the lungs, making breathing difficult



machine device that helps us do work

marrow type of connective tissue found in the
bones that produces red blood cells

mechanical advantage amount by which a machine can multiply a force; calculated by dividing the output force by the input force

mechanical digestion physical breakdown of food into small particles

mechanical mixture heterogeneous mixture; mixture in which the different substances are easy to see

metabolism all the life processes that take place in the cell; includes energy-using and energycreating processes

micro-organisms usually unicellular organisms that can be seen only through a microscope

microscope optical device used for viewing very small objects; has at least two lenses: the objective lens and the eyepiece lens

microvilli finger-like projections on the cells that line the villi (singular microvillus)

microwaves electromagnetic radiation that has a shorter wavelength than radio waves and carries more energy; used to cook food and transmit audio and video signals

mitochondria organelles that convert energy the cell receives into a form it can use (singular mitochondrion)

mixture combination of two or more different pure substances

monitor observe, check, or keep track of something for a specific purpose

motor neurons carry information from the central nervous system to the muscles or other organs

multicellular made of more than one cell

muscle tissue allows movement

muscular system moves bones; moves organs that contain muscle tissue

mycoplasma type of microscopic organisms



**nephrons** filtering units of the kidney that remove wastes from the blood and produce urine

nervous system coordinates and controls all organs and organ systems; detects, processes, and responds to stimuli

nervous tissue tissue of the brain, spinal chord, and nerves

**neurons** specialized cells of the nervous system that receive and transmit information

nicotine addictive drug found in cigarettes that speeds up the heart and raises blood pressure

**nocturnal** describes animals that are active at night

non-luminous describes objects that do not produce light but may reflect it (for example, the moon); most objects on earth are non-luminous

normal line perpendicular to a surface (that is, forms a 90° angle with the surface)

nucleus organelle that directs all the activities in a cell



objective lens lens in an optical device, such as a microscope or telescope, that gathers light from an object to form an image

ommatidium unit of a compound eye; has a lens, focussing cone, and light-sensitive cell (plural ommatidia)

opaque describes materials that do not allow light to pass through; for example, wood, metal, cardboard, etc.

optic nerve nerve that leads from the retina to
the brain

optical device any device that uses light; for example, mirrors, lenses, microscopes, and telescopes

organ group of tissues that work together to perform a specific function

organ system group of organs that work together to perform a certain task, such as digestion or breathing

organelles structures in cells that perform a certain function

organisms living things

**osmosis** diffusion of water through a selectively permeable membrane

output force force a machine applies to an object



particle model of matter model that explains the behaviour of solids, liquids, and gases; it states that all matter is made up of tiny moving particles that attract each other and have spaces between them

Pascal's law when pressure is applied to a liquid in a container, the pressure and force is transmitted equally and undiminished throughout the liquid; an enclosed liquid transmits pressure equally in all directions

pasteurization process of heating food to a high temperature in order to kill harmful microorganisms

peripheral nervous system division of the nervous system composed of the cranial and spinal nerves

 $\begin{array}{ll} \textbf{peristalsis} & \text{wave-like muscle contractions along} \\ & \text{the digestive system} \end{array}$ 

phosphor substance that emits light when
exposed to ultraviolet radiation

phosphorescence process in which a substance emits light after it has absorbed ultraviolet light

photophore light-producing organ found in bioluminescent organisms

photoreceptors light-sensitive cells found in the retina of the eye; there are two types: rods and cones

photosynthetic tissues group of cells containing
 chloroplasts; produces food for the plant

pixel short for picture element; individual element of a digital image

plane mirror flat mirror; reflecting surface that
 has no curvature

platelets cell fragments in the blood that help
stop bleeding at cuts

pneumatic system system that uses a gas under pressure to move loads; device that uses gases in a confined space to transfer forces; works according to Pascal's law

**population** group of organisms of the same species that live in a particular area

Glossary

potable water water that is safe for humans to drink

pressure measure of the amount of force applied to a given area; as an equation p=F/A, where p is pressure, F is force, and A is area; measured in pascals (Pa)

primary colours red, green, and blue light; adding these three colours of light produces white light

**protective tissues** protect a plant and absorb water from soil

pseudopods foot-like projections on an amoeba;
used for movement and capturing food

pulley simple machine made up of a wire, rope, or cable moving on a grooved wheel; may be made up of one or many wheels; can be fixed in place or movable

pump device that moves a fluid through or into something; piston pumps, diaphragm pumps, and Archimedes screws are three common kinds of pumps; the heart is a natural pump

pupil opening in the eye that lets in light
pure substance substance made up of only one
type of matter; matter that has one type of
particle throughout

