McGraw-Hill Ryerson

DISCOVERING SCIENCE 7

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Discovering Science 7

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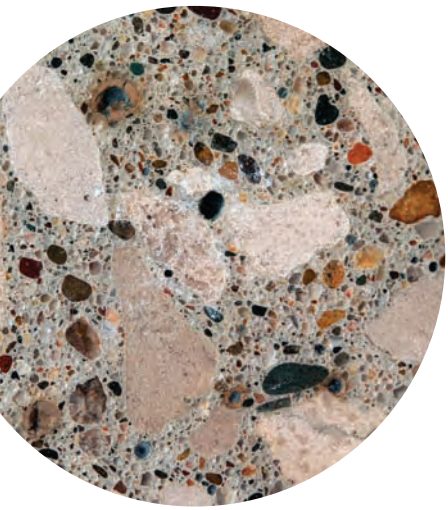

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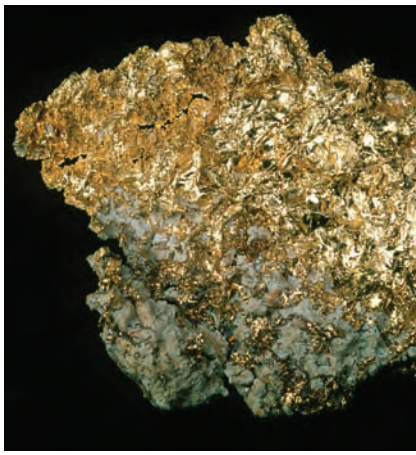

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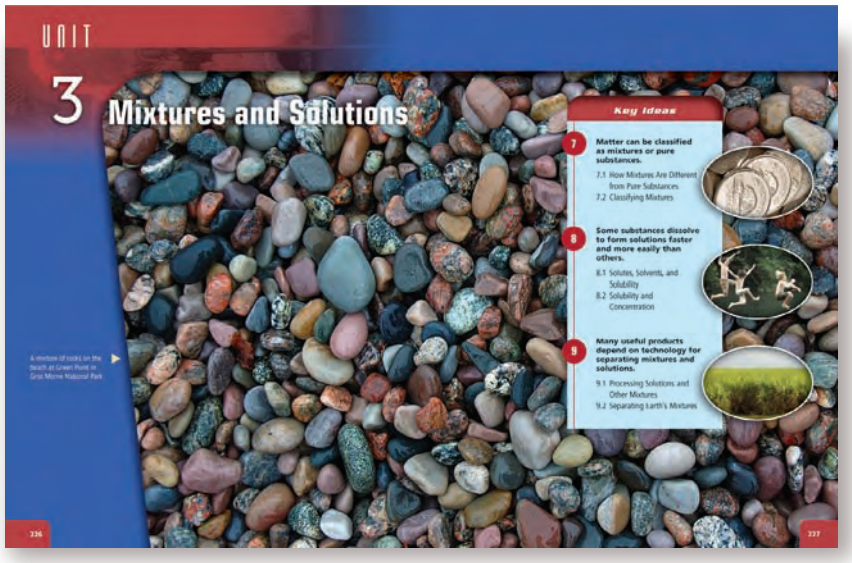
A Tour of Your Textbook

Welcome to ***Discovering Science 7***. This textbook introduces you to the wonders of ecosystems, heat and temperature, mixtures, and Earth's crust. To understand your book and how to use it, begin by taking a brief tour on the following pages. Then do the Scavenger Hunt on page xvii.

Unit Opener

- ***Discover Science 7*** has four major units: Interactions within Ecosystems, Heat, Mixtures and Solutions, and Earth's Crust.
- Each unit opener photo is a window into the world of the Key Ideas you will study in the unit. The caption explains the photo.
- The unit opener identifies each of the unit's Key Ideas. These are the chapter titles.
- The small photos next to the Key Ideas are from the beginning of each chapter.



Getting Started

- The Getting Started helps you recall what you might already know about the Key Ideas in the unit.
- It helps you prepare for studying the unit by giving you the following:

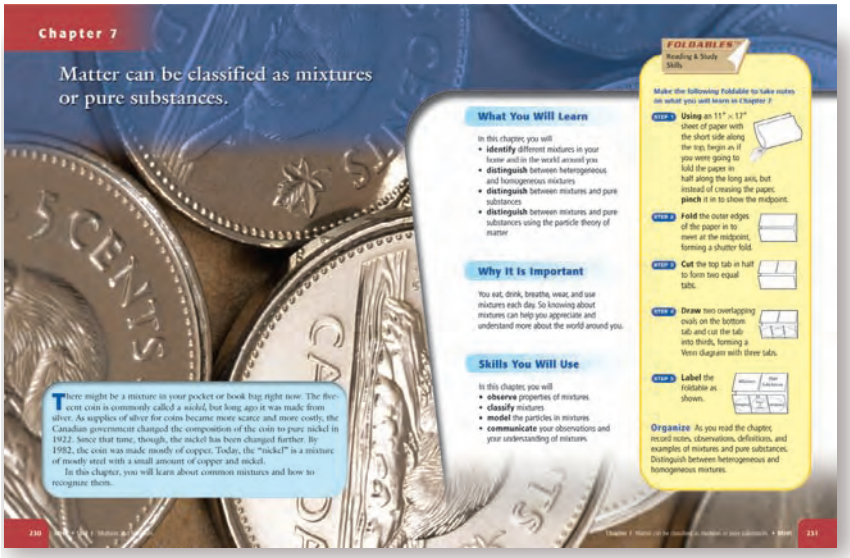
— a short reading about an interesting topic related to the unit

— an **Internet Connect** feature to take you to www.discoveringscience.ca to learn more about the topic

— a short **Find Out Activity** so you can explore an idea related to the unit

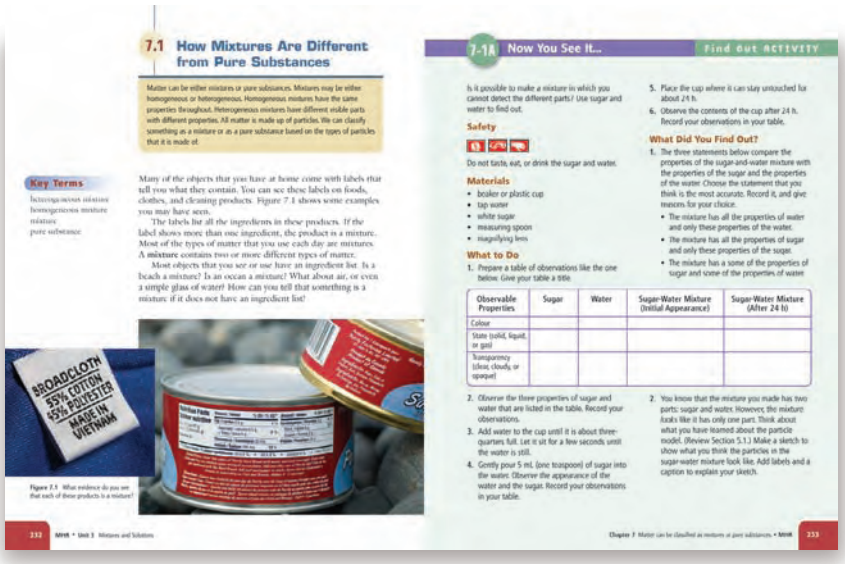
Chapter Opener

- The sentence of the chapter title is the Key Idea that you will study in this chapter.
- The chapter opener outlines What You Will Learn, Why It Is Important, and Skills You Will Use in the chapter.
- The **Foldables** exercise is a fun way to develop your study skills. Look for a Foldables exercise at the beginning of every chapter.



Section Opener

- A number and a short title identify each new section in a chapter.
- The shaded light brown box below the section title contains a summary of the science concepts you will study in the section.
- The list of Key Terms in the margin identifies important new science terms that you will learn in the section.
- The **Did You Know?** margin feature is an interesting bit of information related to the section's topic.
- Each section opener includes a **Find Out Activity** or a **Think About It Activity**.



Find Out Activity

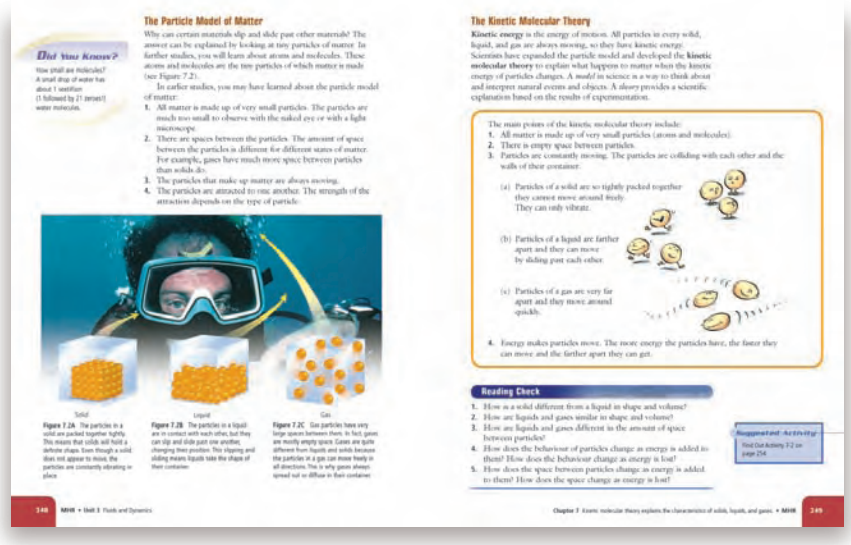
- This short, informal inquiry activity involves hands-on exploration, using simple materials and equipment.
- In these activities and in the investigations, you will use important science process skills, such as predicting, estimating, and hypothesizing.

Science Skill

- This box directs you to one of nine Science Skills sections at the back of the textbook. The Science Skills sections can help you with graphing, writing a hypothesis, using a microscope, and other skills.

Think About It Activity

- These activities look similar to Find Out Activities in the book but you do them at your desk. They do not require any special equipment.
- For these activities, you think about a particular idea related to the concepts you are studying in the section.
- You work on your own, with a partner, or in a group, and share your thoughts with your group or class.



The Particle Model of Matter

Did You Know?

How small are molecules? A small drop of water has about 1 sextillion (1 followed by 21 zeros!) water molecules.

Why can certain materials slip and slide past other materials? The answer can be explained by looking at tiny particles of matter. In further studies, you will learn about atoms and molecules. These atoms and molecules are the tiny particles of which matter is made (see Figure 7.2).

In earlier studies, you may have learned about the particle model of matter:

1. All matter is made up of very small particles. The particles are much too small to observe with the naked eye or with a light microscope.
2. There are spaces between the particles. The amount of space between the particles is different for different states of matter. For example, gases have much more space between particles than solids do.
3. The particles that make up matter are always moving.
4. The particles are attracted to one another. The strength of the attraction depends on the type of particle.

Solid — Figure 7.2A The particles in a solid are packed together tightly. This means that solids will hold a definite shape. Even though a solid does not appear to move, the particles are constantly vibrating in place.

Liquid — Figure 7.2B The particles in a liquid are in contact with each other, but they can slip and slide past one another, changing their position. This slipping and sliding means liquids take the shape of their container.

Gas — Figure 7.2C Gas particles have very large spaces between them. In fact, gases are mostly empty space. Gases are quite different from liquids and solids because the particles in a gas can move freely in all directions. This is why gases always spread out to diffuse in their container.

The Kinetic Molecular Theory

Kinetic energy is the energy of motion. All particles in every solid, liquid, and gas are always moving, so they have kinetic energy. Scientists have expanded the particle model and developed the **kinetic molecular theory** to explain what happens to matter when the kinetic energy of particles changes. A *model* in science is a way to think about and interpret natural events and objects. A *theory* provides a scientific explanation based on the results of experimentation.

The main points of the kinetic molecular theory include:

1. All matter is made up of very small particles (atoms and molecules).
2. There is empty space between particles.
3. Particles are constantly moving. The particles are colliding with each other and the walls of their container.

(a) Particles of a solid are so tightly packed together they cannot move around freely. They can only vibrate.

(b) Particles of a liquid are farther apart and they can move by sliding past each other.

(c) Particles of a gas are very far apart and they move around quickly.

4. Energy makes particles move. The more energy the particles have, the faster they can move and the farther apart they can get.

Reading Check

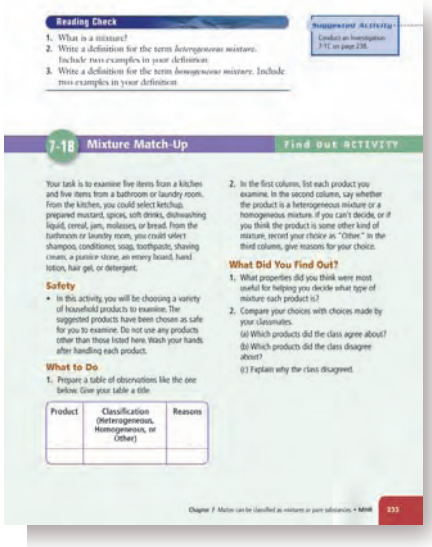
1. How is a solid different from a liquid in shape and volume?
2. How are liquids and gases similar in shape and volume?
3. How are liquids and gases different in the amount of space between particles?
4. How does the behaviour of particles change as energy is added to them? How does the behaviour change as energy is lost?
5. How does the space between particles change as energy is added to them? How does the space change as energy is lost?

Suggested Activity — Find Out Activity 7-2 on page 254

Chapter 7 Kinetic molecular theory explains the characteristics of solids, liquids, and gases. • MHR

Section Text and Activities

- The text of each section is divided into "chunks" to help you understand the content. Each chunk has a title.
- Each picture has a caption that explains what the picture is about.
- Key Terms and other terms you need to know are boldfaced in the text. Each boldfaced term is defined in the text and in the **Glossary** at the back of the textbook.
- **Reading Checks** contain questions that help you test your understanding of what you have just read.
- Find Out and Think About activities may appear throughout the each section of a chapter as well as at the end of a section.



Reading Check

1. What is a mixture?
2. Write a definition for the term *heterogeneous mixture*. Include two examples in your definition.
3. Write a definition for the term *homogeneous mixture*. Include two examples in your definition.

Suggested Activity — Conduct an Investigation 7-1C on page 238.

7-18 Mixture Match-Up — Find Out ACTIVITY

Your task is to examine five items from a kitchen and five items from a bathroom or laundry room. From the kitchen, you could select ketchup, prepared mustard, spices, soft drinks, dishwashing liquid, cereal, jam, molasses, or bread. From the bathroom or laundry room, you could select shampoo, conditioner, soap, toothpaste, shaving cream, a pumice stone, an emery board, hand lotion, hair gel, or detergent.

Safety

- In this activity, you will be choosing a variety of household products to examine. The suggested products have been chosen as safe for you to examine. Do not use any products other than those listed here. Wash your hands after handling each product.

What to Do

1. Prepare a table of observations like the one below. Give your table a title.

Product	Classification (Heterogeneous, Homogeneous, or Other)	Reasons

2. In the first column, list each product you examine. In the second column, say whether the product is a heterogeneous mixture or a homogeneous mixture. If you can't decide, or if you think the product is some other kind of mixture, record your choice as "Other" in the third column, give reasons for your choice.

What Did You Find Out?

1. What properties did you think were most useful for helping you decide what type of mixture each product is?
2. Compare your choices with choices made by your classmates.
   (a) Which products did the class agree about?
   (b) Which products did the class disagree about?
   (c) Explain why the class disagreed.

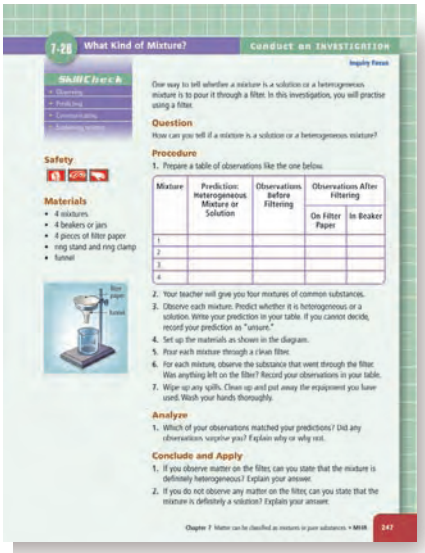
Chapter 7 Matter can be classified as mixtures or pure substances. • MHR 235

Suggested Activity

- These small margin features indicate where your teacher may have you do one of the activities from the end of the section.

Conduct an Investigation

- These formal labs give you the opportunity to develop science skills using various equipment and materials.
- In these investigations, you can ask questions about science, make observations, and obtain results.
- You then analyze your results to determine what they tell you about the topic you are investigating.
- Safety icons and safety warnings alert you to any special precautions you should take to help maintain a safe classroom environment.
- Each investigation has one of the following focusses: inquiry, decision-making, or problem-solving.
- At least once in every unit, you will see an activity or investigation that is identified as "Core", which means that is an especially important topic of investigation.


7-28 What Kind of Mixture? Conduct an Investigation

Inquiry Focus

SkillCheck

- Observing
- Predicting
- Communicating
- Assessing results

One way to tell whether a mixture is a solution or a heterogeneous mixture is to pour it through a filter. In this investigation, you will practise using a filter.

Question

How can you tell if a mixture is a solution or a heterogeneous mixture?

Safety

Materials

- 4 mixtures
- 4 beakers or jars
- 4 pieces of filter paper
- ring stand and ring clamp
- funnel

Procedure

1. Prepare a table of observations like the one below.

Mixture	Prediction: Heterogeneous Mixture or Solution	Observations before Filtering	Observations After Filtering	
			On Filter Paper	In Beaker
1				
2				
3				
4				

2. Your teacher will give you four mixtures of common substances.
3. Observe each mixture. Predict whether it is heterogeneous or a solution. Write your prediction in your table. If you cannot decide, record your prediction as "unsure."
4. Set up the materials as shown in the diagram.
5. Pour each mixture through a clean filter.
6. For each mixture, observe the substance that went through the filter. Was anything left on the filter? Record your observations in your table.
7. Wipe up any spills. Clean up and put away the equipment you have used. Wash your hands thoroughly.

Analyze

1. Which of your observations matched your predictions? Did any observations surprise you? Explain why or why not.

Conclude and Apply

1. If you observe matter on the filter, can you state that the mixture is definitely heterogeneous? Explain your answer.
2. If you do not observe any matter on the filter, can you state that the mixture is definitely a solution? Explain your answer.

Chapter 7 Matter can be classified as mixtures or pure substances • MHR 247

End-of-Section Features

- These features give you an opportunity to learn about applications or explorations of the topic you have studied in the section.
- The "www" in "**www science**" stands for "wild, weird, and wonderful." These features describe interesting and unusual science.
- **National Geographic Visualizing Science** features are exciting visual representations of a science topic.
- **Science Watch** features provide information on past and current scientific topics and research.
- **Science-Math Connect** features connect the science you learned in the section to math concepts.
- **Career Connect** features are interviews with people who have a career related to the unit.

Wild, Weird, Wonderful

www Science

What's the Metal in the Ice Man's Axe?

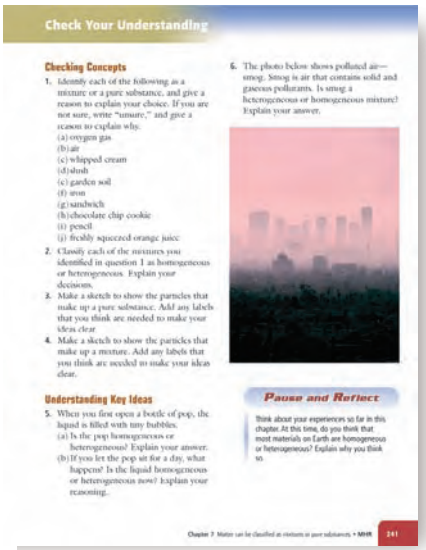
In September 1991, hikers in the Alps, near the border between Austria and Italy, discovered the body of a man. But this was no ordinary discovery. The man had been trapped in a glacier for thousands of years. He was almost perfectly preserved. With him was an assortment of tools, including an axe with a metal blade.

Scientists were especially interested in the axe. At first, they thought that the metal axe blade was bronze, which is a mixture of copper and tin. This was not possible, though. The iceman and his clothing had been dated to be about 5200 years old. Scientists believe that bronze was invented only about 4000 years ago. So, the axe blade could not be bronze.

Scientists then hypothesized that the blade could be copper. People have been using copper for at least the past 6000 years. To test their hypothesis, scientists exposed the axe blade to X-ray radiation. When metals are exposed to high energy radiation, their particles vibrate very energetically. As the vibration of the particles slows down, the particles give off energy that can be examined with specialized equipment. Scientists use this "energy signature" to identify the type of particle that is giving off the energy.

Analysis using this technique confirmed the scientists' hypothesis. The metal of the axe blade was almost pure copper.

240 MHR • Unit 3 Mixtures and Solutions


Check Your Understanding

Checking Concepts

1. Identify each of the following as a mixture or a pure substance, and give a reason to explain your choice. If you are not sure, write "unsure," and give a reason to explain why.
   (a) oxygen gas
   (b) air
   (c) whipped cream
   (d) shrub
   (e) garden soil
   (f) iron
   (g) sandwich
   (h) chocolate chip cookie
   (i) pencil
   (j) freshly squeezed orange juice
2. Classify each of the mixtures you identified in question 1 as homogeneous or heterogeneous. Explain your decisions.
3. Make a sketch to show the particles that make up a pure substance. Add any labels that you think are needed to make your ideas clear.
4. Make a sketch to show the particles that make up a mixture. Add any labels that you think are needed to make your ideas clear.

Understanding Key Ideas

5. When you first open a bottle of pop, the liquid is filled with tiny bubbles.
   (a) Is the pop homogeneous or heterogeneous? Explain your answer.
   (b) If you let the pop sit for a day, what happens? Is the liquid homogeneous or heterogeneous now? Explain your reasoning.
6. The photo below shows polluted air—smog. Smog is air that contains solid and gaseous pollutants. Is smog a heterogeneous or homogeneous mixture? Explain your answer.

Pause and Reflect

Think about your experiences so far in this chapter. At this time, do you think that most materials on Earth are homogeneous or heterogeneous? Explain why you think so.

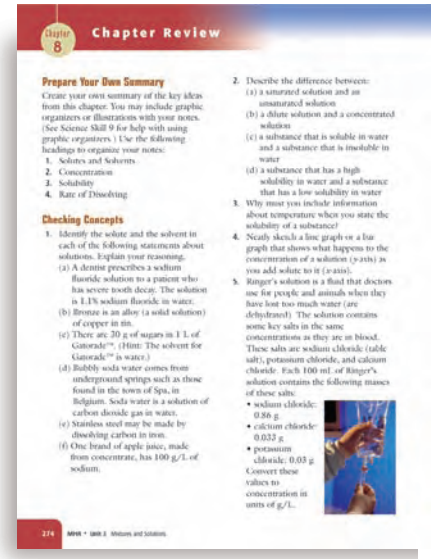
Chapter 7 Matter can be classified as mixtures or pure substances • MHR 241

Check Your Understanding

- These section review questions test your new knowledge.

Pause and Reflect

- These features help you stop and think about what you now know about the topics explained in the chapter. They also make connections among ideas throughout your book.

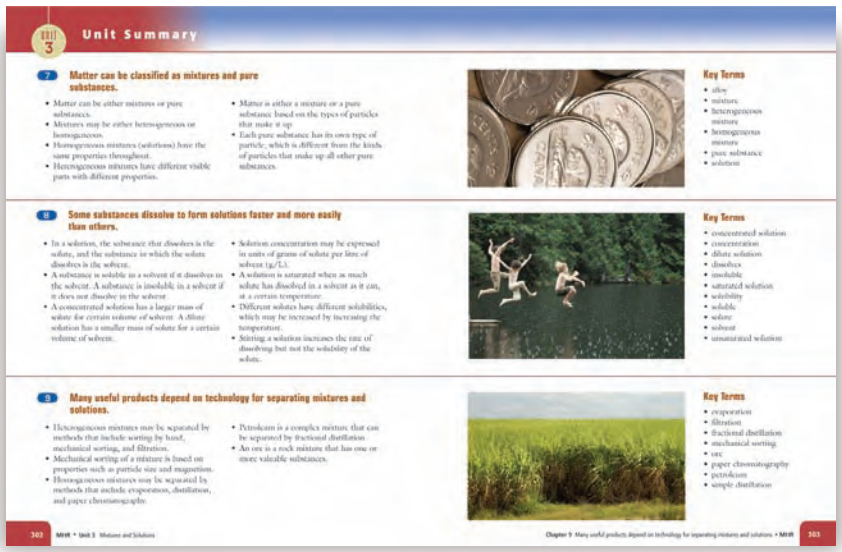


Chapter Review

- At the end of each chapter, these two pages can help you study for a chapter test.
- The guide under the heading "Prepare Your Own Summary" can help you summarize what you have learned in the chapter.
- The review questions help you recall, think about, and apply what you have learned.

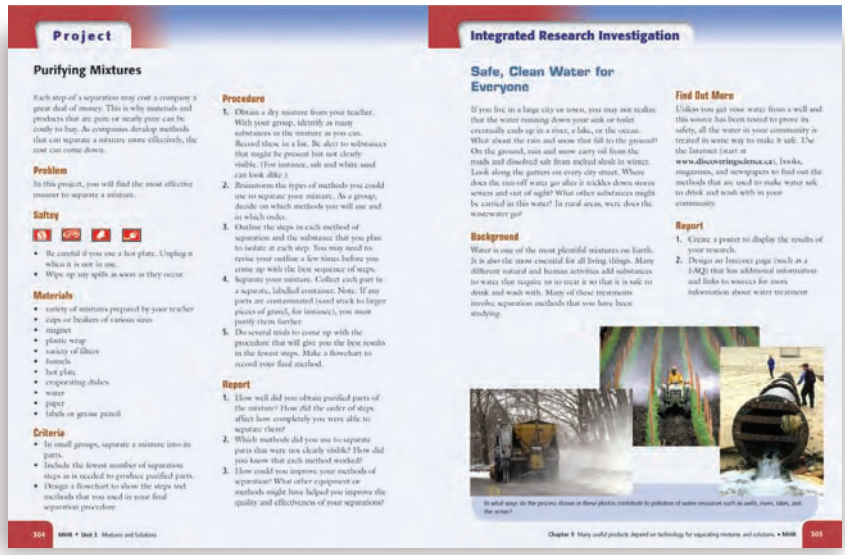
Unit Summary

- This is a summary of the Key Ideas and Key Terms covered in the unit.
- The photographs next to the Key Terms are from the chapter openers to remind you of what you covered in that chapter.



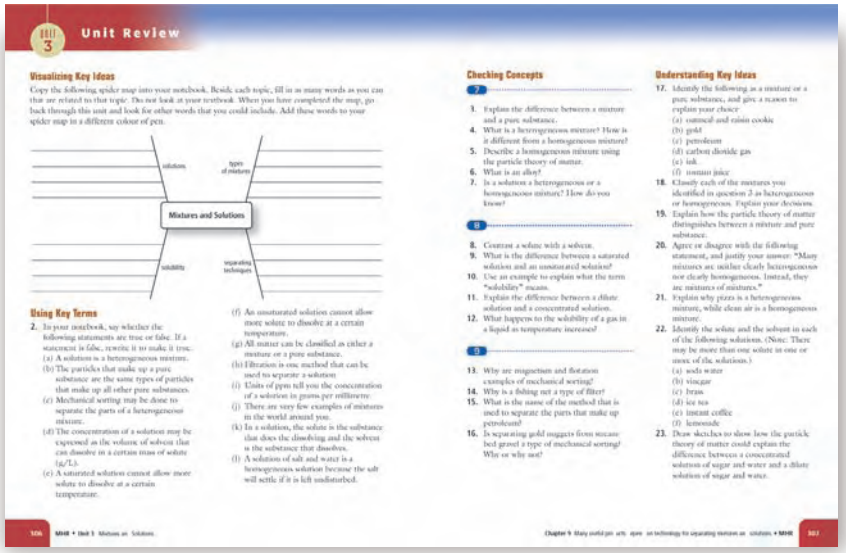
End-of-Unit Project and Integrated Research Investigation

- Each **Project** lets you apply key concepts and skills from the unit. You complete the Project as part of a team.
- For the **Integrated Research Investigation**, you explore a unit-related topic. You have an opportunity to use current information that you have researched to do a report or presentation about that topic.



Unit Review

- At the end of each unit, these pages can help you study for a unit test.
- The review questions help you recall, think about, and apply what you have learned.



Other Features

Word Connect

- The Word Connect margin feature gives you additional information on scientific terms.

Explore More

- You can "Explore More" by following the suggestions in these features to investigate further a topic you have studied.

internet connect

- These features help you research more information about a topic.
- The ***Discovering Science 7*** web site links you to other web sites related to the topic you are researching.

- The safety icons are extremely important. They alert you to any safety precautions you should take, such as wearing safety glasses or a lab coat. Other safety icons used in ***Discovering Science 7*** are shown on page xxi.

At the Back of Your Textbook

Science Skills Guide

- At the back of ***Discovering Science 7***, you will find the Science Skills appendix. It will help you review and develop the skills and knowledge that you need to be successful in this course.

Science Skills Guide

Glossary

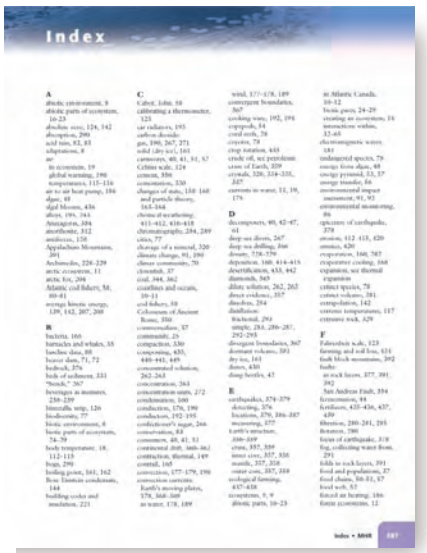
- Each boldfaced term in your textbook is defined in the Glossary at the back of the book.
- The Glossary is organized alphabetically.

Glossary

How to Use This Glossary

Index

- The Index at the back of the book helps you locate a particular topic in the book.
- The Index is organized alphabetically.


Index

Exploring Discovering Science 7

A Scavenger Hunt

Use your ***Discovering Science 7*** textbook to answer the following questions.

1. What is the web address for the textbook?
2. What four units will you study in ***Discovering Science 7***?
3. How many Key Ideas are there in ***Discovering Science 7***?
4. What is a Key Idea? How can the Key Ideas help you study?
5. Where can you find examples of the study tool called Foldables?
6. At the beginning of each section, there is a light brown shaded box containing text. What is the purpose of this shaded text?
7. Name four different margin features and describe what each one is about.
8. What is the purpose of the Reading Checks?
9. Activities have a green background. What are three different types of activities in this textbook?
10. What do the three w's stand for in "www science"?
11. If you needed information on how to make a graph, where would you look?
12. Where can you find the definitions for the bolded words in the text?
13. Before a unit test, what parts of the book could you use to review the concepts covered in the unit?
14. On a sheet of paper or in your notebook, sketch an outline of your classroom. Mark the location and types of safety equipment there. What pages in ***Discovering Science 7*** provide safety information?
15. Scan through ***Discovering Science 7*** to look for something you find interesting and did not know before you read it in this textbook.

Safety in Your Science Classroom

Become familiar with the following safety rules and procedures. It is up to you to use them and your teacher's instructions to make your activities and investigations in ***Discovering Science 7*** safe and enjoyable. Your teacher will give you specific information about any other special safety rules that need to be used in your school.

1. **Working with your teacher …**
   - Listen carefully to any instructions your teacher gives you.
   - Inform your teacher if you have any allergies, medical conditions, or other physical problems that could affect your work in the science classroom. Tell your teacher if you wear contact lenses or a hearing aid.
   - Obtain your teacher's approval before beginning any activity you have designed for yourself.
   - Know the location of the nearest fire exit, safety blanket, eyewash station, first-aid kit, and fire alarm.
   - Know the evacuation procedure for the science laboratory.

2. **Starting an activity or investigation …**
   - Before starting an activity or investigation, read all of it. If you do not understand how to do any step, ask your teacher for help.
   - Be sure you have checked the safety icons and have read and understood the safety precautions.
   - Begin an activity or investigation only after your teacher tells you to start.

3. **Wearing protective clothing …**
   - When you are directed to do so, wear protective clothing, such as a lab coat and safety glasses. Always wear protective clothing when you are using materials that could pose a safety problem, such as unidentified substances, or when you are heating anything.
   - Tie back long hair, and avoid wearing scarves, ties, or long necklaces.
   - Avoid wearing loose or baggy clothing in the science lab.
   - Shorts, short skirts, sandals, and open-toed shoes are not permitted in the science lab.

4. **Acting responsibly …**
   - Work carefully with a partner and make sure your work area is clear.
   - Handle equipment and materials carefully.
   - Make sure stools and chairs are resting securely on the floor.

- If other students are doing something that you consider dangerous, report it to your teacher.

5. **Handling edible substances …**
   - Do not chew gum, eat, or drink in your science classroom.
   - Do not taste any substances or draw any material into a tube with your mouth.
   - Treat all substances in the lab as potentially dangerous or poisonous.
   - This includes common household substances such as sugar and salt.

6. **Working in a science classroom …**
   - Make sure you understand all safety labels on school materials or those you bring from home. Familiarize yourself, as well, with the WHMIS symbols and the special safety symbols used in this book, found on page xxi.
   - When carrying equipment for an activity or investigation, hold it carefully. Carry only one object or container at a time.
   - Be aware of others during activities and investigations. Make room for students who may be carrying equipment to their work stations.

7. **Working with sharp objects …**
   - Always cut away from yourself and others when using a knife or razor blade.
   - Always keep the pointed end of scissors or any pointed object facing away from yourself and others if you have to walk with such objects.
   - If you notice sharp or jagged edges on any equipment, take special care with it and report it to your teacher.
   - Dispose of broken glass in the glass disposal container as directed by your teacher.

8. **Working with electrical equipment …**
   - Make sure your hands are dry when touching electrical cords, plugs, or sockets.
   - Pull the plug, not the cord, when unplugging electrical equipment.
   - Report damaged equipment or frayed cords to your teacher.
   - Place electrical cords where people will not trip over them.

9. **Working with heat …**
   - When heating an item, wear safety goggles and any other safety equipment that the text or your teacher advises.

- Always use heatproof containers.
- Point the open end of a container that is being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Be especially careful with a hot plate that looks as though it has cooled down.
- If you use a Bunsen burner, make sure you understand fully how to light and use it safely.
- If you do receive a burn, inform you teacher, and apply cold water to the burned area immediately.

10. Working with various chemicals …

- If any part of your body comes in contact with a iquid substance, wash the area immediately and thoroughly with water. If you come in contact with dry or powdered chemicals, brush off as much of the substance as possible and then wash thoroughly with water.
- Always handle substances carefully. If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes toward your nostrils.
- Hold containers away from your face when pouring liquids.

11. Working with living things …

- Wash your hands after handling living organisms.

On a field trip:

- Try not to disturb the area any more than is absolutely necessary.
- If you move something, do it carefully, and always replace it carefully.
- If you are asked to remove plant material, remove it gently, and take as little as possible.

In the classroom:

- Treat living creatures with respect.
- Make sure that living creatures receive humane treatment while they are in your care.
- If possible, return living creatures to their natural environment when your work is complete.

12. Cleaning up in the science classroom …

- Clean up any spills, according to you teacher's instructions.
- Clean equipment before you put it away.
- Wash your hands thoroughly after doing an activity or an investigation.
- Dispose of materials as directed by your teacher. Never discard materials in the sink unless your teacher requests it.

Safety

Safety Symbols

The following safety symbols are used to alert you to possible dangers. Be sure you understand each symbol used in an activity or investigation before you begin.

	Disposal Alert This symbol appears when care must be taken to dispose of materials properly.
	Thermal Safety This symbol appears as a reminder to use caution when handling hot objects.
	Sharp Object Safety This symbol appears when a danger of cuts or punctures caused by the use of sharp objects exists.
	Electrical Safety This symbol appears when care should be taken when using electrical equipment.
	Skin Protection Safety This symbol appears when use of caustic chemicals might irritate the skin or when contact with micro-organisms might transmit infection.
	Clothing Protection Safety A lab coat must be worn when this symbol appears.
	Fire Safety This symbol appears when care should be taken around open flames.
	Eye Safety This symbol appears when a danger to the eyes exists. Safety goggles must be worn when this symbol appears.

Instant Practice—Safety Symbols

Find four of the safety symbols in activities or investigations in this textbook. Record the page number and the title of the investigation or activity in which you found the symbol. What are the possible dangers in the activity or investigation you have identified that relate to each symbol?

WHMIS Symbols

Look carefully at the WHMIS (Workplace Hazardous Materials Information System) safety symbols shown here. The WHMIS symbols are used throughout Canada to identify dangerous materials used in all workplaces, including schools.

Make certain you understand what these symbols mean. When you see these symbols on containers in your classroom, at home, or in a workplace, use safety precautions.

 Compressed Gas	 Flammable and Combustible Material
 Oxidizing Material	 Corrosive Material
 Poisonous and Infectious Material Causing Immediate and Serious Toxic Effects	 Poisonous and Infectious Material Causing Other Toxic Effects
 Biohazardous Infectious Material	 Dangerously Reactive Material

Instant Practice—WHMIS

Find any two WHMIS symbols on containers in your school, or ask a parent or guardian to look for WHMIS symbols in a workplace. Record the name of the substance on which the symbols are used, and where you or your parent or guardian saw the containers stored. What dangers are associated with the substance in each container?

UNIT

1 Interactions Within Ecosystems

An osprey scoops up a fish to carry to its nest in a nearby tree.

Key Ideas

1 An ecosystem is all the living and non-living things in a particular place.

1.1 Types of Ecosystems
1.2 Abiotic Parts of an Ecosystem
1.3 Biotic Parts of an Ecosystem

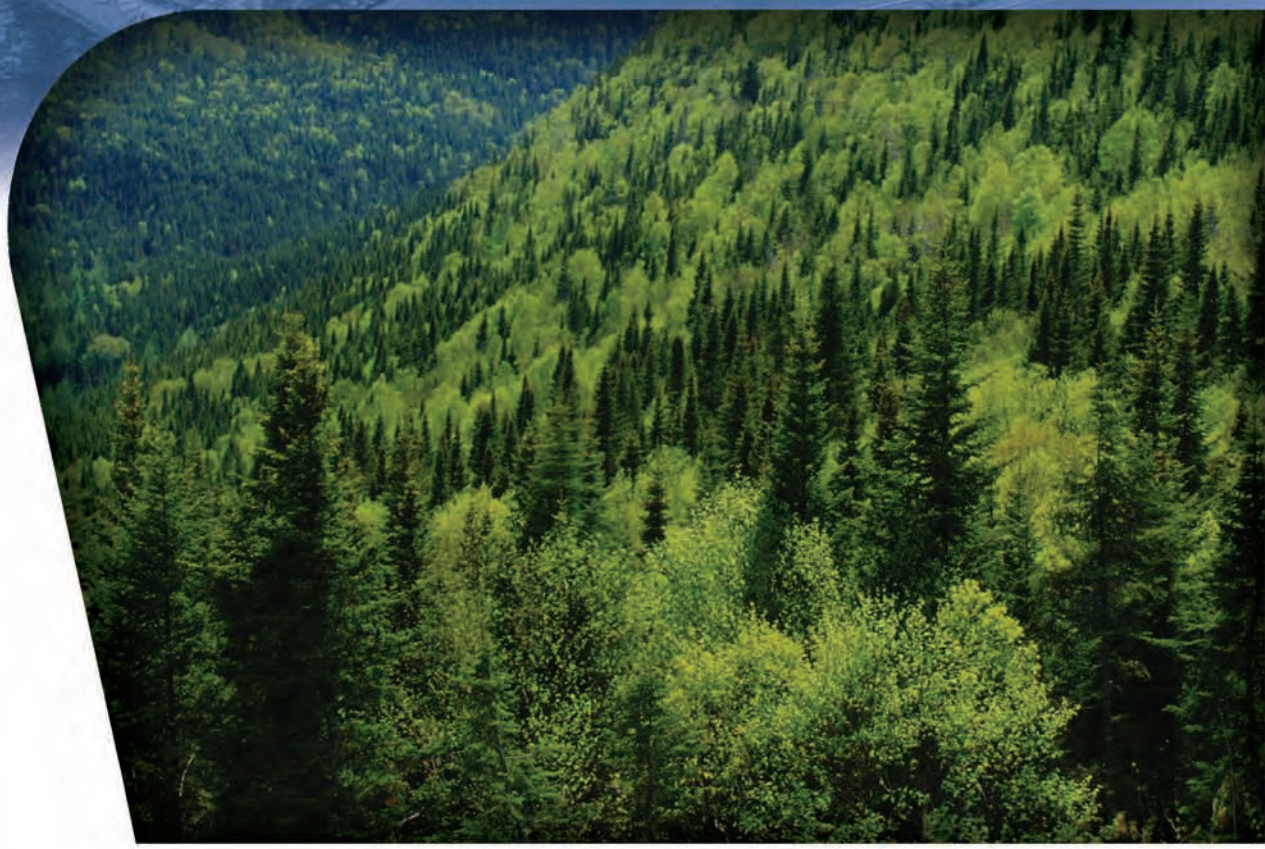
2 Living and non-living things interact in ecosystems.

2.1 Types of Interactions
2.2 Roles of Organisms in Ecosystems
2.3 Food Chains, Food Webs, and the Transfer of Energy
2.4 Cycles of Matter in Ecosystems

3 Natural events and human activities cause changes in ecosystems.

3.1 Natural Disturbances and Succession
3.2 The Impacts of People on Ecosystems
3.3 Monitoring and Managing Ecosystems

Getting Started



How would you describe this forest?

Word Connect

The word "ecology" comes from two ancient Greek words that mean home (*eco-*) and study (*-logia*). Ecology, therefore, is the study of our home, planet Earth.

Suppose you went into a forest like the one in the photograph, looking for animals. Where would you look? What would you expect to see? Apart from animals and trees, what other living things might make their home in a forest?

Now imagine you must describe the forest to a friend. As well as telling your friend about all the living things you observed, you might also say that the forest was dark and cold. Perhaps you noticed the soil underfoot. Maybe you saw a small stream or a pond in the forest. As you study the science of ecology in this unit, you will learn how different parts of the environment such as animals, plants, soil, and water all affect one another.

Natural occurrences such as forest fires, storms, or droughts cause changes in the ways that living things interact with each other and with their environment. Human activities can also cause changes, often in negative ways.

In many parts of the province, forests are being logged for timber. Some people are concerned about logging projects because of the potentially damaging impact on native organisms.

What effects might the removal of trees have on other plants and on animals living in the forest? How might logging affect the soil and streams?

Towns and farmland exist today in areas where forests once grew. What kinds of plants and animals live in towns and on farmland? What changes do you think might take place in a farmer's field if the farmer abandons it?

internet connect

Find out more about the effects of logging on organisms in Newfoundland and Labrador at **www.discoveringscience.ca.**

What Is an Ecosystem?

Find Out ACTIVITY

How is a forest like a lake? Forests and lakes are two examples of ecosystems. In this activity, you will think about a local area that you have observed. Using this knowledge, your class will build a list of terms that help describe ecosystems.

Materials

- large sheet of paper
- pen or pencil
- ruler

What to Do

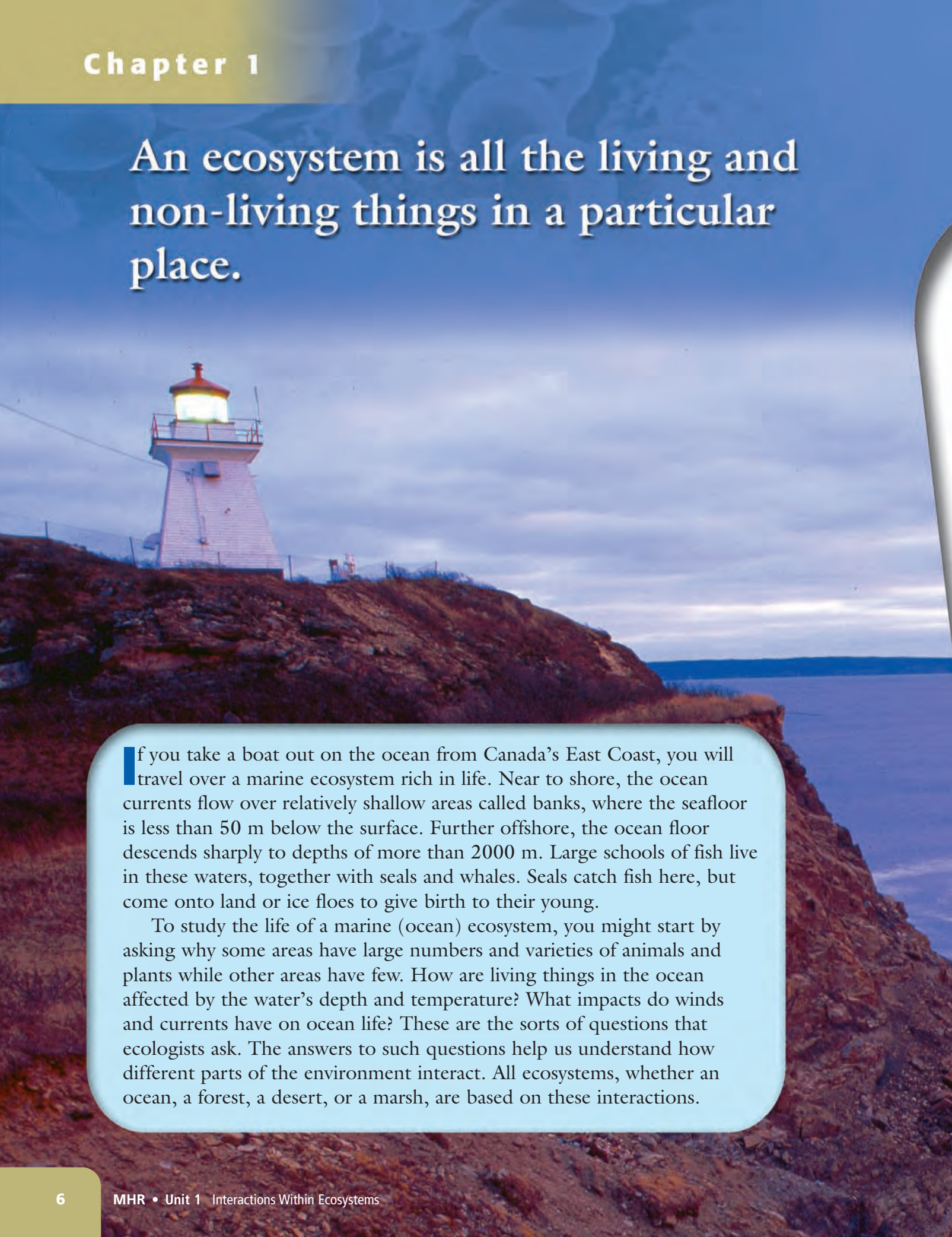
1. As a class, choose a local area to analyze. Write the name of the area at the top of your sheet of paper.
2. Divide the sheet of paper into two columns. Label one column "Living Things." Have a brainstorming session to make a list of all the living things you may have observed in the area, or that you think might live there. Write each suggestion in the column.
3. Label the second column "Local Conditions." Brainstorm a list of conditions found in the area. For example, is it wet or dry? Hilly or flat? Record each suggestion.

What Did You Find Out?

1. The prefix *eco-* means home. Based on this fact and the ideas you have shared with your class, write your own definition of the term *ecosystem.*
2. Could one of the living things on your list also live in a different ecosystem? Give an example. (**Hint:** For example, could a coniferous (evergreen) tree live in a prairie ecosystem? Could a prairie grass such as wheat grow in a forest ecosystem?)
3. Could one of the conditions on your list also be found in a different ecosystem? Give an example. (**Hint:** For example, would you expect to find damp conditions in an arctic ecosystem? Would you expect it to be chilly in a forest ecosystem?)
4. Name another ecosystem in which you would expect to find *none* of the living things on your list.

Chapter 1

An ecosystem is all the living and non-living things in a particular place.



If you take a boat out on the ocean from Canada's East Coast, you will travel over a marine ecosystem rich in life. Near to shore, the ocean currents flow over relatively shallow areas called banks, where the seafloor is less than 50 m below the surface. Further offshore, the ocean floor descends sharply to depths of more than 2000 m. Large schools of fish live in these waters, together with seals and whales. Seals catch fish here, but come onto land or ice floes to give birth to their young.

To study the life of a marine (ocean) ecosystem, you might start by asking why some areas have large numbers and varieties of animals and plants while other areas have few. How are living things in the ocean affected by the water's depth and temperature? What impacts do winds and currents have on ocean life? These are the sorts of questions that ecologists ask. The answers to such questions help us understand how different parts of the environment interact. All ecosystems, whether an ocean, a forest, a desert, or a marsh, are based on these interactions.

What You Will Learn

In this chapter, you will

- **identify** examples of local ecosystems
- **describe** the abiotic (non-living) and biotic (living) parts of an ecosystem
- **explain** how different parts of an ecosystem affect each other

Why It Is Important

Understanding ecosystems is a first step to solving problems in the environment, such as pollution and the decline in fish populations.

Skills You Will Use

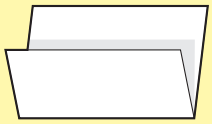
In this chapter, you will

- **record** information using instruments effectively and accurately
- **organize** and display data using tables and graphs
- **communicate** your ideas using scientific terms

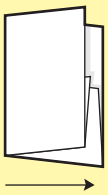
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 1.

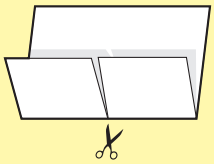
STEP 1 **Fold** an 8.5″ × 11″ sheet of paper as shown, so that about one third of its length is folded upwards. This should leave a tab 8-10 cm long exposed at the top of the sheet.



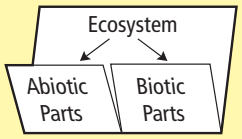
STEP 2 **Fold** the sheet in half width-wise.



STEP 3 **Unfold** the sheet and **cut** the bottom tab along the fold line as shown.



STEP 4 **Label** the Foldable as shown. **Draw** arrows from "Ecosystem" to "Abiotic Parts" and "Biotic Parts" to show the relationship between them.



Organize As you read this chapter, complete the Foldable by recording information, providing examples, and defining terms under the appropriate tabs.

1.1 Types of Ecosystems

All ecosystems include abiotic (non-living) and biotic (living) things. Ecosystems such as oceans and deserts may cover huge areas. Other ecosystems are quite small, such as a rock pool or a rotting log. Each ecosystem can be described by the types of organisms that live in it and by the conditions found there.

Key Terms

abiotic
adaptation
biotic
ecosystem
habitat
organism

During a walk in your local park you may observe robins, squirrels, maple trees, and grass. If you stop and look more closely, you may also notice spiders, ants, and moss. In a microscopic view of the soil, you could also observe bacteria, fungi, and tiny worm-like nematodes. All of these are examples of living things, or **organisms**.

You can find organisms in almost every environment on Earth, from the tops of mountains to the ocean floor, and from hot deserts to polar ice. Each type of organism has **adaptations**, which are inherited characteristics that help it survive in its environment. For example, the webbed feet of a duck are adaptations for swimming.

The particular place where an organism lives is its **habitat**. A habitat includes all of the things that the organism needs, such as suitable food, a source of water, and shelter. For example, an earthworm's habitat is the soil. A turtle's habitat is a pond or lake. The habitat of a toadstool is a rotting log.

Figure 1.1 This green frog's habitat includes abiotic and biotic parts.

Abiotic and Biotic Parts of the Environment

The green frog in Figure 1.1 takes a break from swimming in the water and rests near the shoreline of a pond. Water, rocks, sunlight, and air are all examples of non-living or **abiotic** parts of the frog's environment.

Frogs hunt for beetles, spiders, and worms. A young frog may in turn be hunted and eaten by a heron. All of these animals are examples of the living or **biotic** parts of the frog's environment. The biotic environment also includes plants, fungi, and micro-organisms. You will study some of the ways in which abiotic and biotic parts of the environment interact in more detail in the next chapter.

Studying Ecosystems

From the title of this chapter, you already know that an **ecosystem** consists of all the abiotic and biotic things in a particular place. You also know that different places have different types of organisms and different conditions. For example, a lake ecosystem includes frogs and fresh water, while a marine ecosystem includes cod and salt water. You would not expect to find frogs in the sea or cod in a lake. You can see some examples of ecosystems in Atlantic Canada on the following pages.

As well as having different types of organisms and conditions, ecosystems also vary in size. For example, a forest ecosystem can cover many hundreds of square kilometres. Within this forest there may be a river ecosystem where trout and water plants live. Beetles and toadstools are part of an even smaller ecosystem that exists only in a rotting tree trunk on the forest floor (Figure 1.2).

Figure 1.2 Not all ecosystems are large. For example, this rotting tree is an ecosystem. It is home to many organisms that are adapted to get the food and shelter they need from a rotting tree.

Maybe you have turned over a rotting log and have seen some of the small organisms that were living under it scurrying for cover. These organisms normally live in cool, dark, damp conditions. By moving the log, you have exposed them to sunlight and wind. These conditions can cause drying out of the organisms. If they cannot move back to a suitable habitat, these organisms may die. In a similar way, if people drain a bog or cut down part of a forest, they will change the conditions and alter the interactions in the ecosystem.

Reading Check

1. What is the difference between the abiotic and biotic parts of your environment?
2. What one word describes all of the following: ant, frog, mushroom, and black spruce?
3. Complete this sentence: Inherited characteristics that help an organism survive in its environment are called _____.
4. Give an example of a change in conditions that could affect an ecosystem.

1-1A What Do Living Things Need for Survival?

Think About It

A cod, an owl, and a fiddlehead fern are three very different organisms, but they all have similar basic needs from their environment. In this activity, you will develop a list of the things that organisms need to survive.

What to Do

1. Work with a partner or in a small group. Brainstorm all the things that you think every living thing requires in order to survive. Record your ideas as a list on a sheet of paper.
2. When you have finished, half of your group will join half of another group to exchange ideas. You will explain your own list of ideas to the classmates who join your group.
3. Re-join your first group. Decide if you want to add, change, or remove items from your list.
4. As a class, produce a chart that lists the needs of living things.

What Did You Find Out?

1. As a class, discuss the list you have generated. Are there any organisms that can survive without some of the items on your list? If so, give examples.
2. Using your list, suggest a change in the environment that might affect the survival of a particular organism. Name the organism, and then describe the change and its effect on the organism.

Ecosystems in Atlantic Canada

Common examples of ecosystems in Atlantic Canada include coastlines and oceans, freshwater ecosystems (rivers, lakes, and ponds), the Arctic, and forests. You will be introduced to each of these ecosystems below.

Figure 1.3 Cold, salty winds from the ocean affect the shape and growth rate of these trees growing near the coast. These clumps of weather-beaten conifers, such as spruce, fir, pine, and larch, are locally known as "tuckamore."

Coastlines and Oceans

A challenging habitat exists where the Atlantic Ocean meets the land. These long stretches of rocky coastline are sometimes covered by water, yet are exposed to air as the tides move out. Among the organisms you can find here are large brown seaweeds and numerous small animals such as barnacles, mussels, starfish, and rock crabs. All of these organisms are able to attach themselves to the solid rock surfaces to avoid being washed away by the sea.

internet connect

You can learn more about ecosystems in Newfoundland and Labrador from the Internet. Start your search at **www.discoveringscience.ca.**

A cold ocean current, called the Labrador Current, flows southward along the east coast of Canada. This current affects the local climate, bringing cool summers and fogs to the region along the coast. Figure 1.3 shows how strong winds from the ocean can affect vegetation growing near the coastline.

Organisms living in the ocean must be adapted to cold temperatures, moving currents, and the salt content, or salinity of the seawater. Larger animals such as cod, seals, and whales swim through the water, while many small organisms such as jellyfish, microscopic plants, and the eggs and young stages of some animals simply drift with the flow of water. The maximum depth to which sunlight penetrates water is between 100 and 200 m, depending on the clarity of the water. Below this depth, it is pitch dark and marine plants cannot survive. On the other hand, some types of bacteria and animals are adapted to live and thrive in these hostile conditions.

Figure 1.4 Freshwater lakes, such as Western Brook Pond in Gros Morne National Park, form where the underlying rock and shape of the land prevent water from quickly draining away.

Freshwater Ecosystems: Rivers, Lakes, and Ponds

Rain and snow supply water to freshwater ecosystems such as rivers, lakes, and ponds (Figure 1.4). Have you ever noticed how some places become very muddy and full of puddles after a heavy rain, while other areas dry out quickly? The difference depends on the type of soil and rock under the surface of the ground. The amount of water that is stored in the soil in turn affects the growth of plants. For example, willows and tamarack generally grow only where drainage is poor and there is plenty of water in the ground.

Freshwater ecosystems include habitats for many types of fish such as lake whitefish and sticklebacks, as well as for other animals such as beavers, muskrats, ducks, and geese. Frogs, insects, snails, and other small animals make their homes in the water, together with various species of water plants.

Did You Know?

Lakes occupy more than 8 percent of the land area of Newfoundland and Labrador. This is slightly greater than the overall average for Canada.

Arctic

The northernmost tip of Labrador has an arctic ecosystem (Figure 1.5). This region has very low temperatures and little precipitation, making it a cold desert. In winter, the nights are long and the days are short. A metre below the surface of the ground, the soil is permanently frozen and is called permafrost. There is not enough moisture to support trees. Plant growth includes low shrubs, mosses, lichens, and small flowering plants. Animals found here include caribou, musk ox, wolves, arctic foxes, arctic hares, and lemmings. Many birds fly north to this ecosystem in spring to lay their eggs and rear their young. In the fall, they return south because they cannot survive the arctic winter.

Figure 1.5 This arctic ecosystem has shallow ponds in summer but the ground is frozen a metre below the surface.

Figure 1.6 A thick layer of peat, the dark band under the surface soil, has been exposed by this road cut in Terra Nova National Park, Newfoundland and Labrador.

Suggested Activities

Find Out Activity 1-1B on page 13
Find Out Activity 1-1C on page 14

Connection

Section 1.2 has more information on the characteristics of soil.

Forests

Forest ecosystems cover much of the province of Newfoundland and Labrador, except where poor soils and exposed conditions are not suitable for trees to grow. Summers in these areas are cool and winters are wet. Common forest trees include balsam fir, white birch, black spruce, and mountain ash. Animals living in these forests include moose, caribou, black bear, lynx, red fox, pine marten, and mink.

Poorly drained areas in shallow hollows sometimes develop into bogs and marshes. In these habitats, dead plant material decays very slowly, as it is often covered by water. The build-up of dead plant matter sometimes produces peat (Figure 1.6). Heavy precipitation in the southern Avalon Peninsula of Newfoundland has created extensive wetlands called blanket bogs.

Reading Check

1. "Ocean," "forest," and "arctic" are all examples of what?
2. List four abiotic factors that affect the survival of organisms in an ocean ecosystem.
3. Why is the arctic ecosystem a cold desert?
4. What conditions produce peat?

1-1B Scrutinizing Soil

Find Out ACTIVITY

In this activity, you will observe and analyze a sample of soil.

Question

What are the abiotic parts and the biotic parts of a soil ecosystem?

Safety

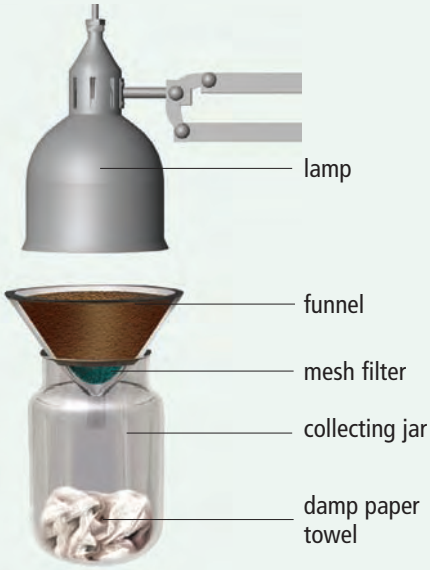
- Do not handle any organisms with bare hands.
- Return all organisms to the place where you found them.
- Handle the glass jar with care.
- Handle the scissors carefully.
- Keep electrical connections for the lamp away from water or moisture.

Materials

- large wide-mouthed jar
- large plastic funnel
- desk lamp with flexible arm
- pie plate
- hand lens and/or dissecting microscope
- scissors
- 2 damp paper towels
- fine-mesh plastic pot scrubber
- garden soil or leaf litter
- paper towel
- paper for drawing

What to Do

1. Place a damp paper towel in the bottom of the jar. Place the funnel in the mouth of the jar.
2. Cut a small square (3 cm by 3 cm) of mesh screen from the pot scrubber. Place this screen over the opening in the neck of the funnel.



3. Fill the funnel with garden soil or leaf litter.
4. Place the lamp over the funnel and turn it on. Turn out all the other lights in the room and leave the lamp on overnight.
5. The next day, remove the funnel from the jar. Empty the contents of the jar onto a damp paper towel in the pie plate. If the contents include small animals that can move quickly, cover the pie plate with clear plastic wrap to prevent them from escaping.
6. Observe the organisms using a hand lens, or a microscope if available. Sketch at least one organism.
7. Observe a small sample of soil from the funnel. Describe the appearance of the soil.
8. When you have completed your investigation, ensure that the soil organisms are returned to the place where they were collected.

What Did You Find Out?

1. Why do you think organisms moved from the soil into the jar?
2. What characteristics of the soil might be important to the organisms living there?

1-1C Creating an Ecosystem

Find Out ACTIVITY

You have been learning about ecosystems and about their biotic and abiotic parts. Although you can observe ecosystems all around you, you can learn a great deal more if you focus on one ecosystem over time and examine it in detail.

Question

What components are necessary to create a successful model ecosystem in the classroom?

Safety

- Do not handle any organisms with bare hands.
- Handle the glass bowl with care so that it does not break.

Materials

- water
- gravel or small rocks
- twigs
- seeds and/or small plants
- potting soil
- clear glass or plastic bowl

Design Criteria

A. Your model ecosystem should contain at least four different plants.

B. Add at least one abiotic element in addition to the essential ones with which the biotic elements can interact.

What to Do

1. With your group, decide what type of ecosystem you will be creating. Conduct research to find out which biotic and abiotic features are usually found in this type of ecosystem. Plan how you will construct your model.

(a) What kinds of seeds and plants will you use? Why? Do they normally grow near each other in nature?

(b) What do the plants in your ecosystem need to stay alive? Must you add anything to your ecosystem over time, such as water?

(c) What location in your classroom will you choose for your ecosystem? Why? What might be the effect of choosing this location over another one?

2. Prepare a labelled sketch of your model. Write a hypothesis about what will happen in your ecosystem. After obtaining your teacher's approval, build your model.

3. Observe your model over an agreed-on period of time. Take careful notes on a regular basis. If you discover problems, try to solve them.

4. As you study your model, write any questions that occur to you about the interactions that are taking place. You might be able to find the answers in the next investigation.

What Did You Find Out?

1. (a) Did your model succeed as you had planned in step 1? Why or why not?

(b) Did you experience any problems? If so, were you able to resolve them? How?

2. Compare your model with other groups.

(a) Which model worked best?

(b) Which model had the most problems? Why?

(c) How might you improve your model if you designed it again?

Checking Concepts

1. List two examples of abiotic parts of a forest ecosystem and two examples of biotic parts of a forest ecosystem.
2. What abiotic factors might affect a dandelion growing in a lawn? Explain why you think so.
3. What biotic factors might affect a dandelion growing in a lawn? Explain.
4. (a) Name two abiotic parts of your environment that you have interacted with today.
   (b) Describe two interactions that you have had with these abiotic parts.
5. (a) Name two biotic parts of your environment that you have interacted with today.
   (b) Describe two interactions that you have had with these biotic parts.
6. Describe the habitat of
   (a) a grasshopper
   (b) a seaweed.
7. Choose an animal that lives in one of the ecosystems in your province, and describe how it is adapted to live there.
8. (a) In what kind of ecosystem would you expect to find the habitat of a beaver?
   (b) Identify three biotic parts of its ecosystem that would be important for a beaver.
   (c) Identify three abiotic parts of its ecosystem that would be important for a beaver.

Understanding Key Ideas

9. "Ecosystems extend over many kilometres." Explain why you agree or disagree with this statement, using examples.
10. Imagine that you are a polar bear. What are some of the ways in which you meet your needs for survival in your habitat?
11. Dandelion seeds form "puffballs" that are spread by the wind. How are these seeds adapted to the dandelion's typical habitat?

Pause and Reflect

Many school labs use an aquarium as a model for learning about ecosystems. Suggest three things that you think you could learn about ecosystems by observing an aquarium that has both plants and animals living in it.

1.2 Abiotic Parts of an Ecosystem

Abiotic parts of an environment include such things as temperature, light, air, water, soil, and climate. Each type of organism is adapted to a particular set of abiotic conditions. Organisms can only survive within a certain range of conditions.

Key Terms

range of tolerance

Why does the right plant in Figure 1.7 look so much more healthy than the left plant? You probably know that a plant needs particular conditions to survive and to stay healthy. Too much sunlight, and its leaves may burn. Too little light, and the leaves may turn yellow. Too much water, and the roots may rot. Too little water, and the plant may droop and wilt. Some plants need acidic soils, while others do not.

Figure 1.7 The potted plant on the left is drooping because it has received too little water.

Different plants are adapted to different abiotic conditions. For example, most ferns grow best where it is cool, shady, and humid. Cacti grow best where it is warm, bright, and dry. Suppose it is a sunny day with a light breeze and you move a potted fern from indoors to outside. Later in the day you notice that the fern is drooping and the edges of its leaves are curled and brown. By moving the fern, you have placed it in a different

set of abiotic conditions. The thin leaves of the fern quickly lose moisture from the effects of the sun and wind. If it is left outside for too long without regular watering, the fern may die.

Range of Tolerance

Palm trees grow in the tropics but not in the Arctic. Dwarf willows grow in the Arctic but not in the tropics. Like all organisms, these plants are adapted to the abiotic conditions of their particular environments. Each plant can only tolerate a certain range of abiotic conditions. For example, a plant may die if the temperature falls below 0°C or goes above 40°C. The range of conditions within which an organism can survive is called the organism's **range of tolerance.**

An organism may have a wide range of tolerance for one abiotic condition, such as temperature, but a narrow range of tolerance for another condition, such as how acidic the soil is. Each type of organism has a different range of tolerance for each factor. Taken together, these ranges determine where different organisms can live.

You can see the dramatic influence of abiotic conditions on plant growth in Figure 1.8. As you climb up a mountain, conditions change with altitude (height above sea level). Higher altitudes are significantly colder and drier than lower altitudes. The altitude at which tree growth becomes impossible is called the treeline. This marks the limit of the trees' range of tolerance.

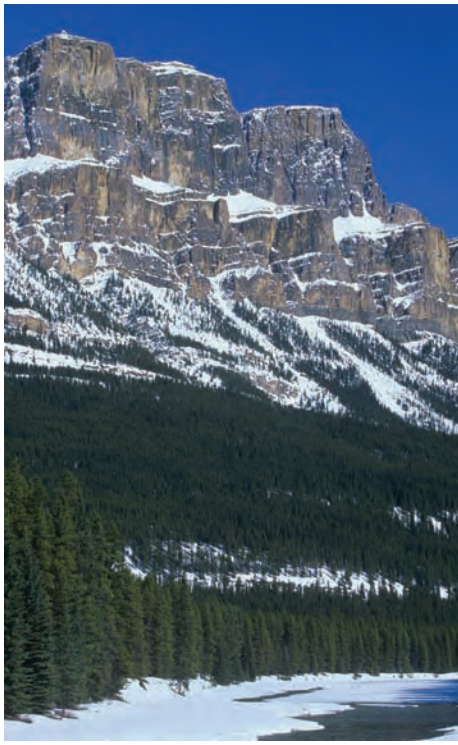


Figure 1.8 The treeline on this mountainside shows where conditions become unsuitable for tree growth.

Reading Check

1. What is a treeline?
2. Complete this sentence: For a tropical fish, a water temperature of 1°C is outside its _____ .

Abiotic Influences

What abiotic conditions are most important in your local ecosystems? How does each condition influence the organisms living there? The notes on the following pages give some examples of the roles of abiotic conditions in ecosystems.

Suggested Activitiy

Conduct an Investigation 1-2A on page 20

Light and Light Intensity

All plants and algae (plant-like organisms) need light to survive. They depend on light energy to produce their food by the process of photosynthesis. Without light, plants and algae cannot survive; they will starve.

Figure 1.9 Worms spend most of their life in dark conditions underground. What adaptations do they have for this habitat?

The amount of light that is available in an area limits the types of plants that can grow there. For instance, seaweeds and some types of water plants can grow at and near the surface of a lake or an ocean. However, the intensity (strength) of the light that can penetrate through water decreases as you go deeper below the surface. Water that is 200 m or more below the surface is completely dark. This is well beyond the range of tolerance of any plants. Deep caves and the deep waters of oceans and lakes are examples of environments that have no light, and therefore, no plants.

Unlike plants, many animals thrive in dark conditions, such as those living in caves, deep water, and in the soil (Figure 1.9). Others sleep in shelters during the day and only emerge at night. They have adaptations that help them remain active in low-light conditions, such as having keen senses of touch, hearing, or smell.

Changes in day length can affect both plants and animals. For example, the reduced number of daylight hours in the fall triggers some trees to shed their leaves and some animals to migrate south.

Figure 1.10 Organisms such as this northern alligator lizard need warm conditions to remain active.

Temperature

The northern alligator lizard in Figure 1.10 is using the sun's energy to raise its body temperature and allow it to become active. Many reptiles, amphibians, fish, and insects depend on sunlight for warmth. The rate of growth and reproduction of many micro-organisms, such as bacteria, also depends on temperature. Fruits such as strawberries only ripen when it is warm and will not develop in cold temperatures.

Soil

The biotic parts of soil consist of fragments of dead plants and animals as well as the solids and the liquids they excrete. This organic material decomposes and provides a source of nutrients to plants growing in the soil. The abiotic parts of soil consist of small particles of rock materials and pockets of air and water. Animals that live in soil, such as ants and earthworms, create small tunnels that allow air and water to move through the soil more easily. Plants anchor themselves in the soil with their roots. Plant roots help prevent soil from being blown away by wind or washed away by water.

Air and Wind

Animals and plants use oxygen from the air for respiration. Plants use carbon dioxide from the air for photosynthesis. Deprived of air, these organisms would die.

Birds, insects, and bats fly through the air, and many plants use the wind to disperse their seeds. In areas that have frequent strong winds, such as along the coast, plants are adapted to bend and not break in the wind. Windy areas also tend to be dry, as the wind evaporates moisture. Plants that grow along the coast must be able to withstand these dry conditions. They also must be able to tolerate salt from the salty spray that blows from the ocean across the coast. Plant-like lichens, for instance, are highly tolerant of salt and are often found growing on coastal rocks. In Figure 1.3 on page 10, you saw another example of how the cold, salty winds affect plant growth. Tuckamore grows in such low, tangled masses that it is difficult even for large animals such as moose and humans to move through it. Some small songbirds, on the other hand, can find food and nesting areas in the dense growth.

Explore More

The weather-beaten *tuckamore* of the Atlantic coast are found in other parts of Newfoundland and Labrador, as well as in other parts of the world. Where else can you find tuckamore? What is it called elsewhere, and why is this name fitting? Start your research at **www.discoveringscience.ca**

Water

All organisms require water, but some are adapted to spend long periods in dry conditions. Many organisms are adapted to live in water. Others, such as ospreys, hunt for food in water.

Water conserves heat and modifies the climate on the land nearby. While the cold Labrador current has a cooling effect on the air temperature, the warmer Gulf Stream current radiates heat and warms the air. When water freezes, the ice that it forms provides hunting grounds for polar bears (Figure 1.11) and breeding grounds for seals.

Figure 1.11 Polar bears travel over sea ice to hunt seals.

Reading Check

1. Light, temperature, and water are all examples of what?
2. List three abiotic parts of soil.

1-2A Field Trip to the Schoolyard

Core Lab

Skill Check

- Observing
- Predicting
- Measuring
- Working co-operatively

You can find living things almost anywhere if you look carefully. Even if your schoolyard is mostly paved over, there is a good chance there will be dandelions and grass growing somewhere. Almost certainly there will be birds, insects, and small organisms living in the soil. The abiotic parts of the ecosystem affect each of these organisms.

Question

What abiotic and biotic factors can you observe and measure in your schoolyard ecosystem?

Safety

- Do not handle any organisms with bare hands.
- Handle the magnifying glass and thermometer carefully so they do not break.
- If you disturb the habitat, be sure to return it to its original condition.
- Do not harm organisms in your study site.

Materials

- notebook
- drawing paper
- pen or pencil
- magnifying glass

- binoculars
- camera
- thermometer
- light meter
- wind-speed recorder
- field guides

Procedure

1. Choose an area of your schoolyard suitable for study, where you can observe some living plants and animals.
2. Brainstorm possible questions to investigate when studying the schoolyard ecosystem. For example, make a list of organisms you predict you might observe. How might the amount of sunlight affect the types of plants growing there? How might soil conditions affect animals such as earthworms?
3. In groups, decide how you will make and record your observations.
4. Prepare tables in your notebook to record the measurements you will take.
5. When you arrive at your study site, sit quietly and observe it. Record the general abiotic conditions and list any organisms you see. Note any signs of organisms such as spider webs, burrows, feathers, or seeds.
6. Walk slowly around your study site and record all of the organisms that you encounter. Use field guides to help you identify them if you have time. You may sketch or photograph organisms for later identification.