#### R

radar acronym for radio detection and ranging; system that detects reflected microwaves

radio waves electromagnetic radiation used in communications around the world

ray diagram diagram used to represent how light travels; each ray has an arrow to show the direction of travel

react respond

real image image formed when rays meet at a point; the image can be projected onto a screen

red blood cells small, pliable cells that have no nucleus and are specialized for carrying oxygen to all the cells of the body

reflecting telescope telescope that uses a curved mirror and a lens to form an enlarged image

reflex automatic response to a stimulus; happens very quickly and without conscious control

refracting telescope telescope that uses two lenses to form an enlarged image

refraction bending of light as it travels from one material to another material

regular reflection reflection that happens when parallel rays hit a smooth surface; all rays reflect at the same angle

resolution the number of pixels per unit area in a digital image

respiratory system supplies blood with oxygen from the outside air and removes carbon dioxide from your blood

response organism's reaction to a stimulus

retina special lining on the back of the eye; when light hits the retina, receptor cells send messages to the brain, which translates them into an image

reverse osmosis movement of water through a membrane from an area of lower water concentration to one of higher water concentration; technique used for purifying water

rods specialized cells in the retina that are sensitive to low levels of light



salinity amount of dissolved salts in water
saturated solution solution in which no more
solute can be dissolved at a given temperature

saturation point point at which no more solute can be dissolved in a given volume of solvent at a given temperature

screw simple machine that consists of a cylinder with a groove cut in a spiral on the outside

secondary colours yellow, cyan, and magenta; colours made from adding any two primary colours of light

**sediments** eroded rock fragments and soil carried by water or wind

selectively permeable describes a membrane with very small openings that allow particles of some substances, but not others, to pass through sensory neurons cells that carry information from the body to the central nervous system

**shutter** part that acts like a door to control the amount of light entering a camera

simple machine tool or device made up of one basic machine

skeletal system provides a mobile support frame for the body; protects soft-tissue organs

smallpox disease that produces a rash and high fever and can cause blindness and death; the first disease to be controlled by a vaccine

solubility ability to dissolve; the mass of solute that can dissolve in a given amount of solvent to form a saturated solution at a given temperature

solute substance that dissolves in a solvent to form a solution

solution homogeneous mixture; mixture of two or more pure substances that looks like one substance

solvent substance that dissolves a solute to form a solution; water and alcohol are common solvents

somatic nervous system division of the peripheral nervous system that controls voluntary responses

specialized cells cells that have specific structures that help them to perform particular functions

speed ratio measure of how the speed of the object is affected by a machine; calculated by dividing the input distance by the output

spontaneous generation false idea that living things could come from non-living matter

stimulus any change in an organism's environment (plural stimuli)

storage tissues stores food in plants

stream characteristics characteristics used to describe a stream or river; these include volume and rate of flow, slope and shape of bed

**structures** parts of an organism that perform specific tasks

subsystem (of a machine) smaller group of parts within a complex machine that performs a specific function

suspension cloudy mixture in which droplets or tiny pieces of one substance are held within another substance; if you leave a suspension undisturbed, its parts will usually separate out

system (in context of machine) a group of parts that work together to perform a general function, forming a complex machine



tar dark sticky substance formed when tobacco

telescope optical device for viewing distant objects; there are two types: reflecting and refracting telescopes

theory of colour addition theory that explains what happens when coloured lights are mixed together

tide daily change in water level of the oceans

tissue group of similar cells working together to perform a specific function

**translucent** describes materials that allow some light to pass through

transmission special type of linkage for transferring the energy from the engine to the wheels in large vehicles such as cars and trucks

transparent describes materials that allow light to pass through with little or no reflection; for example, glass

transport tissues transport food and water to different parts of the plant; includes xylem and phloem



**ulcers** painful sores on the stomach lining often caused by the micro-organism *H. pylori* 

ultraviolet light electromagnetic waves that have more energy than visible light; too much ultraviolet radiation can increase the risk of skin cancer unicellular made of just one cell

unsaturated solution solution in which more solute can be dissolved at a given temperature

urea poisonous substance converted from highly toxic ammonia by the liver



vaccine substance that is taken by or injected into an animal or person to produce an immunity to a disease; usually prepared from a mild form of the disease

vacuoles organelles that store water and other substances required by the cell

valve device that controls the flow of fluids

veins blood vessels that return blood from the body to the heart; have valves

ventricles lower chambers of the heart that pump blood to the body

villi small finger-like projections on the inner surface of the small intestine that absorb nutrients (singular villus)

viscosity liquid's internal resistance or friction that keeps it from flowing

visible light spectrum colours of visible light; the colours in a rainbow or viewed when light is split by a prism



water quality measure of the amount of substances besides water in a water sample; description of how pure a water sample is

watershed area of land that drains into one main lake or river

wave in water, circular movement of water particles that causes a change in pattern that moves along the water's surface; the pattern can move over long distances but the water particles do not wave model of light model used to explain the characteristics and behaviour of light energy; it describes light as energy in the form of waves; the different colours of light have different wavelengths; waves with shorter wavelengths have higher energy than those with longer wavelengths

wavelength distance between the top or crest of one wave and the crest of the next

wedge simple machine that looks like an inclined plane, but is forced into an object

wheel and axle simple machine made up of two wheels of different diameters that turn together; a longer motion on the wheel produces a shorter but more powerful motion at the axle

white blood cells blood cells specialized to fight infection

WHMIS Workplace Hazardous Materials Information System; a system of easy-to-see special warning symbols on hazardous materials

work done when a force acts on an object to make the object move; calculated by multiplying force times distance



X-rays high energy electromagnetic radiation; can be used to make images of the interior of the body

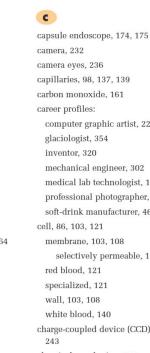
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