   NOTE: Do not pick or break plants or damage flowerbeds. If you turn over a rock or log to see what is underneath, replace it afterwards.
7. Record and measure some of the abiotic conditions where each organism is found. For example, what is the temperature of the air or soil? Is the location exposed to light or is it shaded? Is the area damp or dry? Is the soil sandy or clay-like?

Analyze

1. Make a list of all the organisms recorded by your class. Compare it with the list of organisms you predicted might be present.
2. Briefly describe how the abiotic conditions you recorded might affect one type of (a) animal and (b) plant.

Conclude and Apply

1. Explain why you might get different results if you conducted your study during the summer holiday.
2. Name an animal or plant that you know lives in your province but does not live in your schoolyard ecosystem. Explain why it does not live there.
3. Suggest some ways in which your schoolyard ecosystem might change if a pond was added to it.

1-2B Salty Seeds Core Lab

Find Out ACTIVITY

Consider a plant living by the coast. Cold winds blow salt spray onto the land where it is growing. It must be adapted to survive the cold, the wind, and the salt. Plants that cannot tolerate these conditions will not survive in this habitat. In this activity, you will make observations and measurements of how well one species of plant (a bean plant) tolerates one of these abiotic conditions (salt water).

What You Need

- 2 plastic drinking cups (or similar containers)
- 30 mL salt
- water
- stir stick
- 10 bean seeds
- 2 paper towels
- 2 plastic self-sealing bags
- masking tape
- marker

What to Do

1. Add water to the cups until each cup is half full.
2. Add the salt to one cup and stir. Label the cup "salt water." Label the other cup "fresh water."
3. Place 5 bean seeds in each cup. Leave the seeds to soak overnight.
4. Wrap each set of 5 bean seeds in moist paper towel. Place the towels and seeds in separate self-sealing bags. Label one bag "fresh water" and the other "salt water."
5. After two days, count the number of seeds in each bag that show signs of root growth (sprouting). Record these numbers.

What Did You Find Out?

1. How did the amount of sprouting differ for the seeds kept in fresh water compared to the seeds kept in salt water? Describe any differences you observed in the appearance of the seeds from these two groups.
2. What abiotic factor was studied in this activity?
3. What variables were controlled (kept the same) for the two groups of seeds?
4. What variable was changed (manipulated)?
5. Predict whether seeds from another species of plant would respond to salt in the same way as bean seeds. How could you find out?

Checking Concepts

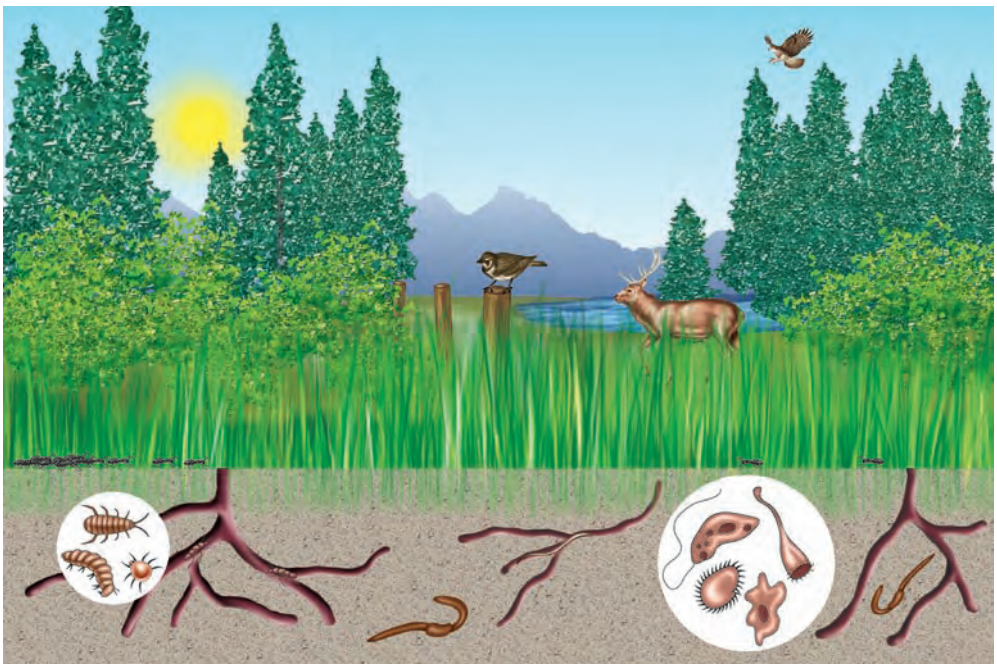
1. All mammals, as well as birds, maintain a constant internal body temperature. This temperature stays the same even when the outside air temperature gets higher or lower. How does the outside air temperature affect the internal body temperature of a reptile such as the northern alligator lizard?
2. How is a dandelion adapted to windy conditions?
3. Name two abiotic conditions found in soil.
4. Describe an interaction between any one of the organisms shown in the diagram below and one abiotic part of its ecosystem.
5. Name one abiotic factor that is important for the survival of tropical fish in an aquarium.
6. Using the term "range of tolerance," explain why swallows fly south from Newfoundland and Labrador during the winter.

Understanding Key Ideas

7. Explain why levels of sunlight may vary in different parts of a forest ecosystem.
8. Why are there no plants growing at the bottom of a deep lake?
9. Roses grow best in sunny conditions. What effect might it have on your roses if your neighbour builds a tall fence next to your rose garden?
10. You learned on page 17 why there is a treeline on the side of a mountain. Where else might you find a treeline? Explain.

Pause and Reflect

Choose an organism that you know something about. What might happen to this organism if a permanent change occurs in the environment to which it is adapted?



1.3 Biotic Parts of an Ecosystem

Ecosystems include many different species of organisms. Individual members of the same species living together in the same area at the same time form a population. Populations of different species interact in communities.

Key Terms

community
individual
niche
population
species

Figure 1.12 How would you begin to study this pond ecosystem?

Suppose you live near a pond and you want to study the pond ecosystem. You approach the pond quietly one summer morning and look around. You notice a dragonfly dart overhead, mosquitoes buzz nearby, and pondskaters skitter over the water surface. There are a few ducks on the pond, and some small birds chirping in the reeds. A splash and some ripples tell you there are fish in the water, and you notice waterweeds growing around the muddy edge of the pond. How can you begin to study all these things?

To tackle the biotic parts of the ecosystem—or, in other words, the organisms—consider ways to organize your observations. First, you may want to list all the different kinds or **species** of organisms that live in or near the pond. A species is a group of organisms that can reproduce among themselves to produce offspring of the same type that can also reproduce successfully. For instance, a mosquito can mate with another mosquito but not with a dragonfly. Mosquitoes and dragonflies are two different species of insects.

Levels of Organization

Wherever you encounter one mosquito, you are soon likely to encounter more mosquitoes. Each mosquito is an **individual** member of its species. A biologist may want to study an individual mosquito in more detail, but ecologists usually want to study the entire group of individuals of the same species that live together in one ecosystem at the same time. Such a group is called a **population.** For example, your pond may have a population of hundreds or thousands of mosquitoes and a population of seven or eight ducks.

Populations can vary in size depending on the time of year, the weather, and the abundance of food. For example, the population of ducks on the pond will increase in the spring when the ducks lay their eggs and raise their young.

The populations of mosquitoes, ducks, dragonflies, fish, waterweeds, and other species living in and around the pond interact with each other. For example, the ducks eat waterweeds, while mosquitoes may feed on the ducks. These interacting populations form a **community** of organisms.

The biotic parts of a community, together with the abiotic parts of the environment that affect the community, form an ecosystem. Figure 1.13 summarizes the different levels into which you can organize an ecosystem when you begin to study it.

internet connect

The cat-like Newfoundland marten is one of the most endangered animals in the world. The total population numbers about 300 individuals, all of which live on the island of Newfoundland. Find out more about this animal and its habitat. Start your search at **www.discoveringscience.ca.**

Figure 1.13 Organisms may be studied at different levels of organization in an ecosystem. What other populations might share this ecosystem with a population of caribou?

Niches

Within a community, each species uses the resources of the ecosystem in a slightly different way. For example, in the pond ecosystem shown in Figure 1.12, the ducks eat waterweeds and mosquitoe larvae while the kingfishers eat fish. Dragonflies catch insects while mosquitoes feed on blood. Some water plants float on the surface of the pond while other species of water plants are rooted in the mud on the bottom of the pond.

Like the firefighters and the teachers that live in your community, different species have different "jobs" or roles in their community. The role of a species includes where it lives, how it obtains its food, and how it affects its environment. These roles make up the ecological **niche** of a species.

Reading Check

1. What is a species?
2. Name three levels of biological organization that can be studied in an ecosystem.
3. What do interacting populations of organisms form?

1-3A Seabirds!

Think About It

Along the coast you can observe large numbers of big, whitish seabirds such as those shown below. Many people call all these birds "gulls." They appear similar at first glance, but usually large flocks include several different species. Each species has a different niche. To study details of the coastal ecosystem, such as changes in population size or food supply, you must be able to identify the species found there. In this activity you will classify each species of bird using a key to identification.

What to Do

1. The drawing shows five species of gulls, two species of jaegers, and one species of tern. Study it carefully and then identify each bird using the key below.
2. When you have finished, confirm your identifications and learn more about each species by using field guides, photographs, and the Internet.

Identification Key for Atlantic Sea Birds

To use the key, start at number 1 and choose A or B, whichever best describes the sea bird you are trying to identify. Proceed to the next number as indicated until you reach the bird's name.

Appearance of bird.	Go to
1. A. Has brown head and neck with black cap. B. Does not have brown head and neck.	2. 3.
2. A. Bill is quite thick; body colour medium brown. B. Bill is not particularly thick; body colour dark brown.	Pomarine Jaeger Parasitic Jaeger
3. A. Slender bird with long narrow wings, forked tail, black cap, and pointed bill. B. Sturdy and robust bird with white head.	Common Tern 4.
4. A. White wing tips. B. Larger bird with darker wings.	Iceland Gull 5.
5. A. Black across back and wings. B. White or grey across back.	Great Black-backed Gull 6.
6. A. Black ring around yellow bill. B. Bill solid yellow or orange.	Ring-billed Gull 7.
7. A. Solid black wing tips. B. White spots in black of wing tips.	Black-legged Kittiwake Herring Gull

What Did You Find Out?

1. Name three things that helped you distinguish one species of seabird from another.
2. Where could you find out more information about gulls and other seabirds? Name three other sources of information.

Wild, Weird, Wonderful

www Science

Coldwater Coral Reefs

When you hear the words "coral reef" you probably think of warm tropical seas. Canada has its own coral reefs, however. They thrive in the deep, dark, cold waters off the coasts of Nova Scotia, Newfoundland and Labrador, and as far north as the Davis Straits.

Corals are marine animals that resemble small sea anemones. Reef-building corals live in colonies of numerous identical individuals called polyps. Each polyp produces a stony coral skeleton of calcium carbonate to protect its soft body.

Colonies of corals can grow very large over thousands of years, building reef ecosystems that are as diverse and complex as forests.

Scientists have known about cold-water corals for centuries, from chunks of reefs broken off and brought to the surface in fishing nets and lines. With new technology for underwater exploration, such as remote-operated submersibles, scientists have recently been able to study living reefs in their natural environment.

Cold-water corals depend on the constant flow of ocean currents to supply the microscopic organisms on which they feed. Their branching skeletons of calcium carbonate resemble bushes or trees, and help the polyps capture food more efficiently. These reef structures create an underwater forest-like habitat that shelters many other animals such as sponges, bristle worms, crabs, lobsters, clams, snails, octopuses, starfish, sea urchins, brittle stars, feather stars, and fish.

When scientists began their research on coldwater corals, they realized that fishing practices, such as bottom trawling, had already destroyed large areas of these unique reefs. Beginning in 1997, the Canadian government established marine protected areas (MPAs) to save parts of the reef from further damage. The first MPA was located in The Gully—a large submarine canyon off Nova Scotia with the highest diversity of coral species in Atlantic Canada.

Checking Concepts

1. Name two plant species and two animal species.
2. What is the population size of students in
   (a) your classroom,
   (b) your school?
3. Give an example of a question that a scientist might answer by studying
   (a) an individual frog,
   (b) the frog population of a pond,
   (c) a pond community.
4. What are the differences and similarities between a population of herring gulls and a community of seabirds? Organize your answers in a chart.

5. Using a local example, create a series of pictures to illustrate four different levels of biological organization, from an individual to an ecosystem.
6. Is it possible for two organisms to live in the same habitat, but have different niches? Explain.

Understanding Key Ideas

7. Describe your niche in your community. How does it differ from the niche of a sibling or classmate?
8. A scientist measures the size of a wolf population at two different times during the year and finds that the population number has changed. Suggest one reason why the population may have increased and one reason why it may have decreased.
9. A home aquarium contains water, an air pump, a light, four identical water plants, two goldfish, and three water snails.
   (a) In a chart, list the abiotic parts and the biotic parts of this system.
   (b) How many species are in the aquarium?
   (c) How many populations are in the aquarium?
   (d) List all the contents of the aquarium that form a community.

Pause and Reflect

Write down a question you would like to ask about a local ecosystem, using at least one of the scientific terms you have learned. How would you set about answering this question?

Prepare Your Own Summary

In this chapter, you investigated examples of ecosystems in your province and discovered some of the different parts that make up an ecosystem. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Ecosystems in Atlantic Canada
2. Abiotic Parts of the Environment
3. Biotic Parts of the Environment
4. Levels of Organization
5. Niches

Checking Concepts

1. Give an example of an organism and its habitat.
2. Name three examples of ecosystems found in Newfoundland and Labrador.
3. List five biotic parts of a marine ecosystem.
4. What abiotic factor has a large impact on a population of mussels living on a rocky seashore?
5. What is the difference between an individual organism and a species of organisms?
6. Make a chart that lists the needs of living things.
7. Compare the feet of a falcon (A) with the feet of a duck (B), shown in the photos.
   (a) In what way are the duck's feet adapted to a pond habitat?
   (b) In what way are the falcon's feet adapted to hunting small animals?

8. List four levels of biological organization in order, starting with the smallest.
9. Draw or find pictures of at least seven organisms you might find in a forest ecosystem.
10. Suppose you are teaching the topic of adaptation to a younger student. Write or draw an example you would use. What question might you ask to assess the student's understanding of adaptation?
11. Describe or make a model of an ecosystem that includes all the terms you have learned in this chapter.
12. Why is it important to correctly use scientific terms, such as species, when discussing scientific subjects?

13. Name five populations of organisms that might live in a pond community.
14. Describe an interaction between two of the species you named for question 13.
15. How is the polar bear in Figure 1.11 adapted to its abiotic environment?
16. Describe the niche of a polar bear.

Understanding Key Ideas

17. Ecosystems can exist within other ecosystems. Give an example that helps explain this statement.
18. A friend tells you: "I took a walk along the beach this morning and counted a population of 96 birds." Is this a scientifically useful statement? If not, give an example of a statement that would be more precise.
19. Assume that the wind blowing along the coast blows from a west direction to an east direction. Make a sketch to show the shape of a tree that is growing along this coast. Explain how you used the wind direction information to infer how you would draw the tree.

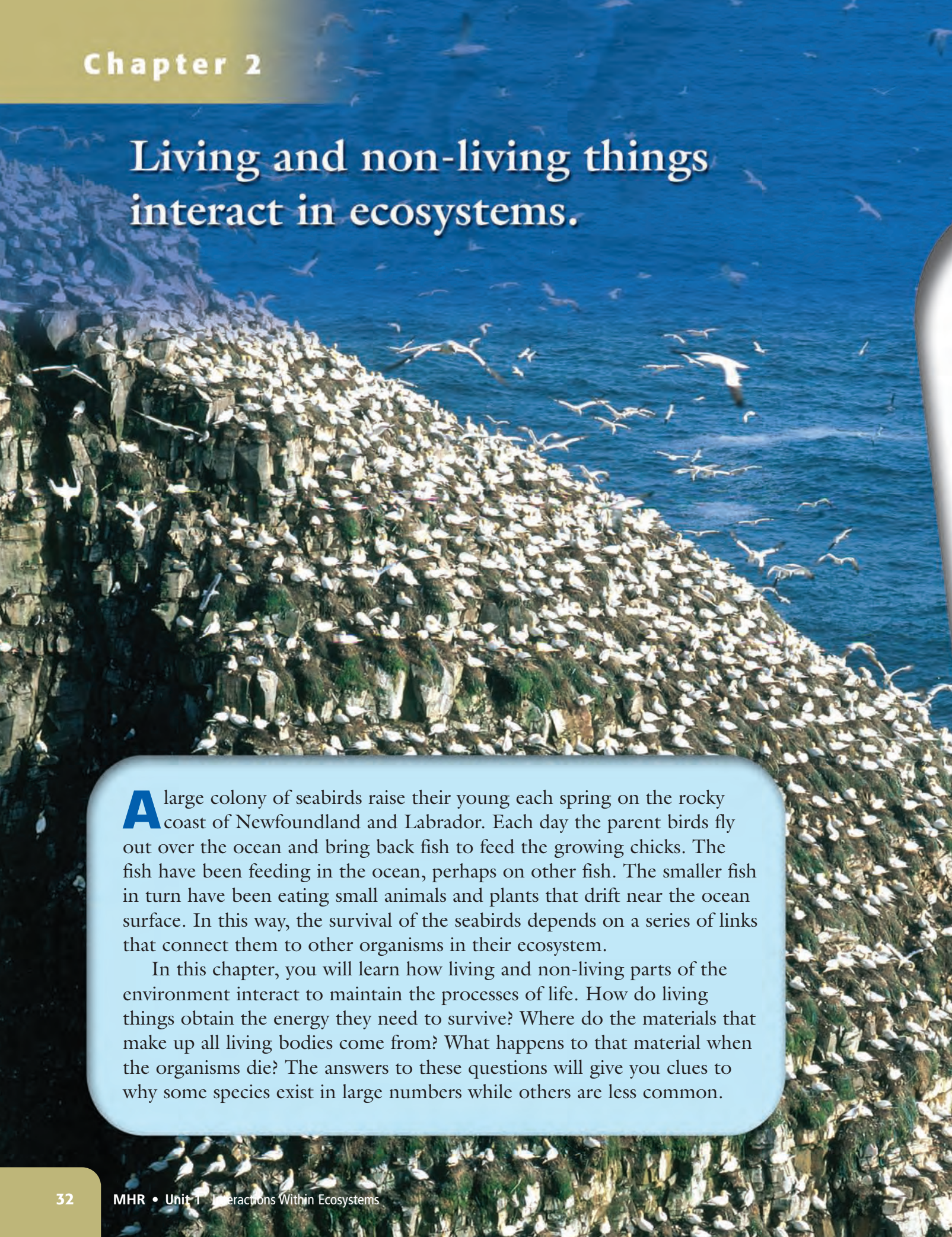
20. Name and describe two abiotic factors that might affect the growth of a group of pine trees growing near the edge of a rock cliff overlooking the Atlantic Ocean.
21. Suppose you want to encourage more butterflies to live in your neighbourhood. How would you go about increasing the butterfly population?
22. Choose and name a local ecosystem. Consider the biotic and abiotic parts of this ecosystem. Is there one abiotic part that has a greater effect on the biotic parts of the ecosystem than the others? Give reasons to justify your answer.

Pause and Reflect

You are asked to make a model of an ecosystem to help teach younger students. What would you put in your model and why? Make or draw such a model and include clear labels for each part.

Chapter 2

Living and non-living things interact in ecosystems.



A large colony of seabirds raise their young each spring on the rocky coast of Newfoundland and Labrador. Each day the parent birds fly out over the ocean and bring back fish to feed the growing chicks. The fish have been feeding in the ocean, perhaps on other fish. The smaller fish in turn have been eating small animals and plants that drift near the ocean surface. In this way, the survival of the seabirds depends on a series of links that connect them to other organisms in their ecosystem.

In this chapter, you will learn how living and non-living parts of the environment interact to maintain the processes of life. How do living things obtain the energy they need to survive? Where do the materials that make up all living bodies come from? What happens to that material when the organisms die? The answers to these questions will give you clues to why some species exist in large numbers while others are less common.

What You Will Learn

In this chapter, you will

- **describe** interactions between biotic and abiotic parts of an ecosystem
- **distinguish** the different roles of organisms in ecosystems
- **investigate** how energy flows through a food chain
- **examine** how matter is cycled in an ecosystem

Why It Is Important

In order to solve problems such as pollution, people need to know how different parts of an ecosystem normally interact to keep the environment stable.

Skills You Will Use

In this chapter, you will

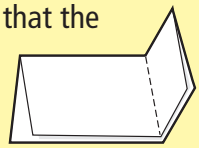
- **observe** what happens to dead organisms
- **model** the way in which energy flows through ecosystems
- **illustrate** and explain the nutrient cycle

FOLDABLES™
Reading & Study Skills

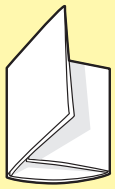
Make the following Foldable to take notes on what you will learn in Chapter 2.

STEP 1 **Fold** an 8.5 × 11″ sheet of paper along the long axis.

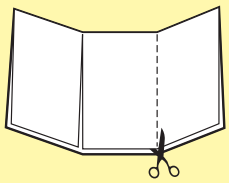
STEP 2 With the paper horizontal and the fold at the top, **fold** the right side in toward the centre so that the right fold covers half of the remaining paper.



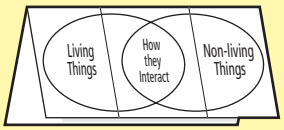
STEP 3 **Fold** the left side in toward the centre to make a three-page book.



STEP 4 **Open** the folded book and **cut** upwards along the folds on the inside layer of paper only.



STEP 5 **Draw** two overlapping ovals across the three tabs to create a Venn diagram. **Label** the left oval "Living Things", the right oval "Non-living Things", and the middle section "How they Interact".



Organize As you read the chapter, make notes under the tabs of the Foldable, giving examples of biotic and abiotic parts of an environment and explaining how they interact.

2.1 Types of Interactions

The biotic and abiotic parts of the environment interact together in many different ways. Symbiosis is an example of interactions between biotic parts of the environment. Symbiotic relationships include parasitism, mutualism, and commensalism. Eating is another interaction between organisms. Feeding relationships can affect the population size of the organisms that are eaten and of the organisms that eat them.

Key Terms

commensalism
host
mutualism
parasites
parasitism
symbiosis
symbiotic

One of the key ideas in ecology is that everything is connected to everything else. Each part of the environment is constantly interacting with other parts of the environment. For example, as you read this book, you are breathing in and breathing out. This is an interaction between you and an abiotic part of your environment.

Figure 2.1 This photo shows an interaction between two biotic parts of the environment.

In the last chapter, you learned that plants are affected by light, water, temperature, and soil. These are examples of interactions between biotic and abiotic parts of the environment. As Figure 2.1 shows, plants are also eaten by animals. Eating is an example of an interaction between two biotic parts of the environment.

Can you think of an example of an interaction between two abiotic parts of the environment? Here's one: after a rainfall, the sun evaporates puddles on the ground. In this chapter, you will explore how ecological interactions like these help maintain life on Earth.

Living Relationships

The barnacle is a distant relative of crabs and lobsters. Young barnacles drift in the ocean currents until they find a solid surface on which to attach. Once fixed to the surface, they grow a hard protective shell and remain in the same place for the rest of their lives. Barnacles may attach themselves to rocks, to the hulls of boats or, as shown in Figure 2.2, to the bodies of whales!

Figure 2.2 The back of this whale is covered with clusters of barnacles.

This relationship between barnacles and whales is an example of **symbiosis**, a biological interaction in which two species live closely together over time. There are three main types of **symbiotic** relationships: parasitism, mutualism, and commensalism.

Parasitism

Ticks (Figure 2.3) and tapeworms (Figure 2.4) are examples of **parasites**. **Parasitism** is a symbiotic relationship between two species in which one benefits and the other is harmed. The parasite obtains its food from its partner. The organism that provides food for a parasite is called a **host**.

Figure 2.3 Ticks feed on the blood of other animals such as cats, dogs, and birds.

Figure 2.4 Tapeworms live inside the intestines of other animals, including humans, and absorb nutrients from them.

Did You Know?

Newfoundland is the only location in North America where the caribou roundworm is found. This parasite is believed to have been introduced into the island's caribou population when reindeer were shipped from Norway to Newfoundland in the early 1900s.

Fleas, ticks, and lice are all examples of *external* parasites, which live on the surface of their hosts. These parasites may stay with their host only for a brief time while they feed or reproduce. Tapeworms and roundworms are examples of *internal* parasites, which live inside the bodies of their hosts. They may stay with their host for their entire lifetime.

Parasites usually do not kill their hosts, or else they would lose their source of food and might die as a result. Sometimes, however, a large population of parasites can weaken their host and shorten its life. For example, in the late 1990s, many woodland caribou on the Avalon Peninsula of Newfoundland were found dead, or weak and staggering. The cause was a large number of parasitic roundworms found in their lungs and brains.

Some plants are also parasitic. For example, the mistletoe plant attaches itself to trees and grows root-like structures into the host to extract nourishment. Different species of mistletoe grow on different species of trees.

Figure 2.5 Termites have micro-organisms in their digestive tract that break down the wood on which termites feed.

Mutualism

Termites are insects that eat dead wood (Figure 2.5). Although this source of food is plentiful, wood is very difficult to digest. In fact, termites cannot digest wood! However, their guts contain tens of thousands of micro-organisms that can. The micro-organisms break down the wood into sugars that nourish both the micro-organisms and the termites.

This type of relationship, in which both partners benefit, is called **mutualism.** The micro-organisms benefit by living in a warm, safe environment and having their food delivered to them. The termites benefit by being able to use a common source of food that few other animals can use.

Another example of mutualism is found in lichens, commonly seen growing on rocks (Figure 2.6). Lichens are a combination of two organisms living together: a species of alga (plural: algae) and a species of fungus (plural: fungi).

Figure 2.6 This crusty lichen growing on a rock is an example of mutualism.

Figure 2.7 shows the structure of a typical lichen. The algae produce food, which is used by both organisms. The threads of fungi make a sponge-like structure that anchors the lichen to rocks, protects the algae, and holds water essential to both. This combination allows the two species to live in environments where neither could survive alone.

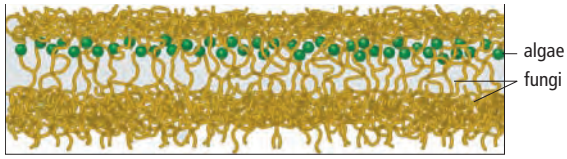


Figure 2.7 Lichen consists of algae and fungi living together in a relationship of mutualism.

Commensalism

The brightly-coloured clownfish in Figure 2.8 swims among the poisonous stinging tentacles of an anemone. The clown fish, however, is immune to the poison. It gets shelter from the anemone and eats scraps left over from the anemone's meal. This type of symbiotic relationship, in which one partner benefits and the other appears neither to lose nor gain from the relationship, is known as **commensalism.** The barnacles and the whale described on page 35 are another example of commensalism.

Figure 2.8 This clownfish is unharmed by the poisonous tentacles of the anemone with which it lives.

Reading Check

1. Define "symbiosis."
2. Give an example of symbiosis from this chapter and an example from your own experience.
3. Define and give an example of each of the following terms: mutualism, parasitism, and commensalism.

Food and Populations

Symbiosis helps organisms survive by providing food or shelter to one or both partners in the relationship. For animals, eating food is essential for survival. It is an important interaction between different species.

Figure 2.9 How might the number of hares in an ecosystem affect the population of lynxes that prey upon them?

Word Connect

Organisms that hunt and kill their food are called *predators.* Organisms that are hunted and killed for food are called *prey.*

When the lynx in Figure 2.9 catches and eats the hare it is chasing, there will be one less hare in the population. In this way, lynxes can affect the population size of the hares. What might happen if there were very few hares? It would then be difficult for lynxes to find and catch enough food to survive. Many lynxes would die of starvation. In this way, the population size of hares can affect the population size of the lynxes.

2-1A The Ups and Downs of Living Together

Think About It

In northern Canada, the main prey of the Canada lynx is the snowshoe hare. Snowshoe hares eat plants. How might an increase in the population of plants affect the hares? How might an increase in the population of hares affect the number of lynxes? When the number of predators increases, what effect might that have on their prey?

In this activity, you will analyze some actual data on populations of hares and lynxes. Use what you already know about predator–prey relationships to interpret the pattern shown by this data.

What to Do

1. The following table shows the approximate numbers of lynxes and hares caught by trappers each year over a period of 20 years. Plot this data, showing both lines on the same graph, and then answer the questions.

Year	Approximate Number of Hares Trapped	Approximate Number of Lynxes Trapped
1900	30 000	4 000
1901	47 000	6 000
1902	70 000	10 000
1903	77 000	35 000
1904	36 000	59 000
1905	21 000	42 000
1906	18 000	19 000
1907	21 000	13 000
1908	22 000	8 000
1909	25 000	9 000
1910	27 000	7 000
1911	40 000	8 000
1912	57 000	12 000
1913	77 000	20 000
1914	52 000	46 000
1915	20 000	51 000
1916	11 000	30 000
1917	8 000	16 000
1918	15 000	10 000
1919	16 000	10 000
1920	25 000	9 000

What Did You Find Out?

1. Describe the pattern shown by the population of
   (a) hares
   (b) lynxes.
2. Explain why changes in the lynx population appear to follow changes in the hare population.
3. How can a predator species control the population size of its prey?
4. How can a prey species control the population size of its predator?
5. What might happen to the number of lynxes if the plants in the ecosystem became rare? Explain your answer.
6. Use the pattern shown in the graph to predict the probable size of each population in 1945.
7. Do you think that using the numbers of animals trapped is an accurate method of estimating population size? What other factors might affect the numbers of animals trapped?
8. The northern habitat where these data were collected has relatively few different species. In other ecosystems, such as a forest, the populations of different species do not usually fluctuate so much. Suggest a reason for this.

Checking Concepts

1. Give two examples of an interaction between two abiotic parts of the environment.
2. Give two examples of an interaction between an abiotic and a biotic part of the environment.
3. What is the difference between parasitism and mutualism?
4. What is the difference between a parasite and a predator?
5. Explain how a growing population of owls might affect the number of mice in their ecosystem.
6. (a) Graph the following data on the moose population in one of Canada's national parks.

Year	Number of Moose
1971	35
1972	52
1974	95
1978	184
1979	192
1984	186
1989	212
1995	295
2000	265

(b) Wolves are natural predators of moose. Would you expect to see the same pattern of population change for the wolf population? Why or why not?

Understanding Key Ideas

7. Consider each of the following pairs of organisms and name the type of symbiotic relationship the partners might have. What are the benefits or disadvantages for each partner?
   (a) a flowering plant and a bee
   (b) a dog and a flea
   (c) a barnacle and a whale

Pause and Reflect

What is the relationship between bees and people? What effect might a decline in the population of bees have on people?

2.2 Roles of Organisms in Ecosystems

Animals obtain their food from the biotic environment by consuming other organisms. They are called consumers. Plants produce their food from the abiotic environment by the process of photosynthesis. They are called producers. Waste and dead matter are a source of food for scavengers and decomposers.

Key Terms

carnivores
consumers
decomposers
fermentation
herbivores
omnivores
producers
scavengers

Figure 2.10 What role does each of these animals have in an ecosystem? Which animals have similar roles?

Animals must eat in order to survive. **Herbivores** are animals such as moose and hares that eat only plant materials. **Carnivores** are animals such as owls and spiders that eat only other animals. **Omnivores** are animals such as bears and chickens that eat both plants and animals.

The food that each organisms eats is more than a matter of taste. Feeding relationships give scientists a way of classifying different organisms according to their role or niche in an ecosystem. For example, the shark, owl, and spider in Figure 2.10 all hunt other animals for their food. Although they are very different species, they all have the role of carnivore. The moose, hare, and grasshopper all have the role of herbivore.

Word Connect

Photosynthesis is the process that green plants use to trap the sun's energy to make food. It comes from the words *photo*, meaning "light" and *synthesis*, meaning "to make by combining different things."

Consumers and Producers

Another way of classifying organisms is to consider *how* they obtain their food from the environment. Whatever animals eat, they must get their food from the biotic environment by consuming other organisms. Because of this, animals are called **consumers**.

In contrast, plants can produce their own food from the abiotic environment. They use energy from sunlight, carbon dioxide from the air, and water from the soil to make sugars, as shown in Figure 2.11. Because they produce their own food, rather than consuming other organisms, plants are called **producers**.

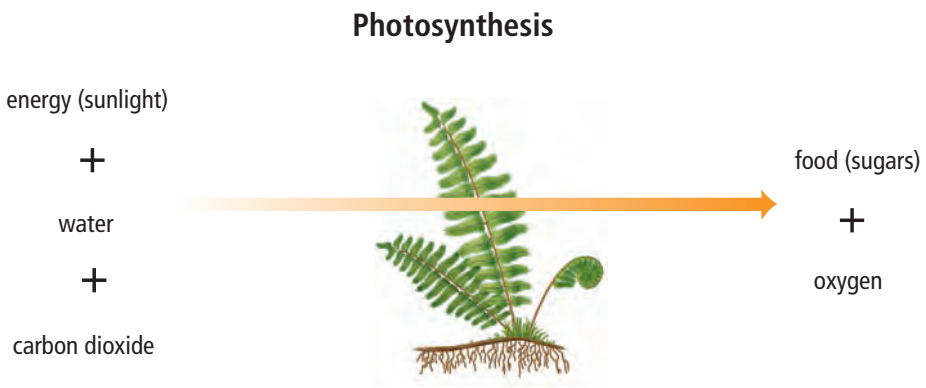


Figure 2.11 Plants make their own food by the process of photosynthesis, using materials from the abiotic environment. Food is not the only product of photosynthesis. Oxygen gas is another product. Plants give off oxygen gas into the air. Nearly all other living things depend on this oxygen to survive.

Scavengers and Decomposers

After animals have eaten, they produce waste matter made up of undigested parts of their meal. What happens to this waste matter? What happens to the bodies of animals and plants after they die? Why do we not see great piles of waste matter and dead bodies in ecosystems?

Did You Know?

The larvae of dung beetles, like the one shown below, feed on animal wastes. A species of dung beetle introduced to Texas in the 1970s is estimated to remove 80 percent of the cattle droppings in some areas.

The answer to these questions lies in a third group of organisms, whose role is to clean up these materials. **Scavengers** are animals such as vultures and dung beetles that eat decaying animals and waste materials. The turkey vulture in Figure 2.12 has a bald head, which is easier to keep clean after this bird has stuck its beak into a carcass to feed. Dung beetles dig burrows under animal droppings and lay their eggs there. Their larvae feed on the dung. Other scavengers include houseflies, crows, and some species of gulls.

Figure 2.12 Vultures such as this turkey vulture are scavengers that feed on dead animals.

Figure 2.13 Fungi are decomposers that help to break down this rotting tree stump.

Decomposers are organisms that break down dead and waste materials into their basic parts. Decomposers include many species of microscopic bacteria and fungi. They do not eat their food as scavengers do. Instead, they release chemicals that break apart dead tissues and cells. Then the decomposers absorb the nutrients into their own cells. The fungus growing on a rotting log in Figure 2.13 is a common example of a decomposer.

Suggested Activitiy

Investigation 2-2C on page 46.

Reading Check

1. What do herbivores eat?
2. What do carnivores eat?
3. What is the role of producers?
4. What are decomposers?

Decomposers and Food

Have you ever forgotten a sandwich in a locker for a few days, only to discover it later covered with green or black mould? Or perhaps you have found smelly milk or slimy lettuce leaves in your refrigerator. When our food begins to "spoil" or "go bad" it is because bacteria, fungi, or other decomposers are feeding on it. They are using *our* food as *their* food!

From the beginning of human history, people have looked for ways to protect food from decomposers. This can be done in two ways:

- by keeping micro-organisms out of it; and
- by killing or slowing the growth of micro-organisms that are already on it.

Keeping Micro-Organisms Out of Food

Decomposers can be found everywhere: in the soil, in water, in the air, and on the surface of objects, including your skin. That is why it is important to wash your hands and to have a clean countertop and use clean utensils when preparing food. Micro-organisms can be kept out of stored food by keeping it well covered, or in a sealed container.

2-2A Food Preservation

Think About It

In this activity, you will think about some of the many ways that people have invented to keep micro-organisms from feeding on our food.

What to Do

1. Make a three-column table with the headings "Food Product", "Preservation Method", and "How It Works".
2. Look at the food products in the picture. A different method of preserving each food is used to protect it from micro-organisms. Fill in the table based on what you know or can infer about each food product. If you are not sure, write "research needed" for that food product.
3. When you are done with the table, do research for each product you were not sure about.

Figure 2.14 In the 1960s, the majority of salt cod produced in Newfoundland was packed in barrels.

Preventing the Growth of Micro-Organisms

Canning, vacuum packing, freezing, freeze-drying, and radiation are all fairly recent methods of preserving food. Canning and vacuum packing keep out air. Freezing keeps out warmth and removes moisture. Freeze-drying removes moisture, and radiation kills micro-organisms.

Few micro-organisms can survive without moisture. Drying food is a traditional preservation method that has been used for many centuries. Some fruits were dried simply by leaving them in the sun. For example, dried grapes become raisins and dried plums become prunes. Meat and fish were cut in thin strips and hung to dry. Sometimes, they were hung in the smoke from a wood fire, which added flavour to the meat.

Figure 2.14 shows barrels of salted cod from Newfoundland. Salting is a very old method of preserving food. Salt draws moisture from cells. The resulting lack of moisture prevents decomposer micro-organisms from growing. Sugar has a similar dehydrating effect. It is used to preserve such products as candied fruit.

Another old method of preserving food is pickling. The simplest method of pickling vegetables is to place them in vinegar. Vinegar is an acid in which few bacteria can survive. Most of the pickled vegetables sold in stores are preserved in this way. Herbs and spices are added to the vinegar to improve the flavour of the vegetables.

A second method of pickling is to soak vegetables in brine (a strong salt solution). Desirable bacteria that can live in brine carry out fermentation and produce lactic acid, which prevents the growth of undesirable bacteria. Foods preserved by pickling include dill pickles, sauerkraut, kimchee (pickled cabbage), and silage (pickled plant material used to feed cattle).

Did You Know?

Workers who built the Great Wall of China over two thousand years ago ate sauerkraut, a kind of fermented cabbage.

Micro-Organisms That Make Food

Did you ever look at the list of ingredients on a container of yogurt or sour cream? It usually includes: "bacterial culture." Many types of micro-organisms are used in processes that help produce certain types of food.

For example, yeasts are single-celled fungi that are carried through the air by wind. When yeast cells land on something sugary, such as soft fruit, they start to feed on it. As they break down the sugars, they produce alcohol and carbon dioxide gas. This process is known as **fermentation.** It is used to make such products as beer, wine, bread, cheeses, pickled vegetables, and some sausages.

Word Connect

The word fermentation comes from the Latin word, *fermentare,* meaning "to foam or rise by bubbling."

2-2B Defending Against Decomposers

Think About It

Decomposers play a vital role in ecosystems by breaking down waste and dead matter. Stored foods such as fruits, vegetables, grains, meat, and fish are materials that micro-organisms normally would start to decompose. In this activity, you will research ways that people have developed to help preserve stored foods and delay or prevent decomposition.

What to Do

1. Read the list of ideas for research projects given in step 3. Make a brief proposal of the project you wish to do, using these suggestions or an idea of your own. With your teacher's approval, carry out your project and make a presentation to the class.
2. Your presentation can be in the form of a display, collage, demonstration, or other technique. It must include some information about the link between methods of food preservation and the conditions needed by micro-organisms to grow and reproduce.
3. Project suggestions:
   - Compare methods of food preservation in the past and present.
   - Conduct a test to determine which preservation technique is best for preserving a perishable food item.
   - Research how food is preserved for shipping from other countries to supermarkets in your province.
   - Report on the history of food preservation and describe the effect of new technologies.
   - Interview a health inspector about the links between food preservation, micro-organisms, and food poisoning.

What Did You Find Out?

1. How is food preservation related to the role of decomposers in ecosystems?
2. Are decomposers harmful or helpful to humans? Explain your answer.
3. Why do people still use methods of food preservation that are hundreds of years old when new techniques have been developed?

2-2C The Dirt on Decomposers

Skill Check

- Observing
- Predicting
- Controlling Variables
- Interpreting Data

Safety

- Do not handle the soil with bare hands.
- Dispose of soil and vegetable matter as directed by your teacher.

Materials

- 2 identical large plastic pots (approx. 750 mL) with drainage holes
- saucers to go under pots
- pieces of window screen or similar mesh
- magnifying glass
- small stones
- labels for pots
- garden soil (not sterilized)
- sterilized soil
- water
- measuring cup
- approximately 500 mL of waste vegetable matter such as peels from carrots, apples, or potatoes, or leaves from cabbage or lettuce

Most decomposers are microscopic and cannot be seen with the naked eye. However, you can see the results of their work in this activity!

Question

How do different variables affect the activity of decomposers?

Procedure

1. Based on what you know about decomposers, predict what will happen to waste vegetable matter when buried in
   (a) garden soil.
   (b) sterilized soil. (Soil has been sterilized by placing it in a hot oven to kill any organisms in it.)
2. Work in small groups. Place each pot on a saucer and put a few small stones over the drainage holes in each pot.
3. Add garden soil to one pot until it is about half full. Add the same amount of sterile soil to the second pot. Label each pot.
4. Place half of the vegetable matter in each pot.
5. Cover the material in each pot with more garden soil or sterilized soil as appropriate until the pots are nearly full.
6. Estimate the volume of water you can add to each pot before water begins to empty from the drainage holes. Measure this volume into a measuring cup. Add the same amount of water to each pot.
7. Cover both pots with a piece of window screen.
8. Place the labelled pots in a secure location where they can remain for three or four weeks. Moisten the soil every few days if necessary, adding the same amount of water to each pot.

9. After a week, remove the uppermost layer of soil and observe the condition of the vegetable matter in each pot. Use a magnifying glass. Record your observations. Replace the soil.
10. Continue your observations until there is a clear difference between the vegetable matter in the two pots.
11. Wash your hands thoroughly after completing each part of the experiment. Clean up your work area as your teacher directs.

Analyze

1. Did either of the samples have little or no sign of decomposition? Suggest why.
2. Did your observations support your hypothesis in step 1? Explain.
3. What variables were controlled in this activity? What was the responding variable?

Conclude and Apply

4. What factors might speed up the decomposition of the materials you studied?
5. What factors might slow down the decomposition of the materials?
6. Based on this activity, design an experiment to observe the effect of one of the following variables on the growth of micro-organisms: temperature, moisture, light, acidity, or salinity. Outline your materials and procedures, using diagrams if necessary.

Career Connect

Professor of Environmental Design

There is no job description for what Professor Tang Lee does, but everything he does relates to sustaining the health of the planet and its inhabitants. As an architect and a Professor of Environmental Design, he teaches and conducts research into topics such as indoor air quality and sustainable building design. He is often called on to give expert testimony in court and to be interviewed on radio and television. As well, he is also a co-owner and operator of a tilapia, fish farm.

Q. What is sustainability?

A. It can be as simple as conducting our lives so that we don't adversely affect future generations. There are many different definitions. You can sustain health, energy resources, food. To my mind, it is all of the above.

Q. Why do you run a fish farm?

A. I look at the oceans being over-fished, and it's destroying water ecosystems. And there's so much pollution being dumped into the ocean—heavy metals, like mercury, cadmium, and lead. … I worry about the health of my children and grandchildren. To make a long story short, I decided to raise fish in a way that does not deplete the oceans—in a way that does not use chemicals, and hormones, and antibiotics, which of course go up the food chain.

Q. How do you operate your fish farm?

A. Lots of fish farms have what's called a flow-through system, which means they take water out of the river and put it through the tank. Waste from the fish and uneaten fish food gets discharged (untreated) into the river. We don't do that. We have a greenhouse, and so the wastewater is put in a hydroponics system as well as soil culture. To make the soil culture we grind up any dead fish and mix this into the soil. We have beautiful compost that we donate to the garden clubs!

We only bring in about 10 percent of the water we use to replace water lost to evaporation, spillage, and so forth. And because of this, we don't discharge large amounts of nutrients downstream. We have equipment and the hydroponics system to filter the water. We also have a constructed wetland on our site, which does the final polishing. After the water goes through the wetland, it's completely clear. Nature is incredible in terms of how it can purify, as long as we don't overload the system.

Q. You also design solar-powered buildings. What motivates you to do this?

A. We live in a privileged period of civilization in which we have fossil fuels to consume. The future is going to be different. … We're not going to be able to use, in the same way, fossil fuels for heating, cooling, and powering our buildings, or for transportation.

Q. What keeps you in a positive frame of mind?

A. I'm hopeful because there are people who are working toward renewable energies, like solar and wind, different types of planning systems, and new types of vehicles. … We see a lot of what we call ecovillages springing up, in which communities are trying to be as self-sufficient as possible.

Check Your Understanding

Checking Concepts

1. What is the role of spiders, cats, and owls in an ecosystem? Name one other animal that has the same role.
2. Classify each of the following as either a producer or a consumer: dandelion, robin, grass, grasshopper, butterfly, cod, algae, spruce, spruce budworm, lobster.
3. Explain what happens to the remains of a moose that dies of natural causes deep in the woods.
4. Name three places where you might find decomposers.
5. If you leave a plum and a prune on your kitchen counter for several days, which will decompose first? Why?
6. Name a food produced by fermentation.
7. Identify the role being performed by each of the organisms shown.

(a)

(b)

(c)

Understanding Key Ideas

8. Are you a producer or a consumer? Explain your answer.
9. Are you a carnivore, herbivore, or omnivore? Explain your answer.
10. How does the method of food preservation shown below prevent the growth of micro-organisms?

11. One day you throw some potato peels into a composter. Two weeks later there is no sign of them. What has happened?

Pause and Reflect

What would happen if all the decomposers in the world suddenly disappeared?

2.3 Food Chains, Food Webs, and the Transfer of Energy

Energy from sunlight is used by plants to make food. Some of this energy is transferred to the animals that eat the plants. Energy in these animals is transferred to the carnivores that eat them. These links form food chains and food webs. Energy is lost at each step in a food chain.

Key Terms

energy pyramid
food chain
food web

Eating is a process that transfers energy from one organism to another. This transfer takes place, for example, when you eat an apple, when a frog eats a worm, and when a moose eats a water lily. Animals consume food in order to get the energy they need to carry out their daily activities. For example, you need energy to ride a bicycle, to shovel snow, and also to breathe and grow.

Food Chains

You can get energy by eating an apple, but where does the apple get its energy? Apple trees, like all plants, trap energy from sunlight to produce sugars, as you learned from Figure 2.11. Some of the stored energy in plants passes into the bodies of organisms that eat the plants (Figure 2.15). In turn, some of the energy in these organisms passes into the bodies of the animals that eat them. This transfer of energy from organism to organism can be illustrated in a model called a **food chain**, as shown in Figure 2.16.

Figure 2.15 Eating transfers energy from the water plants to the moose.

The Roles of Organisms in Food Chains

On page 41, you learned about the roles of producers and consumers in ecosystems. Look at the three food chains in Figure 2.16. Can you see any pattern in the position of producers and consumers in each food chain? Can you see a pattern in the position of herbivores and carnivores?

Because producers are the only organisms that can make their own food using the energy of sunlight, all food chains begin with a producer. Producers include green plants, algae and some micro-organisms.

The second link in all food chains consists of the consumers that eat producers. These are known as herbivores or primary consumers. Herbivores come in all shapes and sizes, from leaf-eating insects to blue whales and elephants.

The third link in all food chains is the consumers that eat other consumers. These are known as carnivores or secondary consumers. Carnivores range from dragonflies and spiders to wolves and sharks.

Food chains may have four or more links. These places are filled by carnivores that eat other carnivores. For example, a hawk can eat a snake that has eaten a frog that has eaten a worm. In all food chains, the energy flows from the producers to the consumers, and from the herbivores to the carnivores.

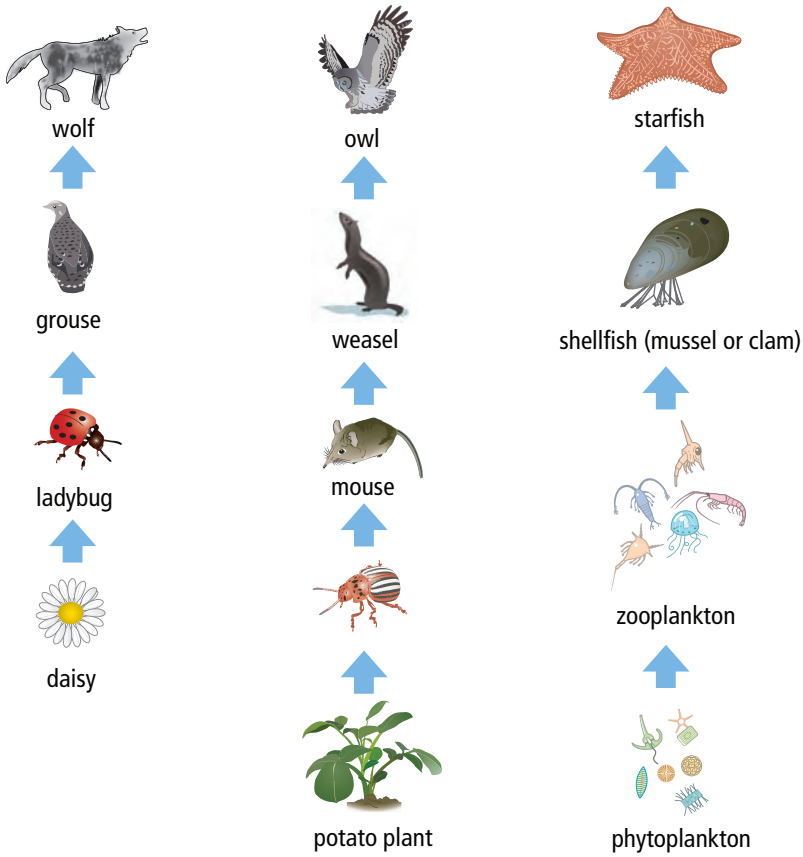


Figure 2.16 Three examples of food chains found in different ecosystems in Newfoundland and Labrador. The arrows show the direction in which energy passes from organism to organism.

2-3A Eating at the Copepod Café

Find Out ACTIVITY

Copepods are tiny shrimp-like animals. They are an important source of food for many animals living in oceans and estuaries, such as herons and fish. In this activity, you will play a game that models a food chain in an estuary.

Materials

- 20 strips of cloth, 30 cm long (10 of one colour, 10 of a different colour)
- 1 large plastic self-sealing bag per student
- 4–5 L of popped popcorn or foam "peanuts" used for packing
- stopwatch
- whistle

Safety Precautions

- Do NOT eat the popcorn you use in this activity.
- This activity involves tagging people as you play the game. Be sure to tag people gently.

What to Do

1. Before you start the game, copy the following tables into your science notebook. Give your table a title.

Number of Live Organisms			
	Copepods	Fish	Herons
Trial 1			
Start of game (0 min)			
After 1 min			
After 2 min			
After 3 min			

Number of Live Organisms			
	Copepods	Fish	Herons
Trial 2			
Start of game (0 min)			
After 1 min			
After 2 min			
After 3 min			

2. Your teacher will divide your class into three groups of equal size: copepods, fish, and herons. Students representing copepods will each tie a strip of one colour around their arms. Students in the fish group will wear strips of the second colour. Students who are herons will not wear armbands.
3. On your school playing field or in the gym, mark off an area to represent an estuary. Spread popcorn throughout this area.
4. Play the game as follows:
   (a) Spread out over the "estuary."
   (b) When your teacher blows the whistle, the copepods begin to "eat" microscopic organisms (popcorn) by picking them off the ground one by one and putting them in their "stomachs" (plastic bags). After 30s, once the copepods have some food in their stomachs, your teacher will blow the whistle again. The copepods stop feeding and stand still.
   (c) When your teacher blows the whistle a third time, everyone will begin to eat:
   - Copepods continue to "eat" the popcorn.
   - Fish "eat" copepods by tagging them and transferring the contents of the copepods' plastic bags into their own plastic bag.
   - Herons "eat" fish by tagging them and transferring the contents of the fish's plastic bags into their own plastic bag.

When you have been eaten, you are out of the game. After you have given the contents of your bag to the predator that tagged you, wait on the sidelines.

(d) After 1 min, your teacher will blow the whistle. Stop where you are. Count and record the numbers of copepods, fish, and herons that are still alive.

(e) When your teacher blows the whistle, continue to hunt for food until the whistle sounds again after 1 min. Stop where you are. Count and record the numbers of copepods, fish, and herons that are still alive. Repeat the procedure one more time.

5. Play the game for a second trial, but this time with different numbers of students in each group. Use the ratio of 1 heron to 3 fish to 9 copepods. For example, if there are 26 students, there will be 2 herons, 6 fish, and 18 copepods.

Analyze

1. Compare the starting populations of copepods, fish, and herons in Trial 1 and Trial 2. Which trial is closer to the situation found in nature? Explain your answer.
2. Predict what might happen to all three populations if the food supply for copepods was reduced by one half.
3. Suppose that there were no fish in the estuary. What might happen to

   (a) the copepod population?

   (b) the heron population?
4. Suppose this model included other species, forming an estuary food web. What effect might this have?

Food Webs

Every organism (including you) is part of a food chain. But feeding relationships in an ecosystem are rarely as simple as single food chains. Most consumers eat, and are eaten by, more than one kind of organism. For example, a mouse eats grasses, bulbs, seeds, flowers, and sometimes insects. Mice, in turn, are eaten by foxes, coyotes, owls, hawks, mink, and snakes!

The interconnection of several different food chains produces a more complex model of feeding relationships called a **food web.** Figure 2.17 shows a typical example of a food web. The arrows indicate the transfer of energy among organisms. Notice how the energy can follow a number of different paths from a particular producer through various consumers.

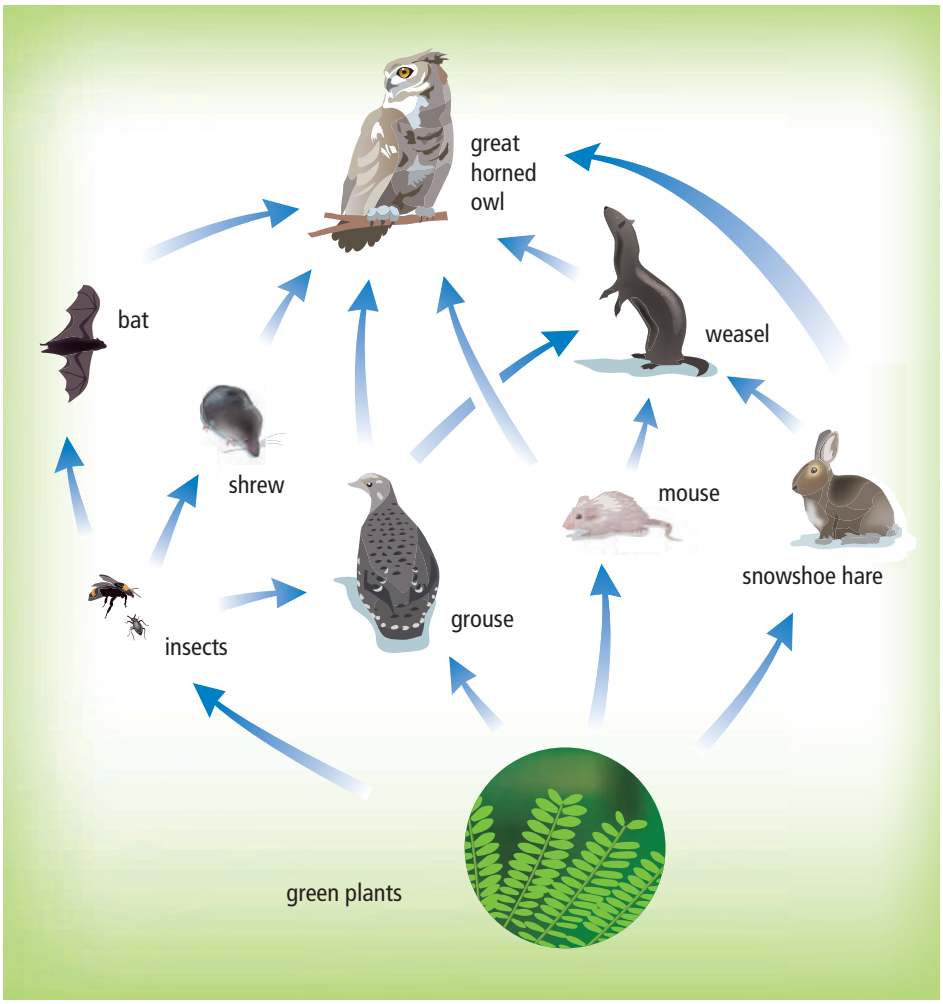


Figure 2.17 A food web shows how energy is transferred from one organism to other organisms in an ecosystem.

Energy Transfer

What happens to the energy in the food you eat after the food enters your body? If you eat a meal with a mass of 100 g, does your body mass increase by 100 g? To answer these questions, you need to consider that energy exists in different forms. Some energy is stored in the bodies of organisms. For example, the fat in your body contains stored energy. Other energy is used to carry out life processes, such as respiration, growth, and movement. This energy is not stored but passes out of the body as heat or waste gases.

The energy in your food consists of the stored energy in the plant or animal that you are eating. You use most of this energy for life processes. Only a small amount becomes a part of your stored energy. Figure 2.18 illustrates this, using a moose eating plants as an example.

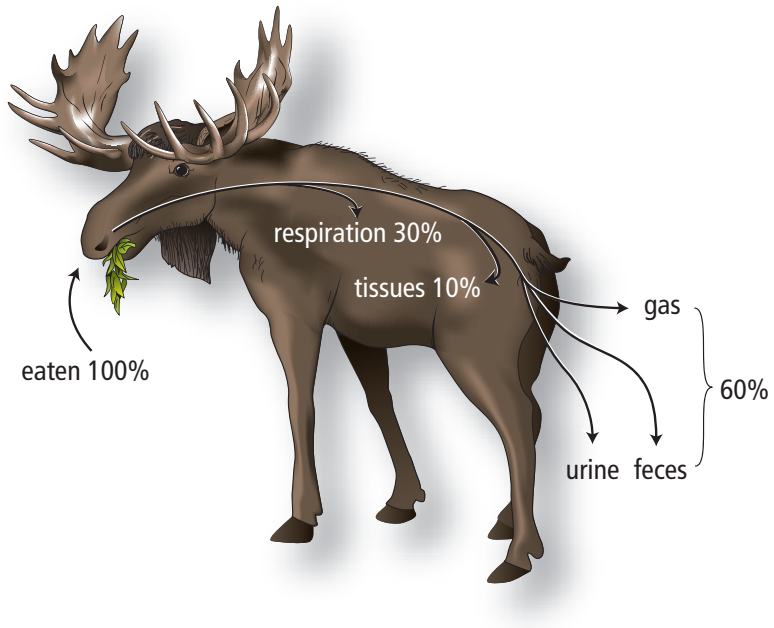


Figure 2.18 Only about ten percent of the energy stored in the plants eaten by a moose eventually becomes stored energy in the moose.

Notice that respiration uses about one third of the energy in the moose's food. All cells in the body carry out respiration. This process releases the energy that the body cells use to grow, reproduce, repair tissues, and produce materials needed by the body.

About 60 percent of the energy in the moose's food leaves the moose in waste matter. Only about ten percent is stored in the moose's body. You can see from this example that most of the energy in the plants that the moose eats is not passed on to the next animal in the food chain.

Energy Pyramids

How might the transfer of energy through ecosystems affect the populations of organisms at different links in a food chain? Since only a small amount of the energy in food is passed from organism to organism, there is less energy at the top of a food chain (the last consumer) than there is at the beginning (the producer).

The largest amount of food energy in an ecosystem is always found in the first link, in the producers. On average, only about ten percent of the energy in producers is transferred to the second link, the herbivores. In turn, only about ten percent of the food energy in the herbivores is transferred to the next level, the carnivores. At each level, most of the energy is lost from the food chain, as shown in Figure 2.19.

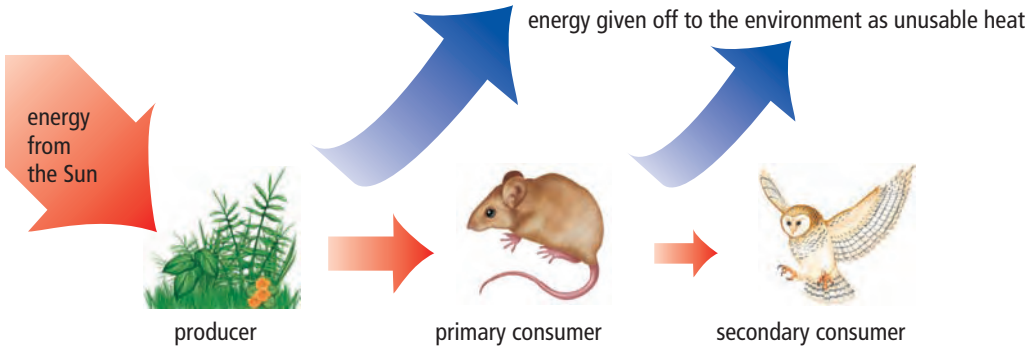


Figure 2.19 Energy is lost as unusable heat from metabolic processes at each link in a food chain. Therefore, less energy is available to the next organism in the food chain.

Ecologists model the gradual loss of energy in food chains as an **energy pyramid**, like the one in Figure 2.20. Because there is less energy available to organisms at each link in a food chain, the animals at the top of a food chain are generally less numerous than those below them. You can make an energy pyramid yourself in the next activity.

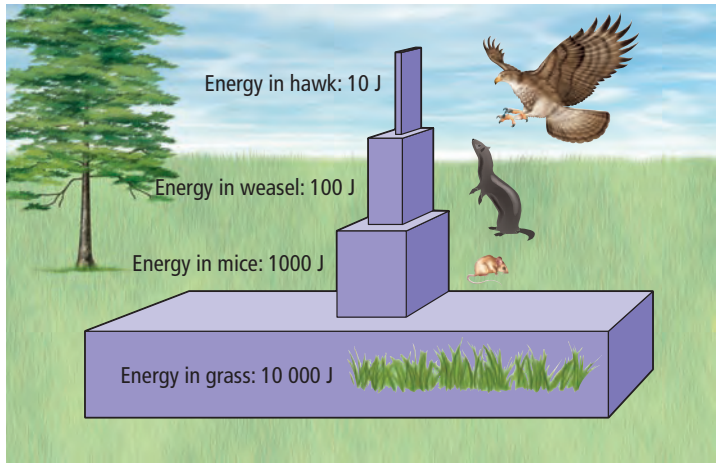


Figure 2.20 Above is a typical energy pyramid. There is a decrease in the total energy available to organisms at each level up the food chain.

Reading Check

1. Draw a food chain with the following organisms in the correct order: hawk, mouse, snake, and berries.
2. What is the difference between a food chain and a food web?
3. What does an energy pyramid show?

2-3B Riddle of the Pyramids

Think About It

Energy is transferred along a food chain when one organism consumes another. When this happens, only about ten percent of the energy is transferred to the consumer. A pyramid of energy shows the different amounts of energy available at each feeding level in the food chain.

Materials

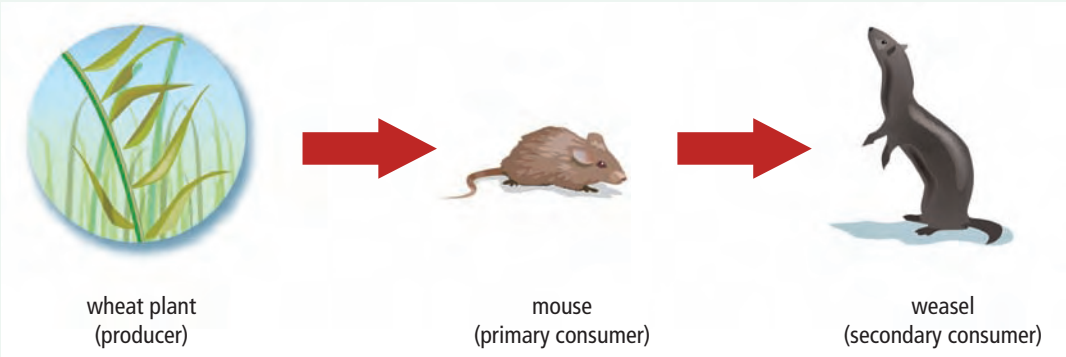
- pencil
- ruler
- scissors
- large sheet of blank paper

What to Do

1. The sheet of paper represents the total energy found in a population of producers at the base of a food chain. Mark off the sheet into ten rectangles of equal size.
2. Cut out one of the rectangles. This represents the energy available to the population of primary consumers in the food chain.
3. Divide the rectangle into ten pieces of equal size.
4. Cut out one of the pieces. This represents the energy available to the population of secondary consumers in the food chain.
5. Arrange your three pieces of paper into a pyramid. Use this model to draw an energy pyramid in your notebook. Label each level in the pyramid. Write the name of an organism you might find at each level.

What Did You Find Out?

1. Why do you think there are fewer numbers of individual organisms at each level up a food chain?
2. Why do you think there are usually not more than three or four links in most food chains?



Science Watch

Fisheries and Ecosystems

The Atlantic cod fishery began in the 1500s, when explorer John Cabot reported huge numbers of cod in the waters off the island of Newfoundland. There were so many, in fact, that an empty bucket lowered into the water could be pulled back up full of fish! For 500 years, the cod stocks surrounding Atlantic Canada continued to be a rich resource for the fishing industry. At its peak during the 1960s, the industry brought in almost two million tonnes of cod per year! The ocean ecosystem, however, could not support high levels of fishing forever. Between 1984 and 1992, northern cod hauls fell from around 39 000 tonnes to less than 12 000 tonnes.

What caused the numbers of cod to fall so low? Scientists have studied biotic and abiotic factors within the ecosystem to determine the reason for the decline. The main problem was the overabundance of a top predator within the food chain: humans. People were simply catching too many cod. The number of fishing boats off the coast had grown considerably since the industry began, and people were using better techniques that allowed them to catch huge numbers of cod. Large *trawlers*, or fishing boats that drag nets through the water to scoop up the catch, even had fish factories on board to freeze and package the fish while at sea. Cod were called the "Newfoundland currency" because of their economic importance to the region.

Scientists studied the rest of the food chain as well. Cod are carnivores in the middle of the food chain, filling the role of both predator and prey. Young cod feed on small *crustaceans*, or shellfish, and other animal plankton. Juveniles eat shrimp, shellfish larvae, small crustaceans, and small fish. Adults feed on an even wider variety of organisms, including jellyfish, capelin, flounder, herring, and other fish, as well as shrimp, crabs, and other shellfish. Since the cod are not dependent on only one species for food, they have the ability to survive when one form of prey is not abundant. However, some scientists believe that declines in the number of capelin and other prey species have put additional pressure on the cod stocks.

Predators of cod include seals, whales, squid, seabirds, and other fish such as haddock and mackerel. Harp seals not only act as predators, but as competitors, since they also feed on capelin and other cod prey. If seals are present in large numbers, they can affect the cod population. Government restrictions on seal hunting may have provided an opportunity for greater competition and predation. The Atlantic Seal Research Project was begun in 2003 to address this concern.

Questions

1. Use the information given in the text to draw a food chain.
2. What abiotic factors could affect the cod population?
3. What would happen to this ecosystem if the entire cod stock died off?
4. Do some research to find out
   (a) what the government has done to help rebuild the cod stocks,
   (b) what the current state of the cod fishery is,
   (c) whether similar regulations are in place for other fish species.

Checking Concepts

1. Place the following three organisms in a food chain: moose, willow, and wolf.
2. Name an omnivore. Draw two food chains to illustrate the feeding relationships of this animal.
3. Why is all the energy in one level of a food chain not available to organisms at higher levels of the food chain?

Understanding Key Ideas

4. What might an energy pyramid look like for the food chain you created in the Science Watch on page 58?

5. Most people eat foods from several levels of a food chain, such as the foods shown in the photograph. Draw two different food chains based on foods you typically eat, which may include some of the items shown. Include at least four levels in one of your food chains.
6. Study the following three food chains that involve humans:
   green plants → humans
   green plants → cow → humans
   green plants → insect larvae → fish → humans
   (a) In which food chain is the most energy in green plants lost before it reaches humans?
   (b) Which food chain provides the maximum amount of energy for humans? Why?
7. The organisms shown below can be found throughout Canada. They are all members of a single food web. Create as many food chains as you can from this group.

Pause and Reflect

How is every bit of food you eat like eating sunshine?

2.4 Cycles of Matter in Ecosystems

Food contains matter as well as energy. Nutrients are used to build and repair cells and tissues. The only source of the nutrients used by all living things is the matter found on Earth. Nutrients are continuously recycled through the biotic and abiotic environment.

Key Terms

nutrients
nutrient cycles

Food is the source of energy for all living things. Food also contains **nutrients**, such as carbon and nitrogen. Organisms need these materials to build and repair their bodies.

You have learned that the energy needed by living things flows continuously to Earth as sunlight. But where do the nutrients come from? The only sources of nutrients for living things are all on Earth. Producers like the tree in Figure 2.21 obtain nutrients from the soil, water, and air. Consumers obtain nutrients from their food.

Because there is a limited supply of nutrients available for organisms, nutrients are continuously re-used. The processes that move nutrients back and forth between the biotic and abiotic environment are called **nutrient cycles**.

Figure 2.21 This maple tree was once a small seed. All the nutrient materials used to build the trees came from the soil, air, and water.

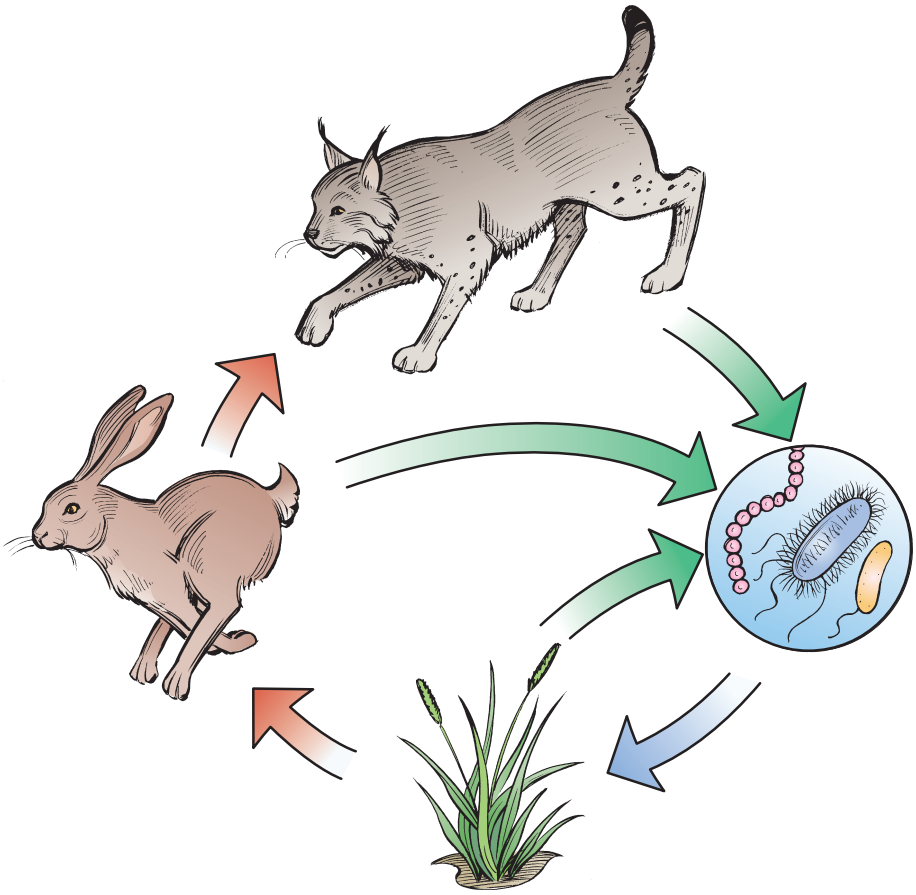
Reading Check

1. Name two examples of nutrients.
2. What do organisms use nutrients for?
3. What is a nutrient cycle?

Nutrient Cycles

Figure 2.22 shows how nutrients are recycled in a simple nutrient cycle. Starting with the plants, nutrients move through a food chain from one consumer to another. Some of the nutrients quickly return to the abiotic environment in waste matter from these organisms. The rest of the nutrients return when the organisms die.

Decomposers play a key role in the cycle. They break down waste matter and dead organisms. This releases the nutrients into the soil, air, or water. Producers take up the nutrients, which they use to help them grow. The nutrients are now back in the biotic part of the environment and start another cycle.



The Nutrient Cycle

Figure 2.22 Nutrients are recycled between the biotic and abiotic parts of the environment.

Just think about it. All of the basic materials that make up your body were once in another part of the environment. Some were in the soil and water and air. Some were in plants and animals. They have come together to be a part of your body today. In the future they will move on to become parts of something else. Without this continuous recycling of matter, life on Earth would not be possible. In the next chapter you will learn how human activities affect nutrient cycles.

2-4A Round and Round It Goes

Find Out ACTIVITY

You have probably heard the expression: "What goes around comes around." In this activity, you will use a model of the nutrient cycle to illustrate how something that you throw away as waste may eventually become part of your food!

What To Do

1. Work in groups of five. Each person in the group will take one of the following roles:
   - student
   - apple
   - soil bacteria (decomposer)
   - dandelion
   - chicken
2. Each group will have one tennis ball. The ball represents nutrients in the cycle that you will model.
3. Read the following story. Act out the story by passing the nutrient ball from person to person in the order described in the story. Each person will explain their role in the cycle when they receive the ball and when they pass the ball to the next person in the cycle.

THE STORY

After finishing a picnic lunch one day, a student tossed an apple core over a hedge into a meadow. Time passed, and the apple core decomposed. The next spring, some chickens were feeding on weeds in the meadow. Some time later, one of the chickens was made into a chicken pie. The student ate some of the chicken pie for lunch.

What Did You Find Out?

1. Name the producers, consumers, and decomposers in this story.
2. Draw or make a model of a nutrient cycle using the five organisms in the story.
3. Draw two alternative food chains to show what other paths the nutrients in the apple core might have taken through different organisms.

Checking Concepts

1. How do producers obtain nutrients?
2. How do consumers obtain nutrients?
3. What is the role of decomposers in a nutrient cycle?
4. There is only a limited supply of nutrients on Earth. Why doesn't this supply run out?
5. How do the leaves in the picture below contribute to the nutrient cycle?

Understanding Key Ideas

6. One day you notice a dead butterfly by a fence. A week later, you observe that the butterfly wings are still there but the rest of the insect has disappeared. How would you explain this observation?
7. Draw an example of a nutrient cycle including all of the following organisms: mussels, algae, cod, bacteria, and orcas.
8. Suppose a poisonous chemical is spilled into a pond. How might this chemical end up inside the body of an osprey?
9. The farmer in the following picture is using a cultivator to till the soil. Why might this be an important step in growing crops?

Pause and Reflect

What would happen to the nutrient cycles on Earth if organisms did not die?

Prepare Your Own Summary

In this chapter, you investigated how living and non-living things interact in ecosystems. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Symbiosis
2. Producers, Consumers, and Decomposers
3. Food Chains
4. Energy Transfer
5. Nutrient Cycles

Checking Concepts

1. Name three types of symbiotic relationships. Give an example of each.
2. How might a species of prey affect the population size of its main predator? Use a specific example in your answer.
3. Explain the difference between a food chain and a food web.
4. What model do scientists use to show how energy is lost at each feeding level as it moves through an ecosystem?
5. Why is there less energy available to a population of owls than to a population of mice?
6. Why are scavengers and decomposers important in an ecosystem? How do they differ?
7. About how much of the energy in your food is stored in your body? What happens to the rest of the energy in your food?
8. Draw a food web including all the organisms shown below.

9. State the role of each organism in the food web you drew for question 8.

Understanding Key Ideas

10. The following food chain is incorrect:
leaves → frog → caterpillar → heron
Explain the error and draw a correct version of this food chain.

11. Give an example of a food chain that connects a person to grass.

12. Why must nutrients be recycled in ecosystems?

13. Food chains generally have few large carnivores. Explain why this might be so.

14. Many micro-organisms grow well in an environment with:
- moisture
- warmth
- oxygen
- non-acidic conditions.

For each of these conditions, describe a method of preserving food that deprives micro-organisms of an environment that is favourable to them.

15. Imagine you are a nutrient in a blade of grass. Describe the journey you might make through various different organisms and the abiotic environment before you end up in another blade of grass to start another cycle.

16. Some of the following statements are true and some are false. Identify which is which. Rewrite the false statements to make them correct.
(a) A tick and a deer have a mutualistic relationship.
(b) A snake is a predator.
(c) Cod, spiders, cats, and seaweed are all consumers.
(d) Decomposers are an essential part of the nutrient cycle.
(e) There is more energy at the top of a food chain than at the base.

17. If you eat a meal with a mass of 500 g, why doesn't your mass increase by the same amount?

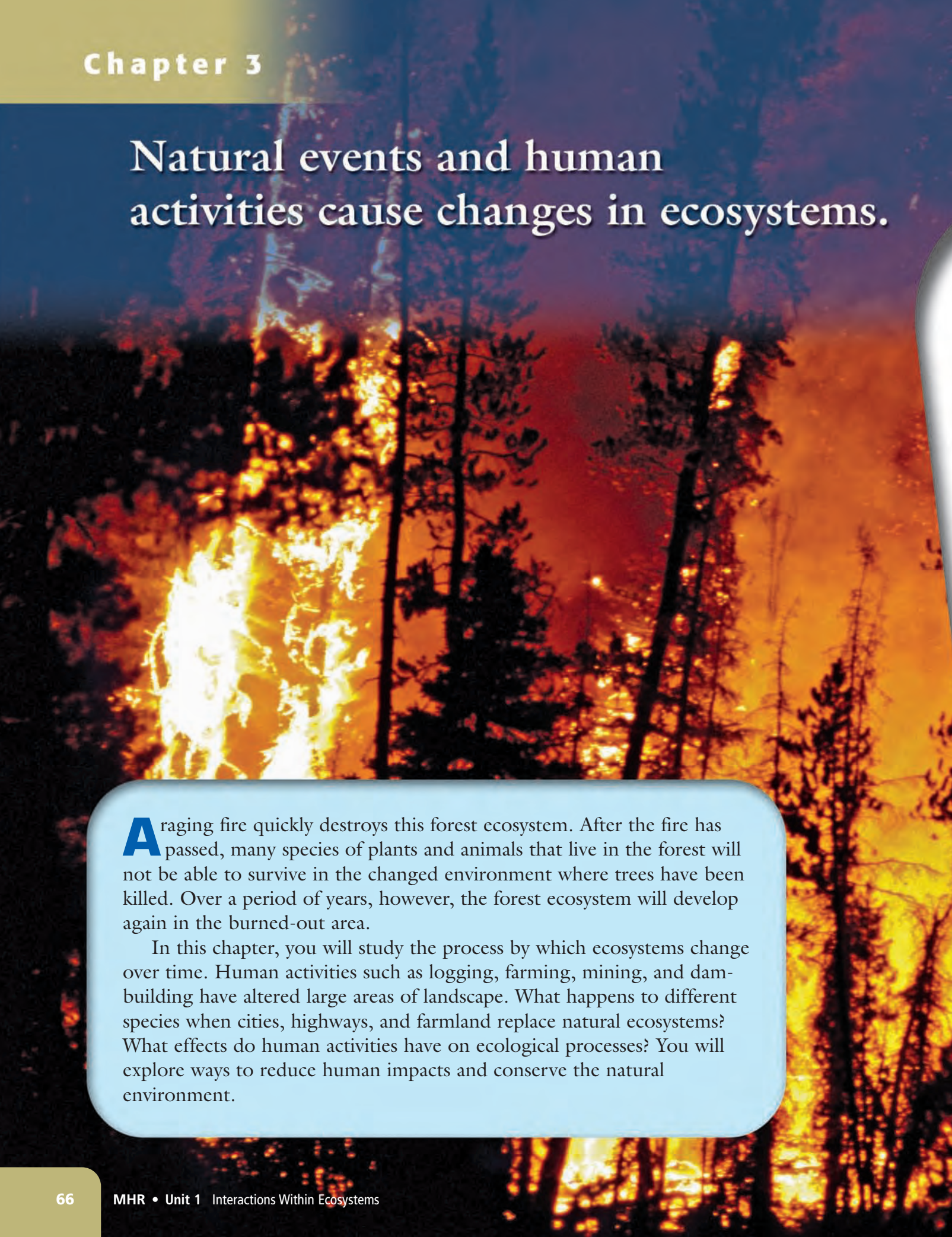
18. Lucy digs manure into the soil around her roses. Explain how this helps her roses to grow.

Pause and Reflect

The largest animals on Earth—blue whales—eat plankton, some of the smallest things on Earth. Based on your understanding of food webs and energy loss in food chains, write a paragraph explaining why these animals can grow so large while eating something so small.

Chapter 3

Natural events and human activities cause changes in ecosystems.



A raging fire quickly destroys this forest ecosystem. After the fire has passed, many species of plants and animals that live in the forest will not be able to survive in the changed environment where trees have been killed. Over a period of years, however, the forest ecosystem will develop again in the burned-out area.

In this chapter, you will study the process by which ecosystems change over time. Human activities such as logging, farming, mining, and dam-building have altered large areas of landscape. What happens to different species when cities, highways, and farmland replace natural ecosystems? What effects do human activities have on ecological processes? You will explore ways to reduce human impacts and conserve the natural environment.

What You Will Learn

In this chapter, you will

- **describe** the process of succession
- **investigate** the impact of human activities on ecosystems
- **debate** the pros and cons of conservation
- **explain** how ecosystems can be monitored

Why It Is Important

Changes in ecosystems can lead to loss of habitats and the species that live in them. Understanding how ecosystems change helps us to conserve and protect the natural environment.

Skills You Will Use

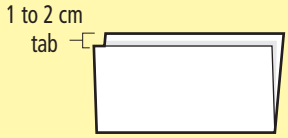
In this chapter, you will

- **model** the process of succession
- **predict** the impact of disturbances on ecosystems
- **communicate** your understanding of habitat conservation

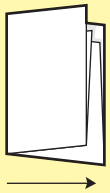
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 3.

STEP 1 **Fold** an 8.5 × 11″ sheet of paper along the long axis, leaving a 1 to 2 cm tab along the top.

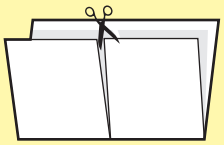


STEP 2 **Fold** the paper in half along its length.



STEP 3 **Unfold** the sheet and **cut** the bottom tab along the fold line as shown.

STEP 4 **Turn** the Foldable so the narrow tab is along the left side.



STEP 5 **Label** the Foldable as shown, with "Changes in Ecosytems" written along the left tab, "Natural Events" on the top tab, and "Human Events" on the bottom tab.

Organize List examples of natural events and human events on the front tabs of the Foldable, and describe the causes and effects of these events under the tabs. A similar Foldable could be made to compare primary and secondary succession, or to examine benefits and drawbacks of conservation efforts.

3.1 Natural Disturbances and Succession

Ecosystems may be disturbed by natural events such as storms and floods and by human activities such as logging and fishing. An area of bare rock can gradually change over centuries into a complex community of species by the process of succession. Each biological community alters its habitat and is replaced in time by populations of other biological communities.

Key Terms

climax community
pioneer species
primary succession
secondary succession
succession

Ecosystems are always changing. Sometimes, a change is rapid and destructive. For example, floods, landslides, and hurricanes can wipe out most of the animals and plants over large areas of land. Human activities can be just as damaging. For instance, paving a parking lot creates an area that is bare of life.

Figure 3.1 This abandoned parking lot has become a habitat for plants adapted to dry, open spaces.

What happens to an ecosystem after it has been damaged by natural events or human activities? Figure 3.1 gives a clue. It shows wild plants growing up through cracks in an abandoned parking lot. If left undisturbed, any area of bare land starts to change as organisms begin to live there.

The first organisms to establish themselves are adapted to survive in dry, exposed areas. As they grow, they change the environment and create habitats for other organisms. For example, the plants in Figure 3.1 provide food and shelter for insects. The insects in turn attract birds and other animals that feed on them. The process by which a biological community changes over time is called **succession.**

3-1A Modelling Succession in a Bottle

Find Out ACTIVITY

Succession can take place in small areas and large areas. It can occur in a short period of time or over many years. In this activity, you will establish an aquatic ecosystem in a bottle. Then you will observe how your ecosystem changes as it slowly becomes drier.

Safety

- Wash your hands thoroughly after handling the materials in this activity.

Materials

- 2 L clear plastic bottle with the top cut off, or large-mouthed jar
- potting soil
- ruler
- water
- small aquatic plant
- 50 mL wild birdseed mix

What to Do

1. Put soil in the bottom of the container to a depth of about 5 cm.
2. Add water to a depth of 7.5 cm.
3. Place the container near a window in an area where it can stay undisturbed for a few weeks. Let the contents settle overnight.
4. Plant an aquatic plant in the container. Although water will evaporate over time, do *not* add more water to the container.
5. Once a week, add three or four seeds from the wild birdseed mix to the container. Record your observations each week.
6. After three or four weeks, add small amounts of water regularly, as you would when watering a houseplant. Continue to record your observations.

What Did You Find Out?

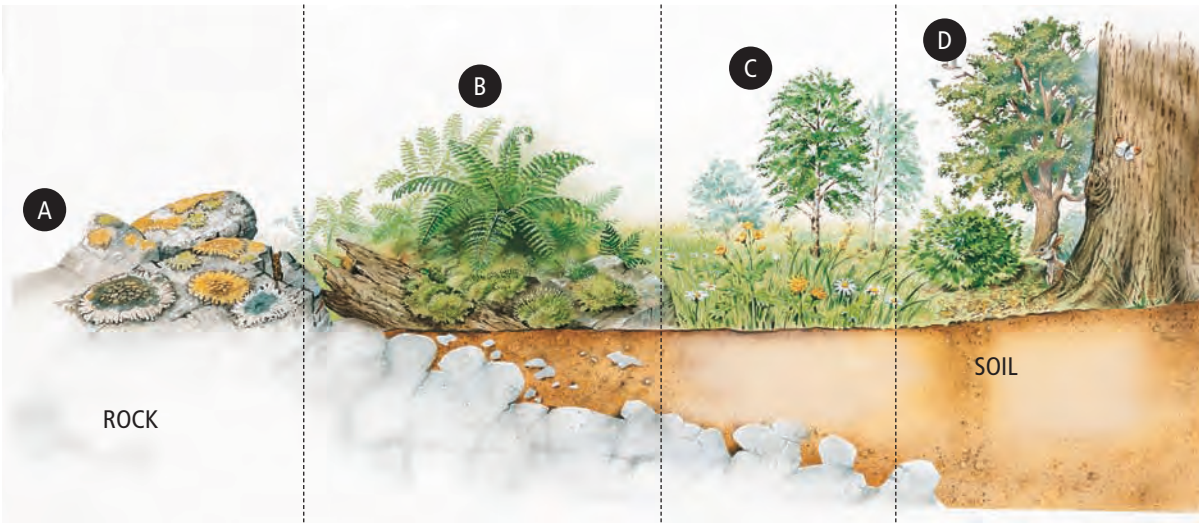
1. Describe what you observed in your container
   (a) before step 5.
   (b) after step 5.
2. Why were you asked not to add water in the initial part of this investigation?
3. Compare the ecosystem in the container at the end of your activity with the ecosystem at the start. Describe both the similarities and the differences.
4. How well do the changes that you observed in the container model succession? Give reasons for your answer.
5. Design your own investigation to observe the effect of a particular environmental change on an ecosystem in a container.

Primary Succession

Just over 10 000 years ago, most of Canada was covered with glaciers. When the glaciers melted, the landscape consisted mainly of bare rock and gravel covered by millions of lakes and ponds. How did this landscape turn into the forests, grasslands, and other ecosystems that we see today?

Organisms that can live in a habitat without soil or shelter include bacteria, mosses, and lichens. Carried by wind or on the feet of birds, lichens can settle and grow on bare rocks as long as they have a supply of water and light. Species that can establish themselves in areas with little or no soil and few nutrients are called **pioneer species.**

Figure 3.2 shows how a simple community of pioneer species can change over time. The sequence of changes that starts with bare rock and eventually develops into a complex community of plants and animals is known as **primary succession.**



A Lichens grow on bare rock. They produce acids that start to break down the rock. Particles of rock and decaying matter from dead lichens begin to form soil.

B The resulting soil is thin and does not have many nutrients. However, plants such as small mosses and ferns can tolerate these conditions. The plants and soil create habitats for insects and other small animals.

C Organisms add more decaying matter and build up the soil. Deeper soils hold water and allow grasses and other plants to grow. More species of animals find food and shelter.

D Taller shrubs create shade. Their deep roots help stop soil erosion. Different communities of plants and animals replace earlier ones. Bushes and trees provide niches for a greater diversity of species.

Figure 3.2 Many ecosystems change and develop over centuries by the process of primary succession.

Does the process of succession ever stop? If an area is not disturbed, it eventually produces a **climax community.** This is a diverse group of species that form a stable ecosystem which can remain relatively unchanged for centuries. Examples of climax communities in Canada include the northern boreal forest and the prairie grasslands.

Secondary Succession

Figure 3.3 shows a forest just after a fire has burned through it. Before the fire, the forest provided a cool, damp, and shady habitat. Now the forest has only blackened tree trunks and a thick layer of ashes on the ground. Sunlight is now able to reach the ground. There are no leaves or branches to soften the intensity of rain when it falls. As a result of the fire, the abiotic conditions of this area have changed. This change has a potent impact on the numbers and species of organisms that visit and populate the area.

Figure 3.4 shows a forest several weeks after a fire. Wildflowers have grown up in the sunny, open spaces between the dead tree trunks. Over time, taller shrubs will grow where the wildflowers once thrived. Trees will begin to grow from seeds left behind in the soil after the fire, or brought by the wind or by animals. After many years, the forest ecosystem will be restored to the type of ecosystem that existed before the fire. The re-growth of a community in an area that has changed dramatically after a disturbance such as fire is an example of **secondary succession.**

Secondary succession is the process by which an ecosystem changes after it has been disturbed. Because the disturbed area is often surrounded by undamaged biological communities, the development of a climax community such as a forest through secondary succession can occur in a matter of years rather than hundreds of years.

Another example of secondary succession in Newfoundland and Labrador sometimes occurs after an area of forest is flooded by a beaver dam. After the dam is abandoned, the shallow beaver pond may, over time, become filled in by soil that is washed in from the surrounding land. This may lead to formation of a bog. As the bog dries out, shrubs and trees take root. Eventually, a forest ecosystem develops again. In many parts of the province, however, abiotic conditions such as the underlying rock, soil acidity or alkalinity, and amount of precipitation do not allow trees and other forest plants to grow. In these areas, a bog forms the climax community.

Figure 3.3 The leaves and branches have been burned off the trees by a forest fire, and the ground is covered with ash.

Figure 3.4 Several weeks after a fire, wildflowers grow among the tree trunks in the bright, open space.

Reading Check

1. What is the difference between primary succession and secondary succession?
2. In your own words, define "pioneer species."
3. What is a climax community?

3-1B Secondary Succession from Beaver Pond to Bog to Forest

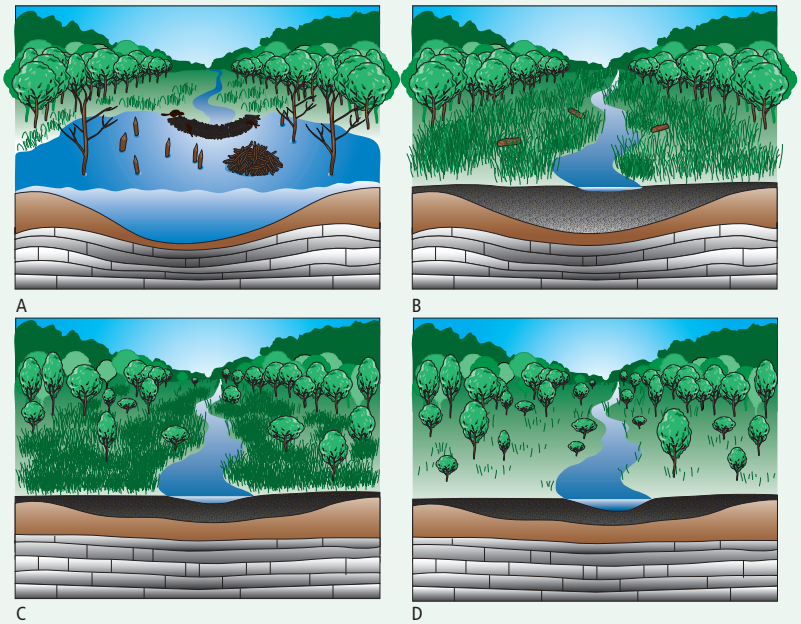
Think About It

A beaver dam like the one shown here blocks a river. The water rises and floods the surrounding forest. The resulting beaver pond kills trees and shrubs by drowning their roots. After a beaver dam has been abandoned and breaks apart, the area gradually dries out. The forest is slowly restored by the process of secondary succession.

A beaver dam creates a pond and drastically alters the forest ecosystem.

What to Do

1. The diagrams below show the stages of secondary succession in a forest ecosystem that was flooded by a beaver pond. In your notebook, make a sketch of each stage. Add labels to identify parts of the ecosystem (for example, beaver pond, bog plants).
2. Describe what is happening during each stage. Refer to changes in
   (a) soil,
   (b) plants,
   (c) animals,
   (d) amount of sunlight.
3. Look at panel C of the diagram below. Suppose you walked in a straight line from the edge of the river through the bog plants and shrubs to the forest trees. Describe how the changes in habitat along your walk represent different stages of succession.
4. Construct your own flow chart of images to illustrate the changes that occur during primary succession, starting with bare rock and ending with boreal forest. How do these changes compare with those that occur during secondary succession?



Check Your Understanding

Checking Concepts

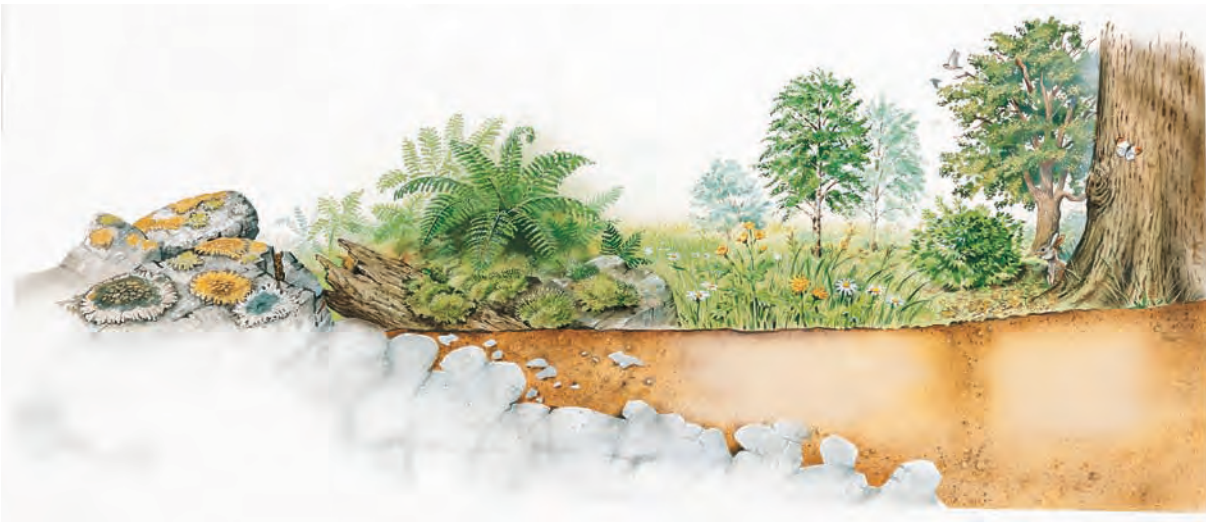
1. Define the term *succession*.
2. Give one example of a natural event and one example of a human activity that is followed by secondary succession.
3. Make a flow chart to show the changes that occur during the process of secondary succession in a forest after a fire.
4. Why is lichen termed a "pioneer species"?
5. Name two examples of a climax community. Where might you find an example of each?
6. The diagram below shows stages of succession from bare rock to the establishment of a forest. Sketch the key features of this diagram in your notebook, and label the diagram to explain what is happening at each stage of succession.

Understanding Key Ideas

7. What evidence would indicate that a shallow pond once existed in an area that is now a forest?
8. During a drive through some farmland you notice an old farm field overgrown with weeds and shrubs. Predict what the field will look like after several more years if it continues to be left undisturbed. Explain your prediction.
9. Use a specific example to explain how a community of plants and animals alters the environment to create new conditions that allow other species to live in the area.

Pause and Reflect

Both natural events and human activities can destroy ecosystems. Does this mean that humans do not have to be concerned about their impacts on the environment? Give reasons to justify your answer.



3.2 The Impact of People on Ecosystems

Humans have a major impact on ecosystems because of our powerful technologies and large human population. The main impacts include loss of habitat, introduction of alien species, overharvesting of natural resources, and pollution. Decisions about conservation of natural areas depend on scientific evidence as well as economic, cultural, and other factors.

Key Terms

acid rain
endangered
extinct
introduced species
monoculture
native species
natural resources
pollutants
renewable resources
sustainable
unsustainable

Imagine you are suspended by a hot air balloon above the place where you live. What do you see below you? There will be buildings and roads. Depending where you live, there may be trees, parks, playing fields, gardens, and perhaps a pond or river. Farther away, you may see fields, forests, bogs, mountains, tundra, the ocean, a mine, an airport, more buildings, golf courses, or factories.

Now imagine you are looking at the same area 50 years ago (Figure 3.5). How would it be different from the way it looks today? What might it have looked like 100 years ago?

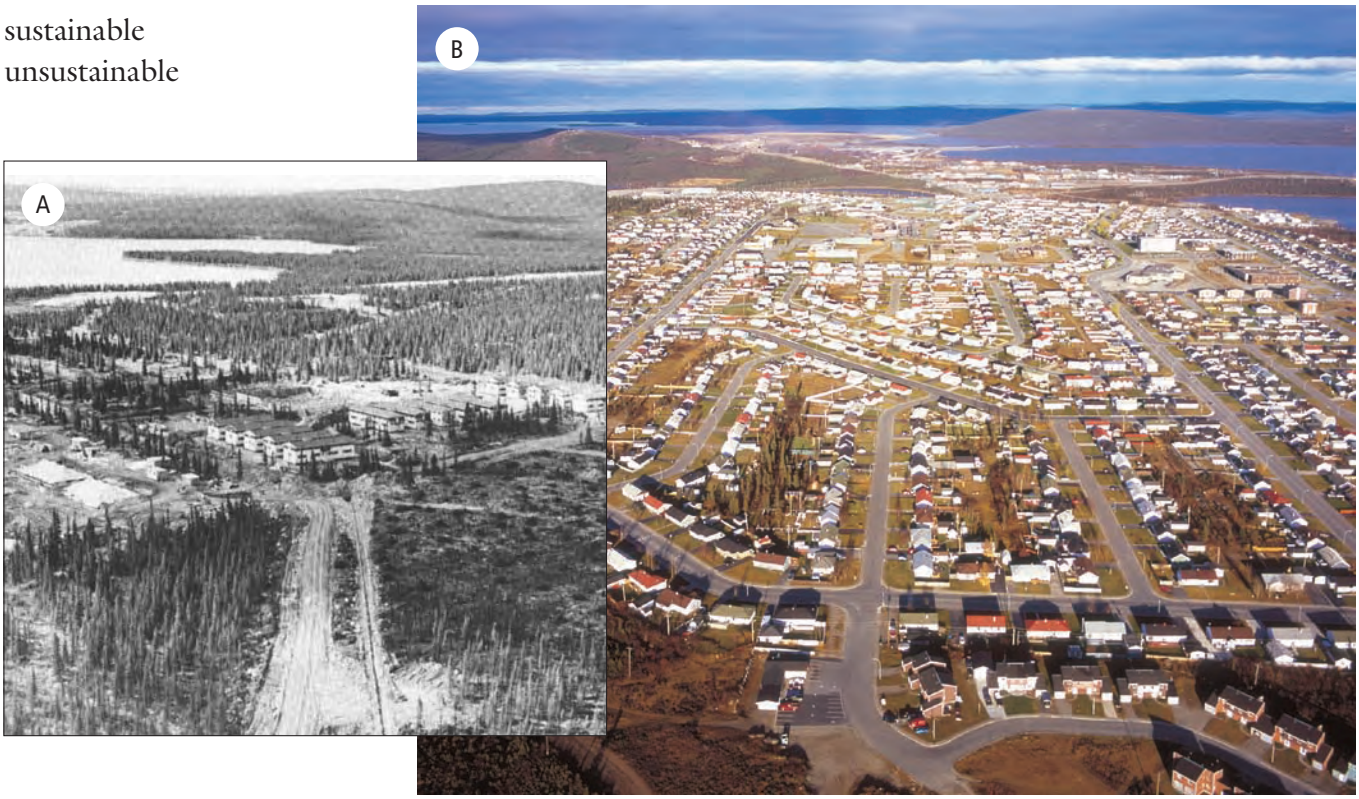


Figure 3.5 The aerial view of Labrador City in 1962 (A) is barely recognizable as the same city forty years later (B).

3-2A Mapping Your Home

Find Out ACTIVITY

How much do you know about the natural world where you live? This activity gives you a chance to find out. Mapping is one tool that people use to record data about ecosystems. What would you include if you drew a map of the ecosystem around your home?

Materials

- large sheet of paper
- coloured markers

What to Do

1. Mark a dot at the centre of your sheet of paper to represent your home. Add a label to identify it.
2. Use the steps below to help you add details to the map. Details do not need to be to scale. Use different colours and labels for each feature. Don't worry if you are not able to answer all the questions. You can carry out research later to fill in more parts of the map.
   (a) Draw the nearest body of fresh water.
   (b) Show the source of your drinking water.
   (c) Add landforms such as mountains, rivers, or coastline.
   (d) Show where wastes from your community go. (Include household garbage and wastes that go down the drain.)
   (e) Sketch areas of vegetation. Include natural (for example, forest, bog) or human-made areas (for example, school field).
   (f) At the side of the map, sketch three plants that are natural to the area.
   (g) Sketch three wild animals that live in the area. Try to include one land animal, one bird, and one aquatic animal, if possible.
   (h) Indicate the direction in which the sun rises.
   (i) Show a natural area that is being conserved or protected from development.
   (j) Show a natural area that is being altered by human activities.
3. Share your map with your classmates. Discuss any questions that you had difficulty answering and add any new information to your map. If you still have unanswered questions, use the library or the Internet to research further. You can also ask your teacher or another adult to help with your research.

What Did You Find Out?

1. How well do you think you understand the environment in which you live? Explain your answer.
2. What are some ways that you could increase your understanding of the environment in which you live?
3. How might your everyday activities affect the natural community around your home?
4. What are two ways that you could monitor plants or animals in your ecosystem?
5. What type of long-term study could ecologists do to learn more about your ecosystem?

Changing Ecosystems

Like all species, humans depend on ecosystems for food, water, and places to live. Unlike other species, however, humans have developed technologies such as powered vehicles and machinery. Our technologies enable us to have a much greater impact on ecosystems than other species do (Figure 3.6).

Figure 3.6 Human development can drastically alter the landscape in an area. This can have a dramatic impact on the local ecosystem.

The impact of a species is also related to its population size. In 1950, the total human population was about 2.6 billion. In 2007, the world population reached 6.6 billion people. The human population increases by over 200 000 people each day. Such large numbers of people, combined with our powerful technologies, has produced a growing demand for natural resources. **Natural resources** are materials and products found in nature that people use to meet their basic needs. Water, oil, metals, lumber, fish, and land for buildings and for growing crops are examples of natural resources.

One of the key differences between the world of today and the world of 50 years ago is that human activities now use greater areas of land. There are more cities and highways, more mines to obtain minerals and metals, and more dams built to produce hydro-electricity. Bogs have been drained and forests cut. Our garbage and wastes pollute more land and water. As human activities have spread, the areas occupied by natural ecosystems have shrunk.

In 1950, about one-third of the world population lived in towns and cities. The majority of people lived in rural areas. Today, more than half of all the people in the world live in cities. It is difficult for city-dwellers to make the connection between their lives in the city and the natural ecosystems on which they still depend (Figure 3.7).

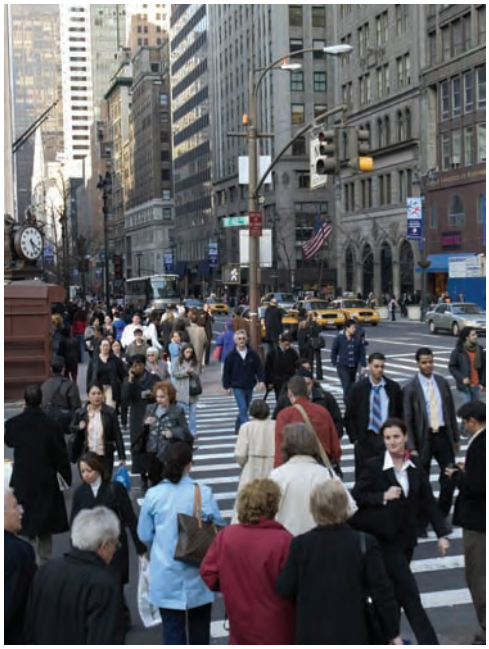


Figure 3.7 City-dwellers often do not see the natural ecosystems on which they depend.

Habitat Loss

Table 3.1 below lists some common human activities and the direct effects they have on land, water, and vegetation. Each activity also has indirect effects on ecosystems. For example, removing vegetation and soil removes food and shelter for many animals. Changes on land can alter the drainage of water, which affects ecosystems in rivers and lakes.

Wherever each of these activities is carried out, habitats for plants and animals are lost. What happens to water plants when a pond is drained? What do moose do when a forest is logged? The loss of habitats usually leads to the loss of many species from an area.

Word Connect

The range of organisms present in a community or ecosystem is known as biodiversity.

Table 3.1 The Effects of Human Activities on Ecosystems

Activity	Physical Impact on Ecosystems
Construction of roads and buildings	Removes vegetation and paves over soil. May alter slope of land and divert rivers and streams.
Mining	Removes vegetation, soil, and rock. Alters slope of the land. May clog streams.
Dam building	Alters river course. Floods land. Creates lakes.
Logging	Removes vegetation. May clog streams and increase soil erosion.
Farming	Removes native vegetation. May drain wetlands and increase soil erosion. May divert water for irrigation and remove nutrients from soil.
Manufacturing and consumption of goods	Produces waste products and garbage that must be disposed of on land or in water. May produce air pollution.
Oil drilling, refining, and transportation	Construction of rigs, refineries, and pipelines damages vegetation, soil, and rock.
Outdoor recreation	Ski lifts, golf courses, all-terrain vehicles, speed boats, and other recreational activities can damage vegetation, soil, and waterways.

Endangered Species

Some plants and animals can live in a wide range of habitats. Coyotes, for example, can survive in grasslands, farmland, woodlands, and even on the outskirts of cities. Most species, however, cannot survive if their habitat is destroyed. The loss of habitat is the largest single cause of the decline in populations of wildlife.

Figure 3.8 The adaptable coyote can survive in environments that humans have altered.

Today, many species in Canada and around the world are in danger of extinction. A species is **extinct** when there are no longer any living individuals of that species anywhere in the world. A species is said to be **endangered** when it has such a low population that it is nearly extinct. Endangered species can only be saved by very strict protection of their habitat or by collecting individuals and breeding them in a refuge such as a zoo or botanical garden.

Does it matter if species become extinct? On page 25 you learned that each species has a different niche in a community. When a species disappears, therefore, ecological processes are disrupted and the entire community is affected. Habitat loss is not the only reason that so many species are at risk of extinction. They are also threatened by the impacts of introduced species, overharvesting, and pollution.

Did You Know?

Twenty species of animals and plants in Newfoundland and Labrador are endangered, threatened with extinction, or of special concern because they are sensitive to human activities and natural events.

Impact of Introduced Species

Most wild species that you see today have lived in their environment since before humans settled the land. They are called **native species.** Some species, however, have spread beyond their natural range into new locations as a result of human activities. These are called **introduced species.** You might also hear introduced species referred to as alien species, exotic species, or non-native species.

Some species are introduced deliberately by humans. For example, early European settlers in Canada brought their farm animals, crops, garden plants, and pets from Europe. Other species arrive by accident, travelling on ships or planes with cargo. For example, pests like the Norway rat and disease organisms such as influenza and smallpox arrived in North America with the first European settlers. With the increase in global travel, introduced species continue to invade ecosystems around the world.

Some introduced species spread rapidly in their new homes. As their populations expand, they can displace or destroy native species, damage ecosystems, and cause harm to the economy or to human health. For example, purple loosestrife is a garden plant introduced to Canada from Europe. People brought it to Canada because its rich purple colour and pleasing shape make gardens look more attractive. Purple loosestrife grows especially well in wetland areas. It grows so well that native species, which normally develop at the next stage of succession around wetlands, cannot become established. As a result, purple loosestrife has now spread through wetland areas over much of North America. Over time, the loosestrife removes much of the water from wetland areas, making them unsuitable for the hundreds of species of plants and animals that depend on wetlands to survive.

Introduced species can also affect ecological processes. For example, Eurasian water milfoil is a water plant found in ponds and lakes in parts of Canada. It grows rapidly to form huge mats of vegetation. When the plants die and decay, large amounts of nutrients are added to the aquatic ecosystem, unbalancing the normal nutrient cycle (See Section 2.4).

Figure 3.10 Dense mats of water milfoil cover the edges of a lake.

Did You Know?

Almost half of the mammal species found on the island of Newfoundland are not native. For example, moose were first introduced from other parts of Canada in the late 1800s.

Figure 3.9 Purple loosestrife is an introduced species that is difficult to control.

Reading Check

1. Give three examples of natural resources.
2. What is the difference between an extinct species and an endangered species?
3. What is the difference between a native species and an introduced species?

Impact of Overharvesting

If you catch some fish in a lake, eventually as the remaining fish in the population reproduce, they will replace those that you caught. If you cut down some trees in a forest, new trees will grow in their place. Living natural resources, such as fish and trees, are called **renewable resources** because they grow and reproduce in a fairly short time to replace those taken from the environment.

When resources are renewed as quickly as they are used, the harvest is **sustainable.** A resource that is harvested at a sustainable rate can be used year after year, indefinitely, without danger of disappearing.

Today, the growing human demand for resources has led to **unsustainable** rates of harvesting. This means that resources are used faster than they can be renewed. The result of unsustainable harvesting is a shrinking supply of resources.

Atlantic Cod Fishery

For hundreds of years, fishing boats brought back rich harvests from the seas off the coast of Newfoundland and Labrador. By the 1990s, the seemingly limitless fish stocks had almost disappeared and the fishing industry of eastern Canada was closed (Figure 3.11). What happened?

- *New fishing technology* Starting in the 1950s, fishing nations built larger, faster fishing vessels. They used larger nets and could stay out in the ocean for longer periods by processing and freezing fish on board. They used underwater sonar and other detectors to scan the ocean for schools of fish.
- *More demand* A growing demand for protein caused fishing nations from around the world to join Canadians in the Atlantic. By the mid-1960s, 18 nations had fishing vessels on the Grand Banks.

Figure 3.11 The reproductive rate of fish is no match for the human rate of catching them.

- *Lack of conservation* Some scientists have warned of the risks of overfishing in the past. In 1974, limits on the quantities of fish caught were set by international agreement. However, each fishing nation wanted the maximum amount of fish it could catch, and regulations were ignored.
- *Unsustainable harvesting* In 1977, Canada extended its control over Atlantic fishing to 322 km (200 miles) from shore. This regulation, still commonly known as the "200 mile limit", was meant to conserve fish stocks. However, Canadian fishing fleets increased their catch after fishing boats from other nations were limited. At the same time, foreign vessels started fishing on the Nose and Tail of the Grand Banks. These were important areas where many species of fish reproduced. The fish populations collapsed.

Reading Check

1. Use examples to explain what is meant by "renewable resources."
2. What makes a renewable resource sustainable?
3. What conditions make the harvesting of a resource unsustainable?

Impact of Pollution

Figure 3.12 shows vegetables growing in a field. This method of planting large areas with a single crop is called a **monoculture.** As well as producing food for humans, however, the field is a huge source of food for insects that eat vegetables. To protect their crops from insect pests, farmers spray the fields with pesticides. To increase the growth rate of their crops, farmers add fertilizer to the fields.

Figure 3.12 Modern farming methods have many impacts on ecosystems, including pollution.

Did You Know?

Waste oil dumped from ships kills over 300 000 seabirds annually off the coast of Newfoundland and Labrador alone.

Figure 3.13 Oil from ships coats the feathers of seabirds. The birds drown or become poisoned when they try to clean themselves.

Added pesticides and fertilizers are two examples of pollutants. **Pollutants** are substances that cause harm to the air, soil, water, or living things. For example, pesticides pass from insect pests into food chains, where they may kill beneficial organisms such as birds or frogs. Fertilizers wash from farmers' fields into waterways, where they cause excessive growth of water plants.

Pollutants are produced by many human activities. Often, they are indirect waste products, such as the exhaust gases that come from vehicles and factory chimneys, or chemical wastes that leak into waterways from garbage dumps. Sometimes they are the result of accidents or deliberate dumping. For example, waste oil is often dumped into the ocean from ships.

Pollutants may have a direct impact on organisms, like the oil covering the seabird in Figure 3.13. Pollutants also have indirect impacts as they move through ecosystems. For example, burning fossil fuels produces waste gases that contain sulfur and nitrogen. These pollutants combine with water vapour in the atmosphere to produce acids. The acids fall from the atmosphere in precipitation as **acid rain.** Acid rain is a particular problem in Newfoundland and Labrador because much of the land is formed of granite rock, which lacks the ability to neutralize acid. Figure 3.14 shows the pH scale on which acidity is measured. A low pH can kill plants and animals on land and in aquatic ecosystems.

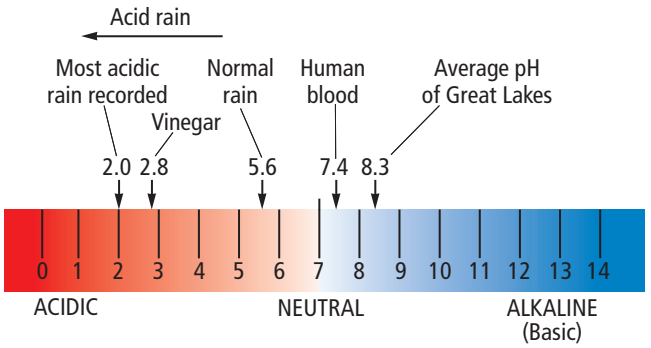


Figure 3.14 The pH scale measures acidity. It ranges from 0 (very acidic) to 14 (very basic). A value of 7 is neutral.

Reading Check

1. What can happen when people grow crops as a monoculture?
2. What are pollutants?
3. How is acid rain formed?

3-2B The Pros and Cons of Conservation

Think About It

From cod fisheries to forests, Canadians have been facing the problems of overharvesting natural resources. On one hand are the risks of overharvesting, habitat destruction, and the loss of biodiversity. On the other hand are concerns for maintaining jobs, demand for resources, and other human needs.

What to Do

Choose a local issue that involves the conservation of natural resources. For example, the construction of a highway may require trees to be cut. Wastes from a factory may pollute a pond or river. A mine may be planned in an area where rare plants are growing.

Research both sides of the issue.

What Did You Find Out?

1. Decide which side you support, then write a letter to a government representative, create a poster, conduct a debate, or use another method to present and defend your position.

3-2C Checking the pH

Find Out ACTIVITY

How acidic is the rain where you live? In this activity, you will find out.

Materials

- clean collecting jars with lids
- labels
- samples of rainwater
- samples of pond or river water
- sample of tap water
- pH indicator paper

Safety

- Use caution when collecting samples from ponds or rivers.

What to Do

1. As a class, collect several water samples from different sources and locations in your neighbourhood. These may include puddles, ditches, streams, ponds, lakes, and melted snow. Collect a sample of tap water. Label each sample.
2. Dip a piece of pH indicator paper into one sample. Observe the colour of the paper and compare it to a pH chart. Record the pH of the sample.
3. Repeat the procedure for every sample.
4. Clean your work area and wash your hands after this activity.

What Did You Find Out?

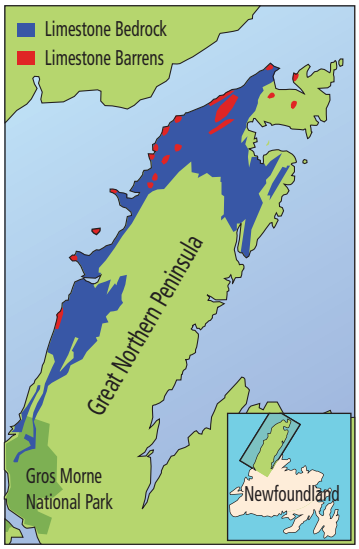
1. Were your neighbourhood water samples acidic, basic, or neutral?
2. Was your tap water sample acidic, basic, or neutral?
3. Based on your results, has the water in your local area been affected by acid precipitation? Explain why or why not.

Science Watch

Protecting the Limestone Barrens

It's hard to believe that part of the island of Newfoundland was once the floor of a shallow tropical sea. Yet, over 450 million years ago that's just what it was. Now known as the Limestone Barrens, this area was later lifted above sea level by moving tectonic plates. The limestone was formed from the layered shells of marine organisms that lived long ago.

The Limestone Barrens stretch 300 km along a narrow strip of land on the west coast of the Great Northern Peninsula. At first glance, this area looks harsh and uninviting. The Barrens are made up of gravel and limestone bedrock pummelled by strong winds and arctic-like temperatures. If you look more closely, though, you'll see that small plants manage to thrive there by anchoring themselves between the rocks and cracks in the limestone.



These calciphiles, or "calcium-loving" plants, don't have large exotic flowers or a lot of leaves, but some of them can't be found anywhere else on Earth. The Limestone Barrens make up only 1 percent of the island of Newfoundland, but they are home to 114 of the island's 271 rare plants. Two examples are Long's braya, which is an endangered species, and Fernald's braya, which could soon become an endangered species.

People used the Barrens to quarry limestone and extract gravel to help pave the Northern Peninsula highway. It was also used as a racetrack for all-terrain vehicles (ATVs), which tear up rare plants and compress the limestone gravel so that new plants can't grow in their place.

Although the rare plants were first described in the 1920s by botanist Merritt Lyndon Fernald (for whom the Fernald's braya is named) it wasn't until the 1990s that local residents realized just how special the Barrens are. Since then, conservation groups like the Limestone Barrens Habitat Stewardship Program (LBHSP) have formed to help protect this fragile habitat.

Group members put up signs on the Barrens to inform people about the unique plants. The members visit schools and community centres to talk about the Barrens. They also conduct field trips to encourage local residents to take pride in the extraordinary ecosystem they once took for granted.

Questions

1. Why are calciphiles able to survive on the limestone gravel soil of the Limestone Barrens?
2. Do you think it is important to save unique places like the Limestone Barrens? Why or why not?

Checking Concepts

1. Name two reasons why the human demand for natural resources has increased over the past 100 years.
2. Describe three human activities that have a physical impact on the landscape.
3. Name four factors that can lead to the extinction of species.
4. Why might the extinction of a species have an impact on an entire biological community?
5. What are introduced species?
6. Why are fish considered to be a renewable resource?
7. Use an example to explain what is meant by "unsustainable harvesting."
8. Describe two activities that produce pollutants.
9. Give two examples of natural disturbances and two of human disturbances to an ecosystem.

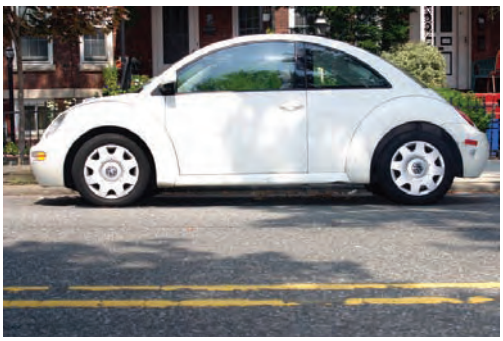
Understanding Key Ideas

10. Humans use technology to meet their needs and their wants. The pictures below show three commonly used technologies. Is each essential to your survival? What resources does each use?
11. A plantation of trees is a monoculture. In your own words, explain the meaning of this statement.
12. Why is habitat loss the biggest single threat to the survival of many species?
13. A species of wildflower grows only near an area of wetland in Newfoundland and Labrador. Researchers discover that the population of this plant has declined since last year. A building project nearby has been draining parts of the wetland and filling other areas with dirt.
    (a) What connection might there be between the decline of the plant population and the human activities occurring in this area?
    (b) What could be done to stop or slow down the decline of the plant population?

Pause and Reflect

Extinctions have occurred ever since there have been living things on Earth. Why should we be especially concerned about the extinction of species today?

A



B

C

3.3 Monitoring and Managing Ecosystems

Environmental monitoring is used to detect changes in ecosystems. Different methods of monitoring focus on physical, chemical, biological, and atmospheric changes. Information from monitoring can be used to help manage and protect ecosystems.

Key Terms

baseline data
climate change
environmental impact assessment
environmental monitoring
long-term monitoring
permanent plot

How would you know if an ecosystem has been disturbed and is in need of protection? Some types of damage are obvious. For instance, an outbreak of spruce budworm can kill trees over a large area of forest in just a few years. Other changes happen slowly and are not obvious. Habitats may be disturbed and species may begin to disappear before people are aware of what is happening. One way to detect such changes is by **environmental monitoring** (Figure 3.15). This refers to checking and measuring different parts of the environment at regular intervals.

Figure 3.15 Examples of environmental monitoring.
A. Physical monitoring tracks changes in the landscape over time. For example, satellite maps show how fast forests are shrinking, and deserts are growing.
B. Atmospheric monitoring measures changes in air and water temperatures and weather patterns, such as hurricanes and droughts.
C. Chemical monitoring tracks changes in the levels of chemical pollutants in the air, water, and soil.
D. Biological monitoring tracks changes in the distribution and population size of organisms.

Figure 3.15 shows four basic types of environmental monitoring. Each measures different parts of the environment and uses different techniques. Together, they indicate how well ecosystems are functioning and how they are changing over time. Monitoring also helps track the responses of ecosystems to human activities and natural events such as volcanic eruptions.

Did You Know?

Bacteria have been found to live in water temperatures of 90°C and in water as acidic as vinegar.

Long-Term Monitoring

Suppose you count a population of 67 moose in a provincial park one year. The next year you count 37 moose. Is this data enough to tell you about the health of the moose population? Not really. You have learned how some populations of organisms may change naturally from year to year. In order to discover if the environment is changing in a significant way, it is necessary to carry out **long-term monitoring** over a period of many years.

To carry out long-term monitoring, researchers often use volunteers, such as the students shown in Figure 3.16, to help them collect data. In addition, groups of bird watchers across Canada carry out counts of the different species of birds they observe in their area each year. Some local groups have been collecting bird population data for over 30 years!

In 2007, the National Audubon Society used information gathered in this way to warn people that 20 of the most common birds living in North America had radically declined in numbers over the past 40 years. For example, observers counted about 31 million bobwhite quail in 1967. In 2007, there were only about 5.5 million.

internet connect

Are you interested in volunteering to be part of a monitoring program in your area? You can find out what's available by starting your search at **www.discoveringscience.ca.**

Figure 3.16 Student volunteers help to collect data that is vital in monitoring the health of a population or an ecosystem.

Methods of Monitoring

The environment is complex and ever-changing. Because of this, the methods of collecting data for long-term monitoring must be consistent. For example, if you want to learn if the climate is changing, you must measure temperature, wind speed, precipitation, and other factors with exactly the same instruments, in the same places, at the same time each day or week or other interval (Figure 3.17). If you do not do this, you cannot easily determine whether changes in data are due to changes in the environment or changes in your methods!

Figure 3.17 Once this weather buoy is deployed and is anchored in the ocean, it will collect data about the atmosphere and ocean. Data from this buoy, as well as others, are transmitted to a central location where they are analyzed and interpreted by computers.

Baseline data are measurements that form a starting point from which later changes can be monitored. For instance, scientists might count the average number of trees per hectare in a forest that they are studying. Suppose there is a forest fire. Scientists can use their baseline data, together with the size of the area burned, to estimate the number of trees that were destroyed. They can also use the baseline data to measure whether the number of trees growing after a fire is greater, less, or the same as before the fire.

Permanent plots are sample areas of a habitat that scientists monitor year after year. For example, it is not practical to monitor millions of hectares of an area such as a grassland. Instead, researchers mark off a few one-hectare plots in different locations. They can study these plots in detail over a long period of time. It is likely that any changes that are observed in the sample plots are also taking place over the grassland as a whole.

Grasses, trees, and other plants stay in one place, but most animals move. Some species migrate over hundreds or thousands of kilometres during different seasons. To study changes in animal populations, scientists may carry out annual surveys. The bird count described on page 87 is an example of an annual survey.

Methods of counting animals depend on the size and habits of the species. For instance, aerial photographs may be used to make graphs such as the one in Figure 3.18. Data from people who hunt or fish are sometimes used to monitor changes in numbers of some species. Many animals can be fitted with tags, leg bands, or radio collars. They are then tracked using equipment such as that shown in Figure 3.19, and the data are mapped to indicate how far the animals move. This data helps scientists decide where habitats might need conserving.

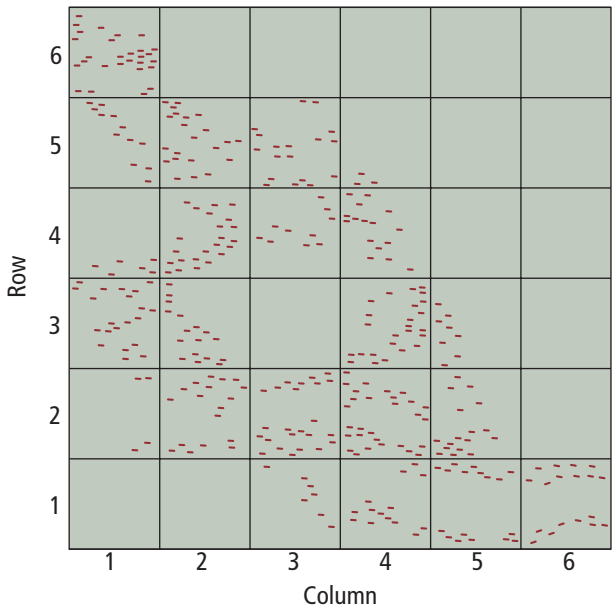


Figure 3.18 This graph was drawn using data from aerial photographs of caribou in Nunavut. The total area of the graph represents 1 km^2 on the ground, and each marking represents one caribou.

Figure 3.19 This researcher is holding an antenna to detect radio signals transmitted from an animal with a radio collar.

Reading Check

1. Name four basic types of environmental monitoring.
2. Give an example of baseline data.
3. Why is long-term monitoring needed to detect significant changes in the environment?
4. Name a method commonly used to monitor the size of animal populations.

Managing Ecosystems

Suppose you are managing a forest that contains moose. Is the moose population too high or too low? How can you manage the numbers of moose? When moose were first introduced to the island of Newfoundland, they spread rapidly. After wolves became extinct on the island in the 1920s, there were no natural predators to control the moose population. Moose hunting was established in 1935. Since then, more than three quarters of a million moose have been harvested by hunters in Newfoundland and Labrador.

A high moose population is a benefit to hunters. It also draws tourists who like to see and photograph these wild animals. But moose are not a benefit to foresters, bird watchers, or unwary drivers. Moose on the island of Newfoundland have altered natural plant communities by overgrazing. They damage young trees, reducing future timber crops. They remove shrubs that shelter nesting songbirds. They are also involved in costly collisions with cars every year (Figure 3.20). Managing forest resources must balance all these different factors.

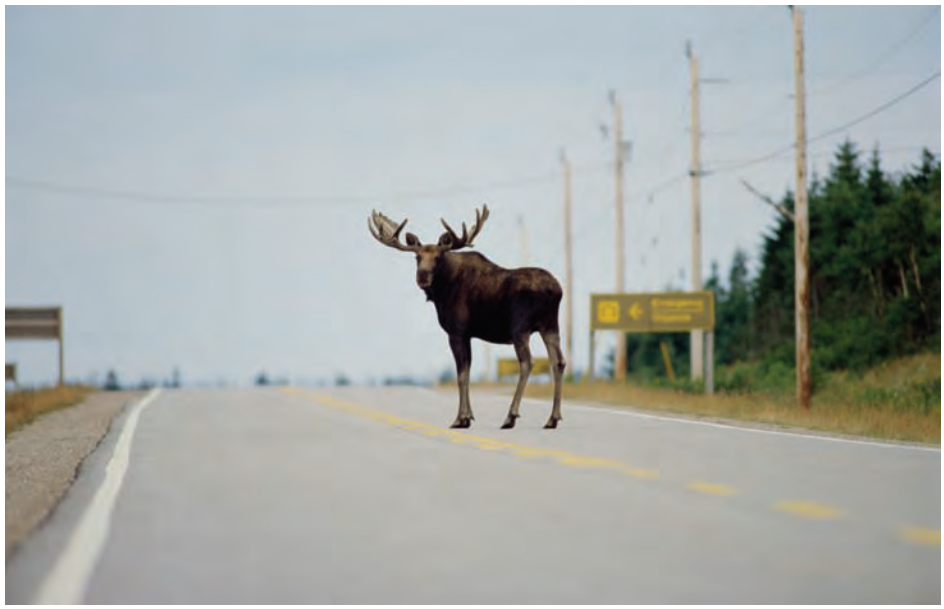


Figure 3.20 Moose are a novel sight for tourists, but they are dangerous to motorists. They can also cause damage to vegetation and bird habitats.

Prevention is Better Than Cure

Whether the threat to an ecosystem comes from animals, plants, pollution, or development, it is easier to prevent harm before it occurs than it is to control damage later. For example, there are laws that protect habitats and rare species. There are also laws that restrict development in certain areas, ban the import of alien species, and ban the use of some toxic chemicals.

Many individuals and organizations in Canada carry out education programs and activities that help conserve natural ecosystems. These groups include The Conservation Corps, World Wildlife Fund, Canadian Parks and Wilderness Committee, and the David Suzuki Foundation.

Predicting Changes to Ecosystems

One goal of environmental monitoring is to measure changes in ecosystems. These measurements also allow us to predict how ecosystems could change in the future. One of the best known examples of prediction concerns **climate change.** Scientists have warned that Earth is undergoing major shifts in climate, based on their long-term monitoring of changes in atmospheric gases, air and ocean temperatures, melting of glaciers, and other data. Analyzing these trends, they predict that one result will be warmer average temperatures over much of the planet.

The ability to predict changes to ecosystems is important for planning future developments. For example, if a company wants to blast rock and cut trees to make a level area to build a shopping mall, what effect will this have on surrounding habitats? Scientists can make reasonable predictions about the impact using studies of the environment as it exists now and data from similar environments that have already been changed.

A report that outlines how an activity will affect the environment is called an **environmental impact assessment.** Developers and governments use these reports to plan how to minimize harm to an ecosystem. If the predicted changes are too destructive, local citizens, conservation organizations, and governments may argue that the proposed activity should not be allowed.

Did You Know?

Canada had its first known case of infection by the West Nile virus in Ontario in 2002. The virus can be transmitted to humans by mosquitoes after they feed on the blood of a bird infected with the virus. The disease organism was once restricted to parts of Africa, but is now able to survive in Canada due to milder winters.

internet connect

In what ways is climate change linked to the health of people and other organisms in Canada? Start your research at **www.discoveringscience.ca.**

Reading Check

1. Why did the moose population on the island of Newfoundland increase so much after the animals were introduced onto the island?
2. Name two groups that help to conserve natural ecosystems in Canada.
3. Give a reason why it is important to be able to predict changes to ecosystems.
4. What is an environmental impact assessment?

3-3A Modelling an Environmental Impact Assessment

Think About It

The ways in which people use land and water can have far-reaching effects. How many resources should be used for human needs and how many for wildlife? Decisions should be made using social, economic, and ecological factors.

What to Do

1. As a class, identify a local project that involves a conflict over land use, or create a scenario that you can use for this activity. Agree on four to six roles that you will use to discuss the project and its impacts. Half of the roles will support the project and half will oppose it. For example, the project may be to open a mine near a fishing lake. Supporters might include unemployed miners, local businesses, and companies that use minerals from the mine. Opponents might include local fishermen, the Minister of Tourism, and residents concerned about water quality.
2. Form groups so that each group represents one role. You do not have to agree with the point of view of your group's role, but you must present it fairly.
3. Use your library, the Internet, and other sources to research the issue. Focus on questions that you may be asked in your group's role. For example:
   - What economic benefits will the project bring?
   - What impacts will it have on the soil, vegetation and water?
4. When you have collected information that answers your questions, prepare a presentation for the Environmental Impact Assessment Board. This role will be played by your teacher. Use charts, tables, or graphs to display data where possible.
5. Present your case to the class, allowing time for questions.
6. Based on the information presented, draft a report that recommends whether the project should be approved, abandoned, or modified. This outcome should be a joint decision by the class.

What Did You Find Out?

1. Give an example of how your studies of ecosystems helped you to research and present your arguments.
2. Were there important questions or issues not covered by this process? If so, what were they?
3. Describe an advantage and a disadvantage of the process you modelled in this activity.

Checking Concepts

1. How does long-term monitoring help people to conserve natural ecosystems?
2. What are four types of ecosystem monitoring? Give an example of something that would be measured for each type.
3. (a) What is meant by baseline data? (b) Why is it useful?
4. Give an example of a monitoring program that uses volunteers. Why are volunteers important in such programs?
5. Give an example of something that can be measured by an annual survey. What method could be used to collect the data?

Understanding Key Ideas

6. What is the goal of an environmental impact assessment?
7. Explain what baseline data you would collect to determine whether acid rain was a growing problem in your area.

Pause and Reflect

Some time within the next 50 to 100 years, we can expect to see humans landing on, exploring, and even living on the planet Mars. One goal of many scientists who dream of living on other planets is to make these planets able to support human life and the life of other organisms we want or need for survival. The process of making a world able to support human life is called terraforming. Terraforming would change the abiotic conditions of Mars. For instance, it would increase the amount of oxygen in its atmosphere. It would also change the climate of the planet.

(a) Do you think that an environmental impact study of another planet, such as Mars, is necessary before humans start to terraform the planet? Give reasons for your answer.

(b) Assume that Mars is shown to have absolutely no life of any kind, now or in the past. Would that change your answer to part (a)? Why or why not?

(c) Assume that Mars is shown to have a few populations of bacteria and other microscopic organisms that live on the planet now. Does that change your answer to part (a)? Why or why not?

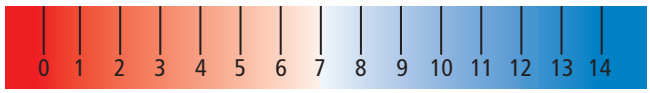
Prepare Your Own Summary

In this chapter, you investigated how natural events and human activities cause changes in ecosystems. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. The Process of Succession
2. Examples of Human Activities
3. Impacts of Human Activities
4. Monitoring and Managing Ecosystems

Checking Concepts

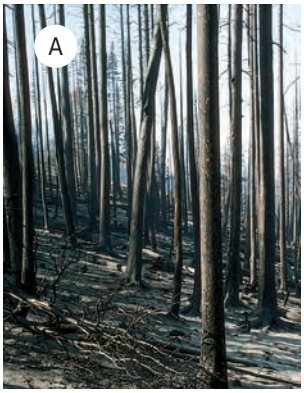
1. Three of the following terms are answers to the three questions below: primary succession, secondary succession, pioneer species, endangered species, introduced species.
   (a) What is the term used to describe the re-growth of an area of forest that has been flooded by a beaver pond?
   (b) The first organisms that live in an area that has been damaged are referred to as this.
   (c) What is the name given to species of organisms that have spread to a new location as a result of human activities?
2. Name three examples of natural resources.
3. Name three examples of pollutants.
4. Describe three causes that led to the overharvesting of cod on the Grand Banks.
5. Are the following statements true or false? If the statement is false, rewrite it to make it a true statement.
   (a) Sustainable rates of harvesting occur when resources are being used faster than they can be renewed.
   (b) If an ecosystem is not disturbed, it eventually produces a climax community.
   (c) A field of potatoes is an example of a monoculture.
   (d) A pine tree is an example of a pioneer species.
   (e) Atmospheric monitoring measures changes in air and water temperatures and weather patterns, such as hurricanes and droughts.
6. Use an example to show how an introduced species might affect an ecosystem.
7. The diagram below shows the pH scale.

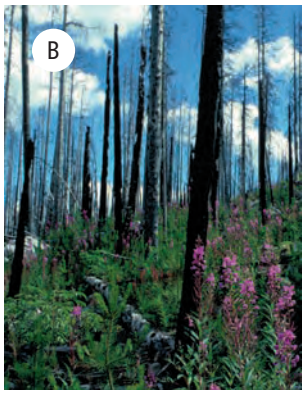


   Imagine that you are analyzing a sample of water that you have collected from a storm drain in your neighbourhood.
   (a) If the water sample is acidic, would you expect its pH to be higher than 7 or lower than 7?
   (b) If the water sample has a pH of 7, what does this tell you?
   (c) Which is more acidic: a pH of 5 or a pH of 2?
   (d) Which is more basic: a pH of 11 or a pH of 9?
   (e) What is the pH of normal rainwater?

Understanding Key Ideas

8. Examine the two photographs.
   (a) Which happened first: the events shown in Photo A or the events shown in Photo B?
   (b) Describe the process that is occurring in Photo B.
   (c) Imagine that you take a photo of this same area 20 years from now. Briefly describe or sketch what you predict you would see.





9. A family cultivated part of their lawn and turned it into a vegetable garden. The family then moved away. The house remained empty, and nobody looked after the garden. Ten years later, the family came back to visit their old property. The lawn looked similar, but it was much weedier. They were surprised, though, to see wildflowers, shrubs, and small bushes growing in their deserted garden. Explain why this is an example of succession.
10. Why is it important to monitor ecosystems over a long period of time?
11. Why is it important that the methods used to monitor ecosystems are consistent?
12. Name an endangered species in Newfoundland and Labrador. Why is it endangered?
13. Give one example of a natural event and one of a human activity that can cause a change in a lake ecosystem.
14. Draw a flow chart to illustrate the process of secondary succession.
15. Give an example to demonstrate how long-term monitoring can help scientists predict future changes in the environment.
16. Imagine you are a biologist, and the company you work for assesses the impact of development projects. There is a plan to build a new luxury resort on the shore of a large bay. Builders need to know what environmental impact the project will have on particular ecosystems. Your job is to estimate the number of organisms in these different ecosystems. How could you sample:
    (a) the number of insects in a large tree
    (b) the number of whales in a large bay off the coast
    (c) the number of fish in a small lake

Pause and Reflect

Should people simply leave all natural ecosystems exactly as they are, or is it acceptable to make changes to ecosystems? What kinds of changes could be acceptable, and under what circumstances would they be acceptable? Use these questions as the basis for a letter to the editor of a school or local newspaper.

Unit Summary

1 An ecosystem is all the living and non-living things in a particular place.

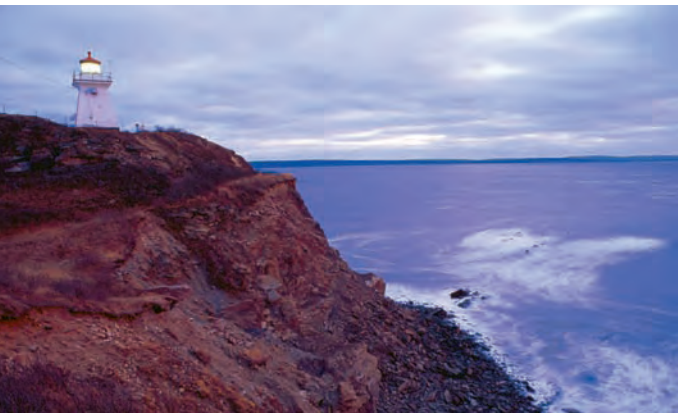
- All ecosystems include biotic (living) and abiotic (non-living) things. (1.1)
- Ecosystems such as oceans and deserts may cover huge areas. Other ecosystems are quite small—such as a rock pool or a rotting log. (1.1)
- Abiotic parts of an environment include such things as temperature, light, air, water, soil, and climate. (1.2)
- Each type of organism is adapted to a particular set of abiotic conditions. (1.2)
- Individual members of the same species living together in the same area at the same time form a population. (1.3)
- Populations of different species interact in communities. (1.3)

2 Living and non-living things interact in ecosystems.

- Symbiotic relationships include parasitism, mutualism, and commensalism. (2.1)
- Feeding relationships can affect the population size of the organisms that are eaten and of the organisms that eat them. (2.1)
- Animals obtain their food from the biotic environment by consuming other organisms. They are called consumers. (2.2)
- Plants produce their food from the abiotic environment by the process of photosynthesis. They are called producers. (2.2)
- Waste and dead matter are a source of food for scavengers and decomposers. (2.2)
- Energy from sunlight is transferred through ecosystems in food chains and food webs. Energy is lost at each step in a food chain. (2.3)
- Nutrients are continuously recycled through the biotic and abiotic environment. (2.4)

3 Natural events and human activities cause changes in ecosystems.

- Ecosystems may be disturbed by natural events such as storms and floods and by human activities such as logging and fishing. (3.1)
- An area of bare rock can gradually change over centuries into a complex community of species by the process of succession. (3.1)
- Humans have a major impact on ecosystems because of our powerful technologies and large human population. (3.2)
- The main impacts include loss of habitat, introduction of alien species, over-harvesting of natural resources, and pollution. (3.2)
- Environmental monitoring is used to detect changes in ecosystems. (3.3)
- Information from monitoring can be used to help manage and protect ecosystems. (3.3)



Key Terms

- abiotic
- adaptation
- biotic
- community
- ecosystem
- habitat
- individual
- niche
- organism
- population
- range of tolerance
- species

Key Terms

- carnivores
- commensalism
- consumers
- decomposers
- energy pyramid
- fermentation
- food chains
- food webs
- herbivore
- host
- mutualism
- nutrients
- nutrient cycles
- omnivores
- parasites
- parasitism
- producers
- scavengers
- symbiosis
- symbiotic

Key Terms

- acid rain
- baseline data
- climate change
- climax community
- endangered
- environmental impact assessment
- environmental monitoring
- extinct
- introduced species
- long-term monitoring
- monoculture
- native species
- natural resources
- permanent plot
- pioneer species
- pollutants
- primary succession
- renewable resources
- secondary succession
- succession
- sustainable
- unsustainable

Making a Garbage-Reduction Diary

Many companies monitor the waste they produce. If they can reduce or eliminate wastes, not only do they help the environment, but they also save money. With family members, classmates, or others, measure how much garbage is produced at home, at school, or at a workplace.

Problem

How can you keep track of all the garbage produced during a week?

Criteria

- Collect data to measure the amounts of garbage produced in your chosen location.
- Determine how to measure and record each type of waste, such as glass, paper, food, and plastic.

Procedure

Part 1 Brainstorming Ideas

1. Create a garbage-reduction diary to record your data for one week. You will need to track the types and quantities of garbage produced by each person in the location for every day.
2. Place your garbage-reduction diary on a bulletin board, refrigerator, or other place where all participants in your project can easily use it.
3. Discuss the procedure for measuring and recording garbage production with each person in your project team. Each of them should record every item discarded.
4. Each day for a week, have all participants record in the diary every item they throw out as garbage. For example, if you throw away a magazine on the first day, record it as one item of paper waste on Day 1. If another person in the project throws away a newspaper on the same day, they will also record it as one item of paper waste, making a total of 2 for that day.

Report Out

1. At the end of the week, total the data and present it in the form of a clear chart. The chart should indicate the totals of each type of waste and also the totals of all the waste produced by each participant during the week.
2. Compare how much waste was thrown away in different categories. For example, how much paper was thrown out compared with plastic waste? Did some individuals produce more garbage than others?
3. List five ways you could have reduced the garbage that was produced during the week. Use your project to plan ways of reducing garbage, for example by composting organic waste and recycling paper, plastic, glass, and tin. Share your plan with other participants and put it into action for the future.

Saving Endangered Spaces

The biggest threat to the survival of wild animals and plants is loss of habitat. Governments must often balance the need for wilderness areas and parks against industrial development. Yet, few people consider that unspoiled natural ecosystems are an important natural resource that contribute to the health of society and the economy, just as fisheries, mines, and pulp and paper mills do.

Background

In the province of Newfoundland and Labrador, only about 4 percent of the land is protected from industrial development. This means that most of the forests can be logged and most of the other land can be developed for mining, highways, construction, agriculture, dam-building, and other land activities.

As natural ecosystems are altered by humans, there are fewer and fewer places for wild species to survive. If human impacts on the environment continue, many of these species will disappear. Provincial, national, and international organizations help promote research and education on environmental conservation. A key step is convincing governments and private landowners to protect shrinking habitats from destruction.

The Bay du Nord Wilderness Reserve is the largest protected river ecosystem in the province of Newfoundland and Labrador.

The Burnt Cape cinquefoil is one of more than 300 plant species that grows in Burnt Cape Ecological Reserve near the tip of the Great Northern Peninsula. About 30 of these species are considered rare.

Find Out More

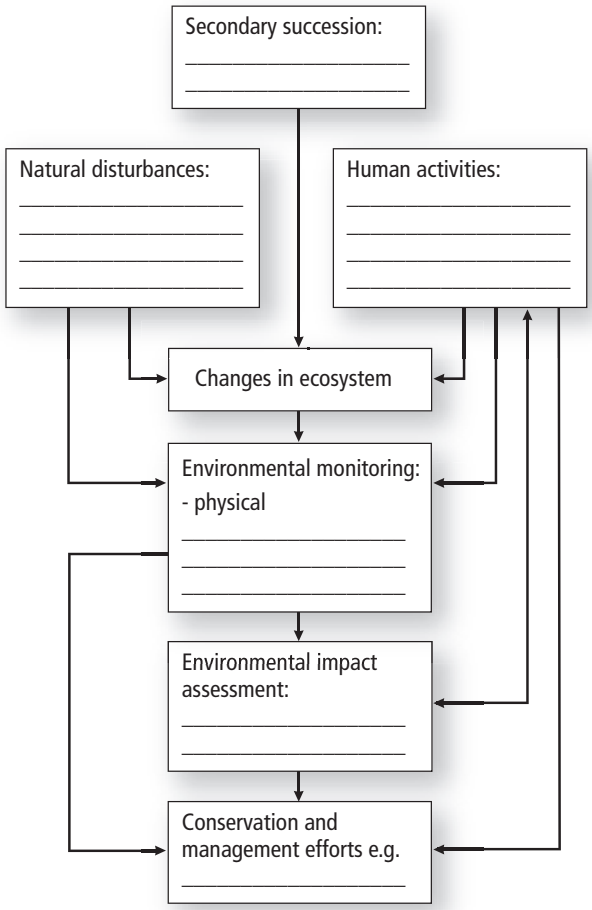
Choose an area in the province that is home to rare or endangered species of animals or plants. Find out if this area is protected or if it is threatened by human activities. Contact conservation groups and write to government departments responsible for managing the land and resources. Use the Internet to research news about development plans for the area. You can start your search at **www.discoveringscience.ca.**

Report Out

Create a poster, brochure, or electronic presentation to inform people about the endangered ecosystem you chose to research. Include details of rare species that live there and the recent history of development or protection in the area. Organize a volunteer activity in your school to support a conservation group that is working to help save the area from development.

Visualizing Key Ideas

1. Copy the following concept map about ecosystems into your notebook. Complete it by filling in the empty spaces.



Using Key Terms

2. Create a quiz by writing a list of ten questions which can be answered using terms chosen from the list below. Create an answer key linking each term to the correct question.
   - ecosystem
   - abiotic
   - species
   - niche
   - symbiotic
   - producers
   - biotic
   - environmental impact assessment
   - climax community
   - decomposers
   - food chain
   - nutrient cycles
   - succession
   - pioneer species
   - extinct
   - introduced species
   - unsustainable
   - pollutants

Checking Concepts

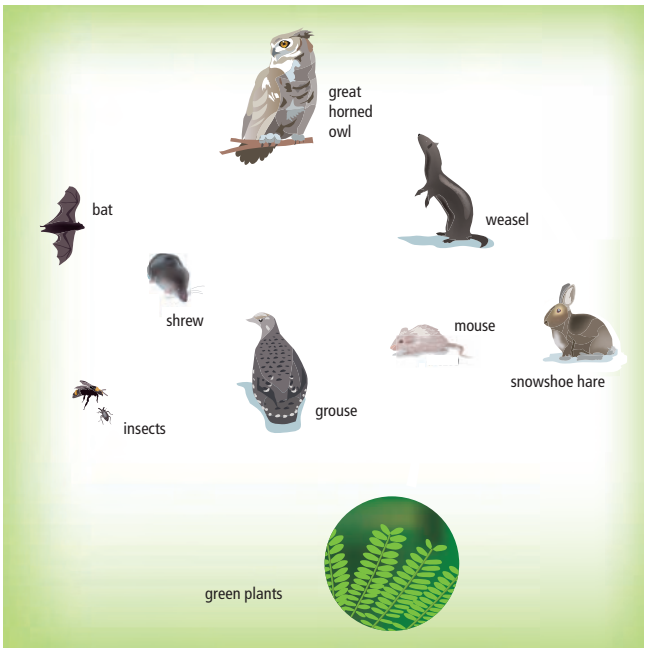
1

3. Choose an organism and explain how it interacts with sunlight, air, water, and soil in its environment.
4. Describe an interaction between two abiotic parts of the environment.
5. Draw a diagram to show the relationships between individuals, populations, communities, and ecosystems.
6. Name three types of ecosystems that can be found in Newfoundland and Labrador. List two plants and two animals that live in each ecosystem.
7. Explain the connection between the terms "range of tolerance" and "tree line."

2

8. Why do all consumers depend on producers for food?
9. (a) Why are scavengers and decomposers important in ecosystems?
   (b) How do they differ?
10. Why is a food web better than a food chain for describing the relationships among organisms in an ecosystem?

11. Draw as many food chains as you can using the organisms shown below.



12. Make a sketch to explain what is meant by a pyramid of energy.
13. Write a paragraph telling the story of a nutrient as it passes through a cycle. Start with a nutrient in a dead leaf that falls from a tree and end when the nutrient becomes part of another plant.

3

14. Explain what succession is, and use an example to support your explanation.
15. Describe three human activities that alter ecosystems. How might each activity threaten the survival of a species?
16. Use an example to explain the relationship between the terms "overharvesting" and "sustainable resource."
17. A farmer notices that shrubs and small trees are starting to grow in a pasture that was once used for grazing cattle. The farmer has not put cattle there for two years. Explain why the pasture has changed.
18. What sort of data is gathered using a permanent plot? Why is this useful?
19. A development is planned in an area that includes the habitat of a rare species of plant. What process can be used to help predict the impact of the development on the plant?

Understanding Key Ideas

20. In your own words, describe what is meant by the term "ecosystem." Give an example.
21. List three non-living parts of the environment.
22. Give an example of
    (a) mutualism,
    (b) parasitism,
    (c) commensalism.
23. Describe the role of each of the following in an ecosystem: spider, hawk, corn, mouse.
24. What might happen in a forest ecosystem if all the carnivores were removed?
25. What are two reasons that might cause a species to become threatened with extinction?
26. What natural factors can control the population size of a species?
27. How can introduced species affect populations of native species?
28. Describe one way you could help to protect a species from extinction.
29. What impacts does a monoculture have on an ecosystem?
30. Name four parts of the environment that can be measured for long-term monitoring.
31. Why does food "go bad"? Describe four methods of preserving food.
32. What condition is necessary to allow a renewable resource to be harvested indefinitely?

Thinking Critically

33. An avalanche removes all the plants and animals from a large area on the side of a mountain, leaving only a bare strip of mud and rock. Predict how this disturbed area might change over the next few years. Explain your prediction.

34. Imagine you are a real estate agent describing an area of recently-burned forest to a group of forest-living animals and plants. How will you persuade them that this might be an excellent place for them to make their home in a few years from now?

35. List your three favourite foods. Explain how each food provides you with energy from the sun.

36. Use an example to explain how forestry, farming, or fishing has affected the population of a native species in Newfoundland and Labrador.

37. What action could you take to increase the biodiversity of an ecosystem near where you live?

38. A plant nursery wants to import a fast-growing plant from Europe to sell to gardeners on the island of Newfoundland. Explain why this is not a good idea.

39. Imagine you are shipwrecked on a small island with only a few hens and a large bag of grain saved from the ship's cargo. There is no other food available for you or the hens. To survive as long as possible, what should you do?
(a) Eat the grain, and then eat the hens.
(b) Eat the hens, and then eat the grain.
Explain your choice.

40. Why should people not release exotic pets such as fish, snakes, or spiders into the wild?

41. (a) How are the meals you eat today different from the meals that your grandparents ate?
(b) What impacts might this difference have on ecosystems?

42. You may have seen a robin eating a worm. Using your knowledge of nutrient cycles, explain how a worm might eat a robin.

43. The bird in the photo is a harlequin duck. These shy and uncommon birds spend the winter along the rocky coasts of Newfoundland and Labrador but fly north to the Arctic in summer. Scientists studying this bird have put a red band on its leg to record where and when it was caught. How does this band help researchers learn more about the habitat and needs of this species?

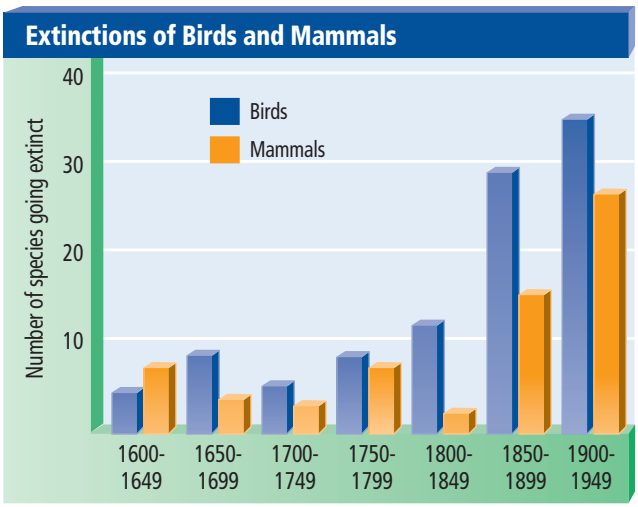
44. Why should people who live in a large city be concerned about changes that happen in a forest or lake in a part of the province far from where they live?

Developing Skills

45. How is a species of organism different from an individual organism? Explain your thinking.

46. As a class, discuss how you could make a model of an ecosystem. What would you include in your model? Why?

47. The graph shows extinction rates for species of birds and mammals around the world since 1600. Use this graph to answer the following questions.



(a) In what interval did most extinctions of mammalian species occur?
(b) Approximately how many species of birds became extinct in the interval 1650–1699?
(c) Approximately how many species of birds became extinct in the interval 1900–1949?
(d) Based on this data, predict how many species of mammals became extinct in the period 1959–1999.

48. Choose a species that lives near your home and describe how you would monitor long-term changes in its population size.

49. Create a plan to illustrate a way in which you could increase the biodiversity of a habitat in your neighbourhood.

50. Draw diagrams to show
(a) how energy moves through ecosystems
(b) how nutrients are cycled.

51. Imagine that you are an ecologist. A group of people in your community wants to introduce an organism into the local ecosystem that will get rid of the mosquito population. Identify the mosquito's place in the food chain and explain to the group why introducing a new organism would not be a good idea.

52. Think of (and observe if possible) an ecosystem near your home. Make a chart or diagram to show abiotic-biotic interactions in the ecosystem.

53. Consider the ecosystem you observed in question 52. Predict what would happen if each of the following major changes occurred:
(a) The rain becomes acidic.
(b) A hydro line is built through the area.
(c) Chemical fertilizers are used in a neighbouring area.
(d) One species in the ecosystem (e.g., earthworms) is attacked by a parasite and its numbers are severely reduced.

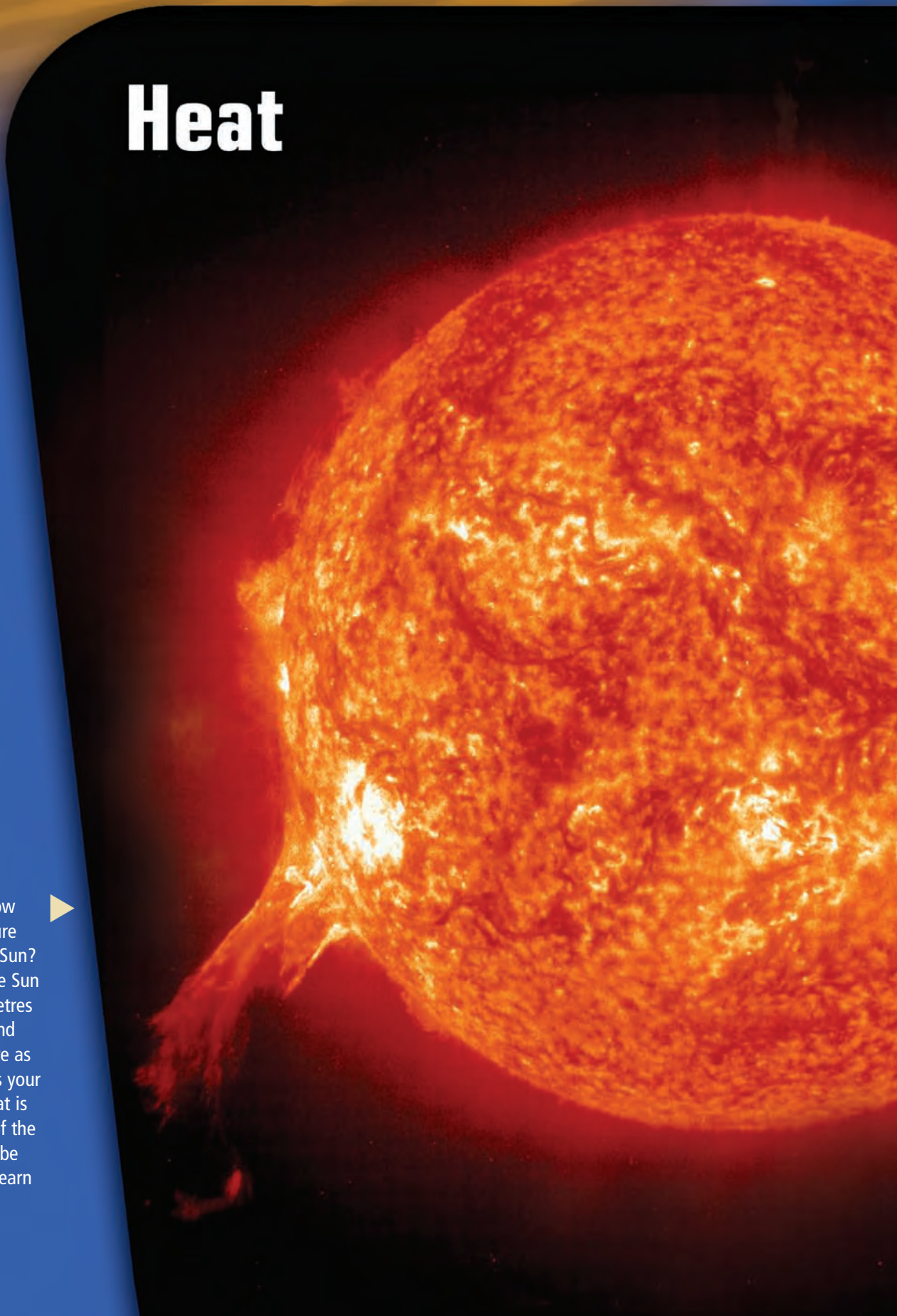
54. Think about each of the following pairs of organisms, and name the type of symbiotic relationship the partners might have. Indicate what the gains and/or losses might be for each partner:
(a) a flowering plant and an insect
(b) a cat and a flea
(c) a nectar-eating bat and a flowering cactus
(d) a bird and a water buffalo

Pause and Reflect

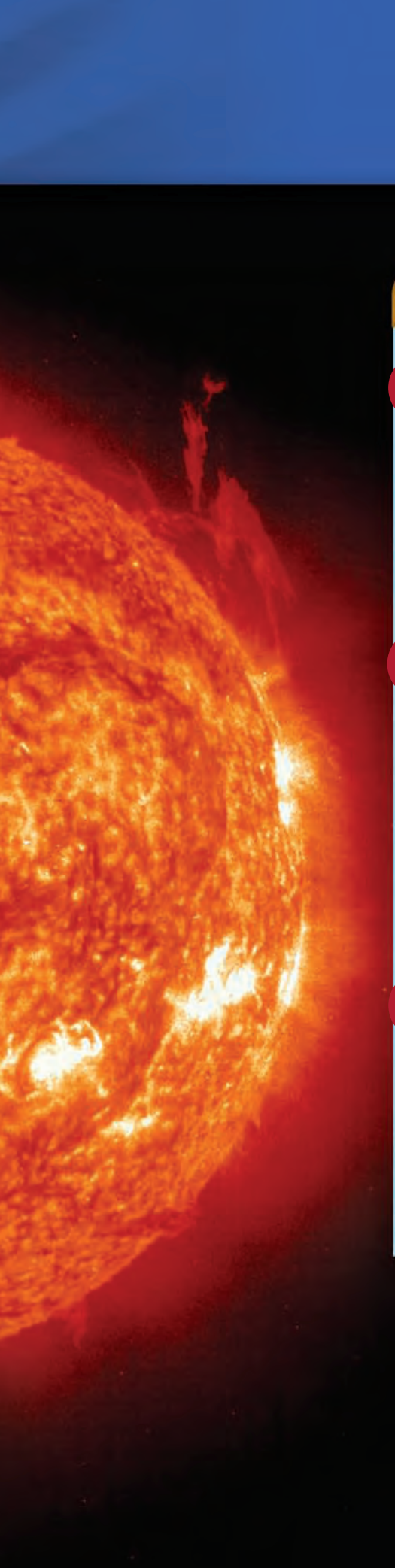
"The landscape is not just a supply depot. It is also the home in which we must live." What does this statement mean? Should people consider the entire planet as our home?

UNIT

2 Heat



How hot is the Sun? How can astronomers measure the temperature of the Sun? How does heat from the Sun travel millions of kilometres through empty space and warm Earth? Is a bonfire as hot as the Sun? What is your body temperature? What is heat? These are some of the questions that you will be able to answer as you learn about heat in this unit.



Key Ideas

4 **Temperature describes how hot or cold an object is.**

4.1 Describing Temperature
4.2 Measuring Temperature

5 **Scientists use the particle theory of matter to describe temperature**

5.1 Particle Theory of Matter
5.2 States of Matter
5.3 Particle Theory Explains Changes of State

6 **Heat is transferred from one object to another by three different processes.**

6.1 Processes of Transferring Heat
6.2 Conductors and Insulators
6.3 Temperature versus Heat

Getting Started

Campfires help campers in many ways. They provide light at night. You can roast marshmallows or cook food over them. They also keep you warm after dark.

Camping can be a lot of fun, especially when sitting around the campfire at night. A campfire is not only pretty but you might need the fire to keep you warm in the evening. Have you ever noticed that your face and the front of your body can be almost too warm while your back is cool? Just a tiny breeze can cause a chill on your shoulders. How can you feel so warm and cool at the same time?

Suppose you go to your tent to get a jacket. Your hands might feel very chilly so you rub them together. How can rubbing your hands give you a feeling of warmth similar to holding them near the campfire? Now suppose you decide to have some hot chocolate and put a kettle of water on the camp stove. When you pick up the kettle to pour your hot water, you might wonder why the handle got so hot. It wasn't touching the camp stove. Nevertheless, the hot chocolate feels good as it goes down. Finally, the fire is nearly out and it is time to crawl into your sleeping bag and get a good night's sleep. Even though the sleeping bag does not generate any heat like the campfire does, you feel very cozy and warm inside it.

internet connect

Nearly all of Earth's heat comes from the Sun. Why are regions near the equator so much warmer than regions, such as Canada, that are farther from the equator? How do average temperatures differ between Canada and Brazil, a country in South America? Start your search at **www.discoveringscience.ca.**

When you go camping, you realize the importance of heat and finding different ways to stay warm. In this unit, you will learn more about heat and temperature. You will learn how scientists through the years developed ways to measure the temperature of different objects. You will learn how scientists explain the difference between hot and cold objects. You will also find out how heat travels from one place to another.

Careful! The handle on the pot might be hot!

Word Connect

Early philosophers believed that a mixture of heat, cold, moisture, and dryness in a person determined their temperament. The word *temperature* comes from the same root as the word temperament.

Baffle Your Skin

Find Out ACTIVITY

In this activity, you will discover whether your skin is a good instrument to determine how hot or cold an object is. You will do this by placing your hands in water of different temperatures.

Materials

- 3 bowls of water large enough to dip your hands into the water
- very warm tap water
- room-temperature water
- cold water (refrigerator temperature)

What to Do

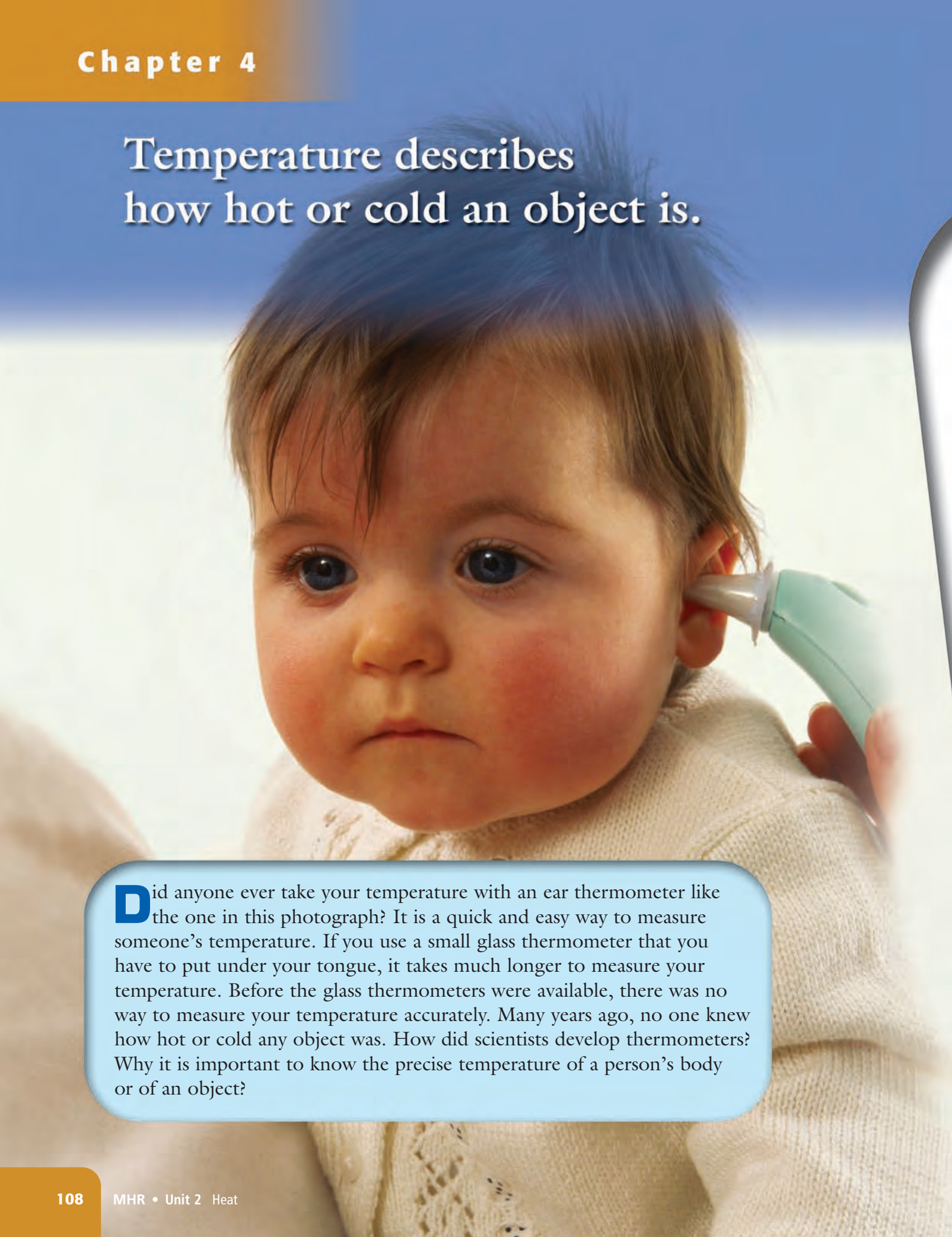
1. Put one hand in the bowl of cold water and the other hand in the bowl of hot water. (If the hot water is too hot to keep your hand in it, cool it with a small amount of room-temperature water.) Hold your hands in the two bowls of water for one minute.
2. Quickly put both hands in the bowl of room-temperature water.
3. Repeat steps 1 and 2 but use the opposite hands that you used in step 1.

What Did You Find Out?

1. Describe how each hand felt in step 2 when you put both hands in the same bowl of water. Give a possible explanation for your observations.
2. Was there any difference in your observations in step 3 compared to step 2? If there was, suggest a possible reason why.
3. Use your observations to explain how the same air temperature can seem warm in the winter and cool in the summer.

Chapter 4

Temperature describes how hot or cold an object is.



Did anyone ever take your temperature with an ear thermometer like the one in this photograph? It is a quick and easy way to measure someone's temperature. If you use a small glass thermometer that you have to put under your tongue, it takes much longer to measure your temperature. Before the glass thermometers were available, there was no way to measure your temperature accurately. Many years ago, no one knew how hot or cold any object was. How did scientists develop thermometers? Why it is important to know the precise temperature of a person's body or of an object?

What You Will Learn

In this chapter, you will

- **describe** the temperatures of a variety of common objects and substances
- **explain** the difference among the temperature scales
- **demonstrate** the use of a thermometer
- **explain** how different thermometers work

Why It Is Important

Understanding the differences among temperature scales is important for interpreting weather reports and for cooking food in an oven. Being able to read and interpret a thermometer helps you plan your activities and know how to dress appropriately for the weather.

Skills You Will Use

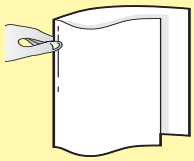
In this chapter, you will

- **observe** how well your skin can determine temperature
- **predict** the temperature of a variety of objects
- **measure** temperature with a thermometer that you constructed

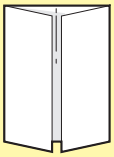
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 4.

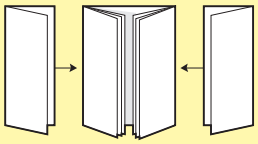
STEP 1 **Using** an 11″ × 17″ sheet of paper, begin as if you were going to fold the paper in half along the long axis, but instead of creasing the paper, **pinch** it in to show the midpoint.



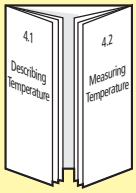
STEP 2 **Fold** the outer edges of the paper in to meet at the midpoint, forming a shutter fold.



STEP 3 **Staple** one sheet of 8.5″ × 11″ paper, folded along its length, into each side of the shutter fold to create a notebook on each side.



STEP 4 **Label** the left side of the notebook "4.1 Describing Temperature" and the right side of the notebook "4.2 Measuring Temperature".



Organize Record information, define terms, and solve problems from the chapter in the pages of the notebook you have created. In the middle section of the Foldable, create a chart comparing average temperatures in Newfoundland and Labrador to other places in the world.

4.1 Describing Temperature

Knowing the temperature of common things, such as room and body temperatures, helps you better understand temperatures of less common things. Maintaining a constant body temperature is critical to your health. A person might not be able to recover if hypothermia is prolonged. Temperature scales are based on reference points such as the freezing and boiling points of water. To construct a thermometer, you need something that changes visibly as the temperature changes.

Key Terms

body temperature
hypothermia
room temperature

Figure 4.1 shows one way that temperature affects your life. Every day, you and many other Canadians check the weather forecast to decide what to wear. "What is the temperature? Do I need a heavy coat and gloves or will I be comfortable in a light jacket?" Temperature affects your life in other ways too. Perhaps you take a lunch to school. You might take soup in a Thermos® to keep it warm but you eat your sandwich at room temperature. You might buy cold milk at school. Do you know what comfortable room temperature is? What is normal body temperature? Find out how well you can match a temperature to a description by completing the Find Out Activity on the next page.

Did You Know?

The highest temperature ever recorded anywhere in the world is 57.7°C. This temperature was recorded in El Azizia, Libya, a country in Africa. The lowest temperature ever recorded is –89.2°C. This temperature was recorded in Vostok in Antarctica.

Figure 4.1 How you dress and the activities you participate in depend on the weather.

4-1A Boiling Hot, Freezing Cold

Find Out ACTIVITY

In this activity, you will try to match temperatures to descriptions of places or things. You will probably be able to guess many of the temperatures of common things. Other temperatures might surprise you. Read the directions and then see how well you can match the temperatures to the descriptions.

What to Do

1. In your notebook, make a table with three columns. Write the following headings at the top of the columns: Very Cold, Everyday, and Very Hot.
2. Read each of the descriptions in the list below. As you read a description, decide which heading in your table fits the description. Write the description under that heading in your table.
3. For each description, choose the temperature from the list that you believe is the correct temperature. Write the temperature beside the description in your table. Discuss your answers with your partner until you agree on each one.
4. Check your answers against the list that your teacher has. Correct any mistakes that you might have made.

Description	Temperatures (°C)
Temperature of lava from Hawaiian volcanoes	4 to 10
Temperature of ocean currents off Canada's east coast	–5
Temperature of ocean currents off Canada's west coast	–87
World record coldest air temperature	–121 to –156
Comfortable room temperature	92
Body temperature of a budgie bird	15 000 000
Temperature outside the Space shuttle while it orbits Earth	–10 to –15
Temperature of a candle flame	200
Comfortable temperature for heat-loving bacteria	20 to 25
Normal human body temperature	37
Temperature of ice cream	40
Oven temperature for baking bread	1
Temperature of food in a freezer	100
Temperature of the interior of the Sun	6000
Temperature of hot tea or coffee	1150
Temperature of boiling water at sea level	55
Temperature of a slush of pure water and ice	800
Temperature of the surface of the Sun	0

This "Morning Glory Pool" is heated by energy from deep within Earth. The water remains at about 95°C even if there is snow on the ground nearby.

What Did You Find Out?

1. How many temperatures were you able to guess correctly?
2. Which temperature surprised you the most?
3. What was the most important thing you learned from this exercise?

Temperatures of Common Things

You have probably heard the phrase "comfortable room temperature" many times. What is "comfortable room temperature?" Some people are comfortable at temperatures that other people might consider too cool or too hot. Most people, however, are comfortable when the **room temperature** is somewhere between 20°C and 23°C. Many people, like the person in Figure 4.2, feel that it is more comfortable to sleep when the temperature is lower such as 18°C.

Figure 4.2 A temperature of 18°C is considered comfortable for sleeping.

Have you ever baked cookies? What was the temperature of the oven? Oven temperatures vary for different foods. For cookies, you usually set the temperature at 175°C. To cook a roast or poultry, as in Figure 4.3, the oven temperature is usually set at 160°C. You need a very hot oven—about 250°C—to bake pizza.

It is important to keep a refrigerator and freezer at the right temperatures so that food will not spoil. The temperature of the refrigerator should be 4°C and the freezer should have a temperature of –18°C.

Figure 4.3 Be sure to check the recipe to find the right temperature for the food that you are baking.

Body Temperatures

Your **body temperature** is an important indicator of your health. Your normal body temperature is 37°C. A temperature above 37°C indicates that you have an infection or an illness. The increased temperature is your body's way of fighting an infection. Bacteria (germs) can be destroyed by an increase in temperature. However, if your temperature rises above 40°C, the heat can also harm your own tissues, especially your brain.

If skiers or hikers do not dress properly, or if a person falls into cold water, as shown in Figure 4.4, their body temperatures can drop dangerously low. The condition is called **hypothermia.** When the body temperature decreases a few degrees, the heart begins to slow down and body organs do not function correctly. If a person's body temperature drops below 32°C, it is very difficult to revive the person.

Figure 4.4 If someone falls into icy cold water, it is very important to get them out of the water and give them warm dry clothing very soon. Hypothermia is very dangerous.

Did You Know?

The temperature of the filament of an incandescent light bulb is 2500°C. Although these bulbs waste a lot of energy, they have been used for more than a hundred years. However, the federal government plans to ban inefficient incandescent light bulbs by the year 2012.

internet connect

Learn more about preventing and treating hypothermia by doing research on the Internet. Start your search at **www.discoveringscience.ca.**

A temperature of 37°C is normal for humans but not for all animals. Figure 4.5 shows an extreme example of body temperature for one animal. Table 4.1 shows you the normal body temperature for several different birds and mammals. Look for trends in the table. For example, how does the normal body temperature of birds compare to the body temperatures of the mammals in the list?

Table 4.1 Temperatures of Some Birds and Mammals

Animal	Body Temperature (°C)
Dog	38.5
Horse	37.7
Pig	39.5
Sparrow	41.0
Chickadee	42.0
Gray Jay	40.4
Kangaroo	35.9
Hedgehog	34.0

Did You Know?

Arctic cod, relatives of the more familiar Atlantic cod, swim in waters that are so cold that the bodies of other fish would freeze. The arctic cod do not freeze because their bodies make a chemical that acts like antifreeze and prevents their tissues from freezing.

Figure 4.5 An oryx is a type of antelope that lives in hot dry regions of Africa. The body temperature of an oryx can get as high as 43°C in the daytime. However, the temperature of the oryx brain does not get higher than 39°C.

Animals other than birds and mammals cannot generate enough heat in their bodies to keep their temperatures constant. The body temperature of these animals is affected by their surroundings. Lizards often stretch out in the Sun so that the sunlight will warm their bodies. Animals that live in cold climates have many ways to adapt to the low temperatures.

Did You Know?

The coldest temperature ever recorded in Newfoundland and Labrador is –51.1°C (Esker Station). The highest temperature recorded in Newfoundland and Labrador is 41.7°C (Northwest River).

Reading Check

1. If you were asked what room temperature is, why would it not be possible to give a specific temperature?
2. What is the typical temperature in a refrigerator?
3. What is your normal body temperature?
4. What is hypothermia?

Air Temperatures

When you hear the word *temperature*, the first thing you probably think of is weather. Nearly every day, you hear a weather report. The reporter tells you how high and how low the temperature will be for the next few days. Sometimes the weather report will include average temperatures for the month. Figure 4.6 shows the monthly highs and lows in your province.

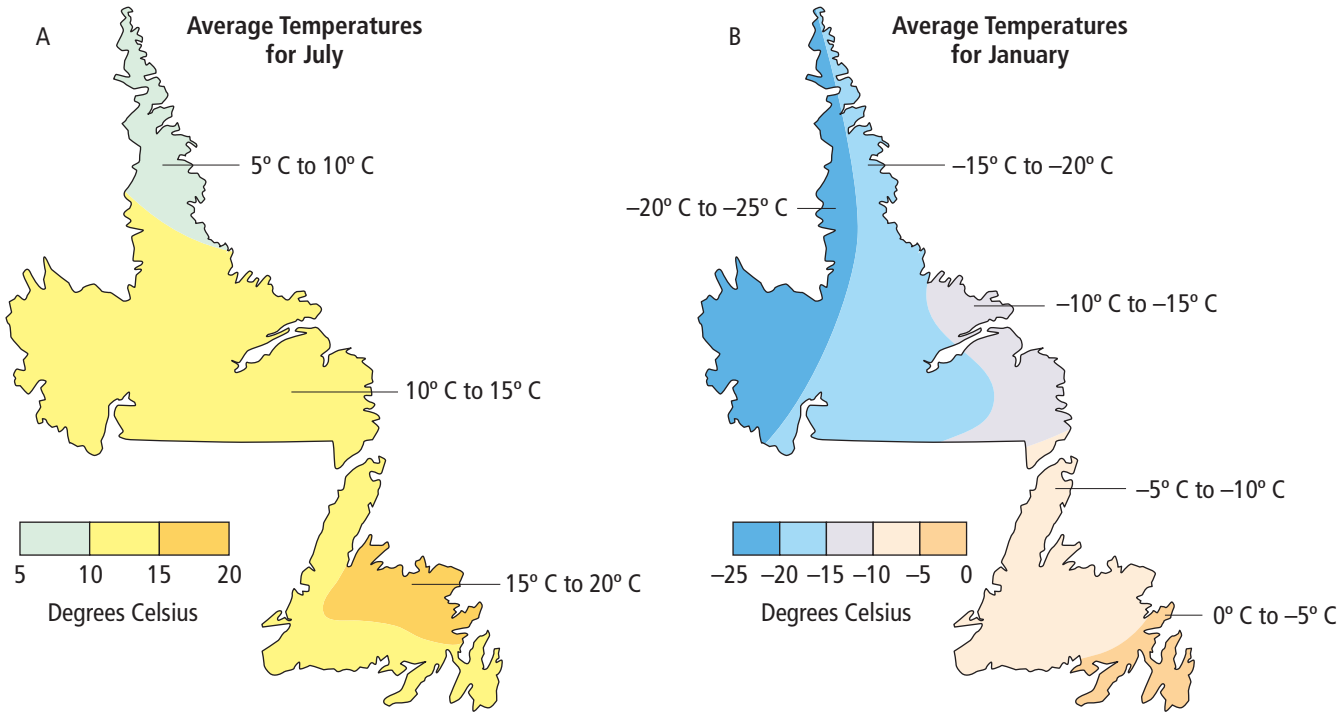


Figure 4.6 Map A shows average temperatures for July and map B shows average temperatures for January. Locate the place where you live on the map and find the average temperatures in July and January.

How do the average temperatures in Newfoundland and Labrador compare to other places in Canada? Table 4.2 lists data of average temperatures for the months of January and July in several cities across Canada.

When you look at the average temperatures, remember that the highs can be much higher and the lows can be much lower than the average temperatures. For example, the all-time record high temperature in Saskatoon, Saskatchewan is 40.6°C and the record low temperature is –50.0°C.

Table 4.2 Average Temperatures for January and July in Some Canadian Cities

City	January (Temperature °C)	July (Temperature °C)
Gander, Newfoundland and Labrador	–6	16
Halifax, Nova Scotia	–5	18
Goose Bay, Newfoundland and Labrador	–16	16
Montreal, Québec	–9	21
Toronto, Ontario	–6	21
Resolute, Nunavut	–31	4
Winnipeg, Manitoba	–17	20
Saskatoon, Saskatchewan	–17	19
Edmonton, Alberta	–12	18
Yellowknife, Northwest Territories	–27	17
Vancouver, British Columbia	3	17

Reading Check

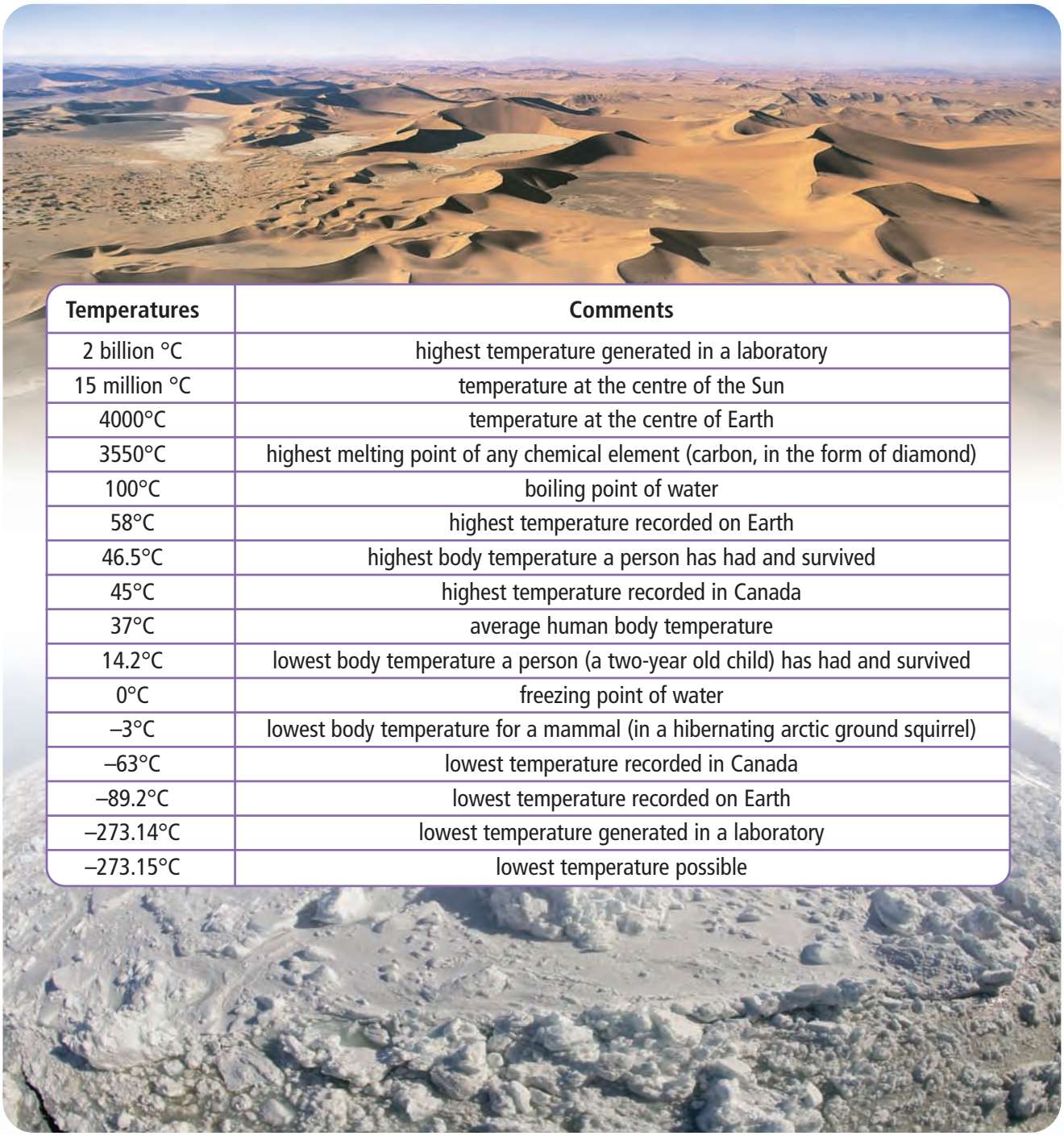
1. According to Table 4.2, the average temperature for January in Gander is –6°C and in Goose Bay it is –16°C. On a January day, could it be colder in Gander than it is in Goose Bay? Explain.
2. Which places in Table 4.2 have higher average temperatures in January than Gander? Which places have lower average temperatures in July than Gander?
3. Examine Map B in Figure 4.6 and answer the following questions.
   (a) Is the section of Newfoundland and Labrador that is warmest in January by the ocean or inland?
   (b) Is the section of Newfoundland and Labrador that is coldest in January by the ocean or inland?

Wild, Weird, Wonderful

www Science

Going to (Temperature) Extremes

What are some of the highest of the highs and lowest of the lows in temperature? Some of these values might surprise you.



Temperatures	Comments
2 billion °C	highest temperature generated in a laboratory
15 million °C	temperature at the centre of the Sun
4000°C	temperature at the centre of Earth
3550°C	highest melting point of any chemical element (carbon, in the form of diamond)
100°C	boiling point of water
58°C	highest temperature recorded on Earth
46.5°C	highest body temperature a person has had and survived
45°C	highest temperature recorded in Canada
37°C	average human body temperature
14.2°C	lowest body temperature a person (a two-year old child) has had and survived
0°C	freezing point of water
–3°C	lowest body temperature for a mammal (in a hibernating arctic ground squirrel)
–63°C	lowest temperature recorded in Canada
–89.2°C	lowest temperature recorded on Earth
–273.14°C	lowest temperature generated in a laboratory
–273.15°C	lowest temperature possible

Science Watch

Wind Chill

What does a weather report mean when it says that the temperature is –15°C but it "feels like" –24? The "low" number tells you how cold it feels. A low temperature is not the only thing that makes you feel cold. You have probably noticed that a gentle breeze on a cold day can make you feel much colder. Have you ever wondered why quiet air does not feel as cold as moving air?

The heat in your body heats the air in contact with your skin. That thin layer of warmed air insulates your skin from the colder air. When the wind blows, it moves that warmed layer of air away from your skin and replaces it with colder air. The colder air draws more heat from your skin making it feel even colder. As the wind speed increases, it removes the warm layer of air away faster until there is no longer a layer of warm air protecting your skin from the cold.

The "feels like" number in the weather report is called the wind chill. The wind chill number is the temperature of still air that would have the same effect on exposed skin as the combination of the actual temperature and wind. For example, a temperature of –15°C and a wind speed of 20 km/h would have the same effect on your skin as a temperature of –24°C with no wind.

Wind chill is as dangerous to your skin as low temperatures. Environment Canada provides the following guidelines to help people avoid the dangers of wind chill.

Wind Chill Hazards

Wind Chill	Description	Hazard
0 to –9	Low	• Slight increase in discomfort
–10 to –24	Moderate	• Uncomfortable • Exposed skin feels cold • Risk of hypothermia if outside for long periods
–25 to –44	Cold	• Risk of frostbite • Check face, fingers, toes, ears, and nose for numbness or whiteness • Risk of hypothermia if outside for long periods
–45 to –59	Extreme	• Exposed skin may get frostbite in minutes • Check face, fingers, toes, ears, and nose for numbness or whiteness • Serious risk of hypothermia if outside for long periods • Be ready to cut short or cancel outdoor activities
–60 and colder	Extreme	**DANGER** • Outdoor conditions are hazardous • Exposed skin will get frostbite in less than 2 min

Source: Environment Canada, Wind Chill Information Site: *www.windchill.ec.gc.ca*

Questions

1. What is wind chill?
2. How can you protect yourself from frostbite if you have to go out when the wind chill is very low?

Check Your Understanding

Checking Concepts

1. What does it mean when your body temperature is above 37°C?
2. What is hypothermia?
3. What is the typical temperature of the freezer compartment of a refrigerator?
4. What are some common oven temperatures for baking different foods?
5. What is the average temperature in July and in January in the region where you live?

Understanding Key Ideas

6. If you were told that something had a temperature of 4°C, where would you expect to find that object?
7. Why might you put a thermometer in the refrigerator?

8. Estimate the temperatures of the following items.
   (a) a cup of soup
   (b) the flame of a candle
   (c) the record cold temperature in Québec
   (d) an ice cream cone
   (e) a person who has the flu
   (f) a carton of ice cream in a freezer
   (g) a container of juice in a refrigerator
   (h) a container of juice on a kitchen table
9. The thermometers in the following picture are called meat thermometers.
   (a) Describe how you think meat thermometers might be used.
   (b) Suggest a reason why meat thermometers are used.

Pause and Reflect

Imagine that you saw someone fall through the ice on a frozen lake. Describe the steps that you would take to prevent the rescued person from getting hypothermia.

4.2 Measuring Temperature

To measure temperature precisely, you need something to change visibly as the temperature changes. Galileo used the change in the volume of air trapped in a glass tube to measure temperature. Other instruments used the change in the volume of a liquid to measure temperature. Some temperature measuring devices use the difference in the expansion of metals as the temperature of the metals increases. Other devices use an electric current in different metals to measure temperature. The Fahrenheit temperature scale was the first widely used scale. The Celsius scale is based on 0°C as the freezing point of water and 100°C as the boiling point of water. The Kelvin scale is based on 0 K as the coldest possible temperature.

Key Terms

bimetallic strip
calibrate
Celsius scale
Fahrenheit scale
Kelvin scale
thermocouple
thermogram
thermometer
thermoscope

Several of your senses can tell you that someone is cooking something in an oven, as in Figure 4.7. When the oven heats up, often you can smell the odour of something cooking. You can also see the glow of the coils in the oven. As you approach the oven, you can feel the heat. Your senses of sight, smell, and touch tell you that the temperature of the burner is high.

Figure 4.7 The glow of the coils in the oven tells you that the coils are very hot.

You can often easily sense a change in the temperature of an object or a substance using several of your senses. However, it is usually quite difficult to sense the precise temperature. You need a special instrument to measure the precise temperature of an object or a substance such as the air around you. In this section, you will learn how scientists developed instruments that measure temperature. You will also learn about different temperature scales.

Did You Know?

Pottery makers bake their clay pots in extremely hot kilns. They use cones that bend at different temperatures to estimate the temperatures in the kilns.

4-2A Building a Thermoscope

Find Out ACTIVITY

Teacher Demonstration

An instrument that measures temperature must contain a substance that changes visibly as the temperature changes. In this activity you will observe a change in the volume of air as the temperature of the air changes.

Safety

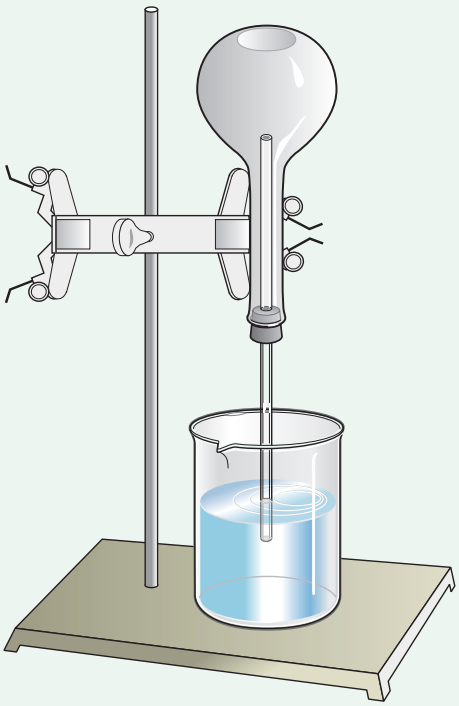
Handle the glass tubing carefully to avoid breakage.

Materials

- glass tube
- rubber stopper with hole
- spherical flask
- modelling clay
- beaker
- coloured water
- clamp
- retort stand
- cloth
- ice water

What to Do

1. Push the glass tube through the hole in the rubber stopper.
2. Put the stopper in the opening of the flask. Use modelling clay to help ensure that the apparatus is airtight.
3. Rub your hands together briskly and then grasp the flask in the upside down position.
4. Hold for a moment while the flask becomes warm from your hands.
5. Insert the end of the glass tube into the beaker of coloured water.
6. Release your hands from the flask and secure the flask with the clamp on the retort stand as shown in the diagram. (A volunteer from the class might be asked to assist for this step.)
7. Observe the coloured water in the glass tube while the air in the flask returns to room temperature.
8. Wet a cloth with ice water and place it on the flask. Observe the position of the coloured water.



What Did You Find Out?

1. What happened to the coloured water when the flask cooled to room temperature?
2. What happened to the coloured water when the cold cloth was placed on the flask?
3. Give a possible explanation for what you observed.

The Invention of Thermometers

About four hundred years ago, several scientists became interested in precisely measuring temperatures. One person who worked on temperature measuring instruments was the famous Italian scientist, Galileo Galilei (1564–1642). In 1596, Galileo developed an instrument called a **thermoscope** that is similar to the one shown in Figure 4.8. The thermoscope consists of a glass bulb with a very long, narrow tube and a container filled with a coloured liquid. The end of the glass tube sits in the liquid. When the air in the bulb is cooled, it contracts and the liquid rises up higher in the tube. When the air in the bulb is then warmed, the air expands and pushes the liquid down. When you see the coloured liquid in the tube rising or falling, you know that the temperature of the air in the bulb is changing.

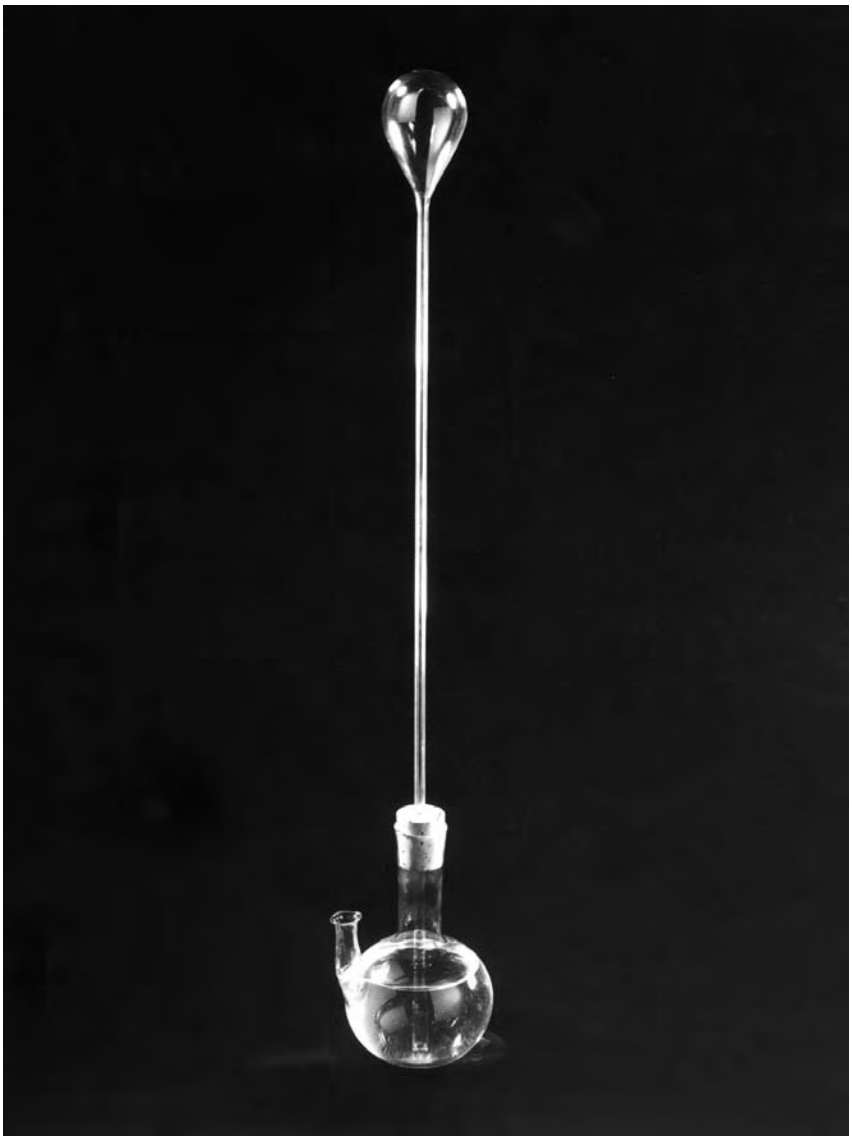


Figure 4.8 Galileo's original thermoscope looked much like this one. As the air warms, the coloured liquid drops down in the tube. As the air cools, the coloured liquid rises.

Galileo's instrument was not called a thermometer because it had no scale (numbers) on it. The thermoscope showed whether the air was hot or cold but did not show a temperature in numbers. Scientists continued to improve the air thermoscope and developed other types of temperature measuring devices such as the liquid thermoscope shown in Figure 4.9. It is the liquid in this thermoscope that expands when it is heated and contracts when cooled.

As scientists continued to develop these instruments, they started adding a number scale on the tubes so they could compare temperatures in different experiments. These instruments can correctly be called **thermometers.** However, the

numbers were different on each thermometer and, therefore, had different meanings. Scientists could not compare measurements made with different thermometers. They needed a way to give a specific meaning to the numbers on all thermometers.

The Fahrenheit Scale

Many scientists were developing temperature scales but the scale developed by Gabriel Fahrenheit (1686–1736) was the first to be widely used. Other scientists had tested many different liquids for use in thermometers including alcohol and mercury. Using carefully planned experiments, Fahrenheit made many improvements on these thermometers.

To assign numbers to a scale on his thermometers, Fahrenheit chose two things known to have constant temperatures. The coldest thing that could be generated in the laboratories in Fahrenheit's time was a mixture of salt, ice, and water. The temperature of this mixture was called zero. Since body temperature is also constant, it was used as a second reference point. Body temperature is near 100 on Fahrenheit's scale. The space between zero and 100 on the thermometer was divided into 100 units. The units on Fahrenheit's scale are called degrees Fahrenheit and symbolized, °F. As thermometers were improved and the scale developed, several fixed points on the **Fahrenheit scale** were observed. The freezing point of water is 32°F and the boiling point of water is 212°F. Body temperature is now known to be 98.6°F.

Figure 4.9 The liquid rising up the tube of this thermoscope shows that the temperature is increasing.

Did You Know?

The only countries that still use the Fahrenheit scale are the United States, Burma, South Yemen, and Tonga.

The Celsius and Kelvin Scales

Some scientists felt that it would be more convenient to have a scale with the freezing point of water as zero and the boiling point of water as 100. However, scientists were not sure that the freezing and boiling points of water were the same at different places on Earth, or under different amounts of atmospheric pressure. Anders Celsius (1701–1744), a Swedish astronomer, did detailed studies of the freezing point and boiling point of water. He showed that both are affected by atmospheric pressure. However, he also showed that the freezing and boiling points of water are always the same if they are measured under the same conditions. Therefore, to create a reliable temperature scale, he had to choose the conditions to use. He chose standard atmospheric pressure, which is atmospheric pressure at sea level. The values for the freezing and boiling points of water under these conditions became the standards for the temperature scale. In honour of his detailed work, the temperature scale was named the **Celsius scale.** Today, the Celsius scale is the most commonly used temperature scale.

In the 1800s, William Thomson, who was given the title of Lord Kelvin, and several other scientists were studying the effects of changing temperatures on gases. While analyzing the results of many experiments, Lord Kelvin developed the idea that there is a coldest possible temperature. He called this temperature *absolute zero*. No substance or object can become colder than absolute zero. Lord Kelvin proposed a new temperature scale that started at absolute zero and had units that were the same size as the units in the Celsius scale. In his honour, this temperature scale is now called the **Kelvin scale.** The units are not called degrees but instead are called kelvins and are symbolized K. Figure 4.10 shows a comparison of the Fahrenheit, Celsius, and Kelvin scales.

Did You Know?

When Celsius first proposed his scale, he assigned 0° to the boiling point of water and 100° to the freezing point. After his death, the numbers were reversed.

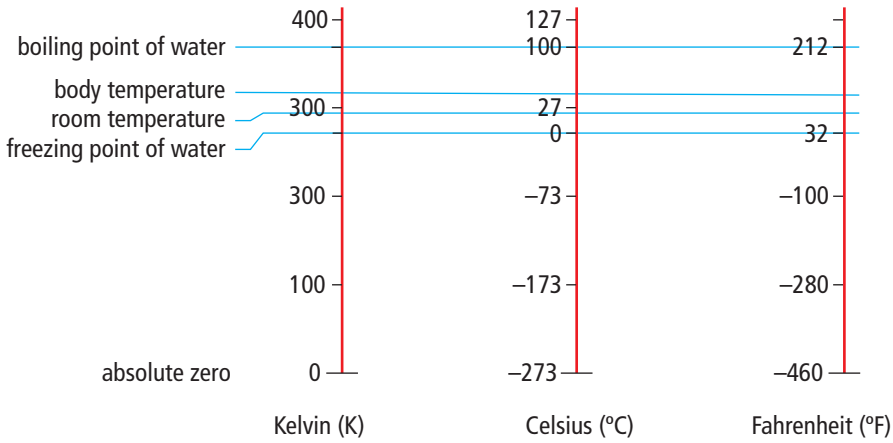


Figure 4.10 Absolute zero is really –273.15°C but it is often rounded to –273°C.

Reading Check

1. What is the difference between a thermoscope and a thermometer?
2. What was the first temperature scale to be widely used?
3. What is the difference between the Celsius and Kelvin temperature scales?
4. Why did Celsius have to choose specific conditions such as standard atmospheric pressure in order to design his temperature scale?

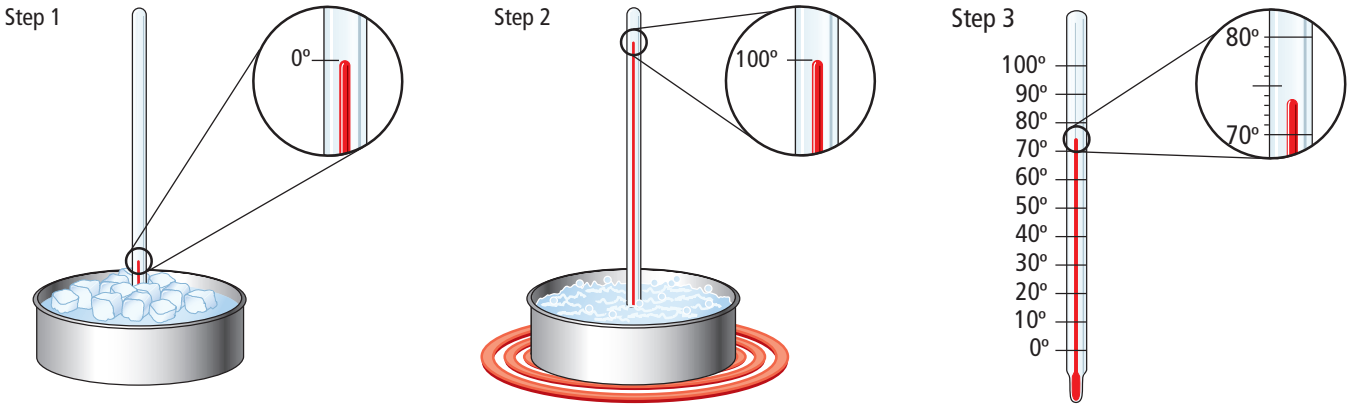
Calibrating a Thermometer

To **calibrate** an instrument means to accurately assign the numbers on a scale. A method for calibrating a thermometer is shown in Figure 4.11. You would start with a thermometer that had no markings on it and follow the steps below.

- Place the bulb of the thermometer in a mixture of pure water and ice.
- Observe the coloured liquid until it no longer moves.
- Mark the point at the top of the coloured liquid and label it 0°C.
- Remove the thermometer from the ice water and place the bulb in boiling water.
- Let the liquid rise until it no longer moves.
- Mark the point at the top of the liquid and label it 100°C.
- Divide the space between 0°C and 100°C into 100 equal spaces. Each space would represent one degree.

Suggested Activities

Investigation 4-2B on page 128.



The liquid level in an ice-water bath is marked as 0°.

The liquid level in boiling water is marked as 100°.

The scale is divided into 100 equal degrees and numbered.

Figure 4.11 The thermometer bulb is put in freezing water and boiling water to mark the positions of the liquid when the temperature is 0°C and 100°C.

The Bimetallic Strip

In recent years, scientists and engineers have developed a variety of devices that can accurately measure temperature. For example, in thermostats that turn a furnace on and off, a **bimetallic strip** is used to measure the temperature. A bimetallic strip is made of two different metals such as copper and iron that expand by different amounts when heated. One side of the strip is made of one of the metals and the other side is made of the other metal. Figure 4.12 shows you what happens when a bimetallic strip is heated. The metal on one side expands more than the other and causes the strip to bend.

Figure 4.12 When heated, a bimetallic strip bends.

For a thermostat, a bimetallic strip is made in the form of a coil. When the coil is heated, the outside expands more than the inside and this causes the strip to coil more tightly. When the coil is cooled, the outside contracts more than the inside, causing it to uncoil. Figure 4.13 shows how this coiling and uncoiling is used to turn the furnace on and off. The end of the coil is attached to a glass capsule containing a drop of mercury. When the coil is cool and loose, the mercury flows toward a pair of wires and makes an electrical connection between them. An electric current can then flow from one wire to the other, turning the furnace on. The heat from the furnace increases the temperature in the house and heats the coil causing it to tighten. When the coil is tight enough, the glass capsule tilts and the mercury flows away from the wires and the electrical connection is broken. Electric current can no longer flow and the furnace turns off.

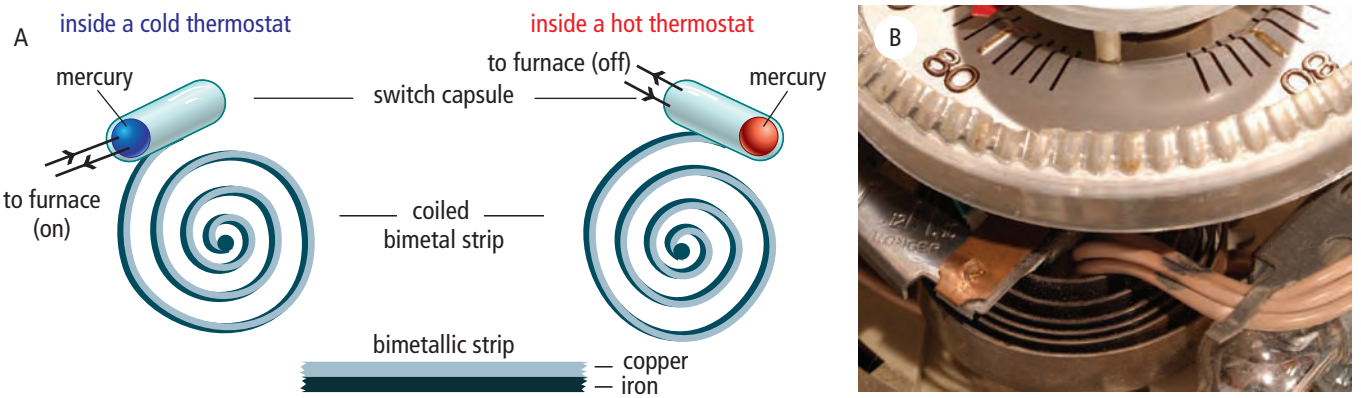


Figure 4.13 The diagram in A shows how the bimetallic strip coil moves the glass capsule with mercury. The photograph in B shows a thermostat with the cover removed. You can see the coil and the glass capsule containing the mercury.

The Thermocouple

A **thermocouple** has two wires made of different metals. The two metals are connected at both ends. A temperature difference between the two ends causes a small electric current to flow through the wires. One end, called the reference junction, is held at a known temperature. The other end, called the measuring junction, is used to measure an unknown temperature. The thermocouple can be calibrated so that the amount of current indicates the temperature. Thermocouples are more durable than most other instruments for measuring temperature. In addition, they can measure much higher temperatures than typical thermometers. Figure 4.14 shows a diagram of a thermocouple.

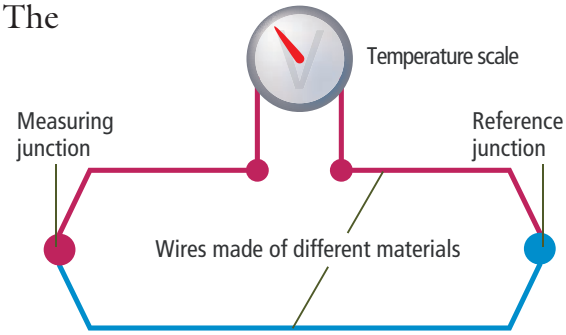


Figure 4.14 The amount of electric current that flows in a thermocouple depends on the difference in the temperature between the points where the two different types of metal wires are connected.

Infrared Thermograms

All objects give off infrared radiation. Your eyes cannot see infrared radiation but some special types of film and some electronic detectors can sense it. Film and electronic devices convert the infrared radiation into colours that can be interpreted as temperature differences. This is called a **thermogram.** Figure 4.15 shows a thermogram of a building and a photograph of the same building beside it. You can see where heat is escaping from the building by the red and yellow areas of the thermogram.

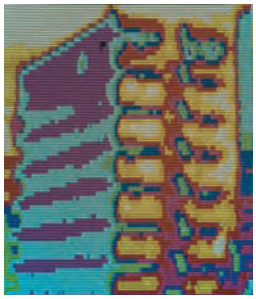


Figure 4.15 Building contractors and structural engineers can tell where a building is losing heat by studying thermograms. They can then plan ways to improve the buildings to reduce heat loss.

Reading Check

1. What does it mean when you say that you are going to calibrate a thermometer?
2. What happens when you place a bimetallic strip in the flame of a burner? Explain why this happens.
3. Name and explain the purpose of two important parts of a thermocouple.
4. If you cannot see infrared radiation, how can it be used to detect temperature differences?

internet connect

All living bodies give off a lot of infrared radiation. Doctors can use thermograms of body parts to help with the diagnosis of a medical problem. Learn more about body thermograms by starting at **www.discoveringscience.ca.**

4-2B Make Your Own Thermometer

Skill Check

- Measuring
- Controlling variables
- Evaluating information
- Working co-operatively

Materials

- small glass bottle with a narrow neck
- drinking straw or tubing
- one-hole stopper
- stand and ring clamp
- dishcloth
- ruler
- bowl of coloured water
- modelling clay
- ice-cold water
- two calibration devices

Today thermometers and other scientific instruments are mass-produced in factories. Early scientists, however, had to build their own measuring devices. Their clever designs used everyday materials, yet produced accurate measurements. Can you use modern materials to build a working model of one of the earliest thermometer designs?

Safety

Problem

Use everyday materials to build a thermometer that accurately measures temperatures in your classroom.

Criteria

A. Thermometers built in part 1 should detect increases in temperature when your teacher warms them gently with a hair dryer, and decreases in temperature when they are cooled with a cold washcloth.

B. At the end of part 2, the thermometer will have a properly constructed scale with evenly spaced degree markings and suitable numbering.

C. The thermometer must measure the temperature of the classroom accurately. The reading should be within 2°C of the temperature measured by a standard laboratory thermometer.

Part 1

Assembling the Thermometer

Design and Construct

1. Using the materials your teacher provides, your group will design and assemble a thermometer like the one illustrated the diagram. Notice that the cloth over the bottle is not part of the thermometer. It illustrates the method for cooling the air in the bottle as described in Criteria part A. The straw or tubing needs to have an airtight seal against the bottle's neck. You could use modelling clay to make a good seal.
2. Warm the bottle with your hands. Record what happens in the dish at the end of the straw. *Troubleshooting:* If nothing happens, your hands are probably about the same temperature as the bottle. Try wetting a washcloth with warm water, wringing it out, and draping it over the top of the bottle.
3. Wet a washcloth with cold water, wring it out, and drape it over the bottle. What happens to the level of the water inside the straw?

4. When you are sure that your thermometer is working correctly, have your teacher certify that it meets Criterion A.

Evaluate

1. Which part of your thermometer responds to changes in temperature? Describe how it responds when the air in the bottle (a) warms up (b) cools down.
2. Why might you add marks and numbers to your thermometer? Where would you put them?

Part 2

Calibrating the Thermometer

Design and Construct

1. Plan a method for creating a scale for your thermometer so that it can measure temperatures accurately. Here are some hints:
   (a) You must have a way to fasten your scale to the thermometer, take it off for measuring and marking, and then replace it on the thermometer in its original position.
   (b) Start by marking the scale at two known temperatures at least 10 degrees apart. You could use two wet washcloths. Soak one in water with a known cool temperature. Wrap it around the top of your thermometer and watch the liquid level rise. Mark the highest level.
   (c) Repeat step (b) using a washcloth soaked in water with a known warm temperature. Mark the lowest level the liquid in your thermometer reaches.
   (d) You now have two markings on your scale, for two different temperatures. Leaving the straw in place, remove the scale from the thermometer. Mark the proper temperatures beside each mark.
   (e) Measure and record the distance between the two marks in millimetres.
   (f) Determine the temperature difference between the two marks. Do this by subtracting the lower temperature from the higher temperature.
   (g) Divide the distance measured by the temperature difference. The answer gives you the number of millimetres that represent one degree.
2. Use your calculations to finish making your thermometer scale. Number the scale every 5 or 10 degrees.
3. Show your teacher or another lab group that your calibrated thermometer meets Criteria B and C.

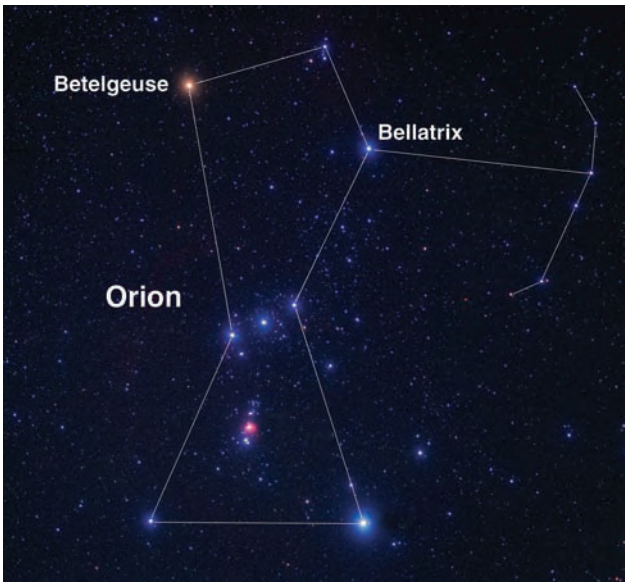
Evaluate

1. Did your thermometer meet the design specifications? How could you improve it?
2. What main problems did you have building your thermometer. How did you overcome them?
3. Why are the thermometers constructed in this activity not very useful in everyday life?

Wild, Weird, Wonderful

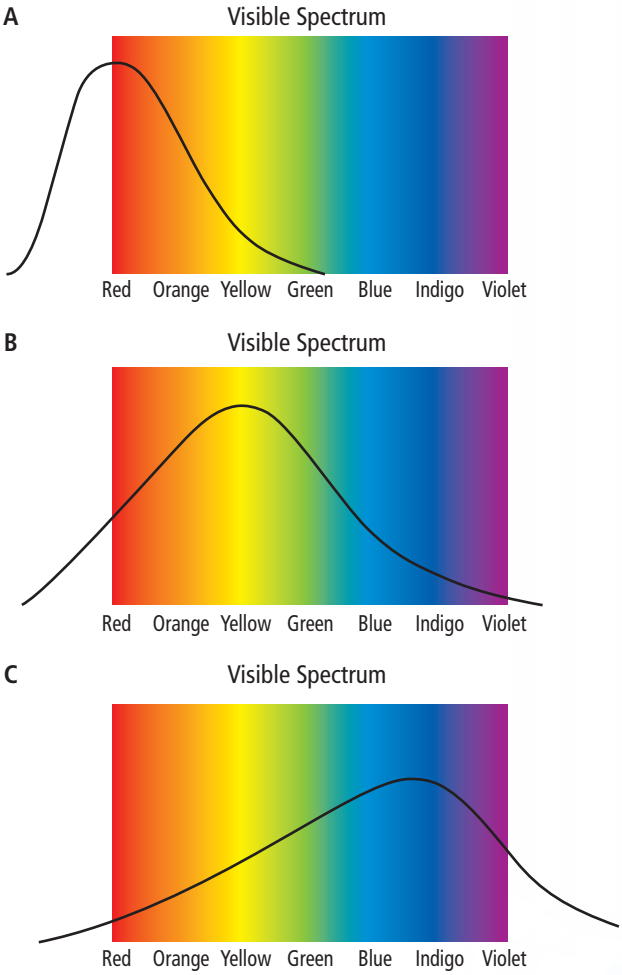
www Science

Measuring the Temperatures of Stars



The photograph shows the constellation Orion. Astronomers tell us that the temperature on the surface of the star Betelgeuse is 3100 K and the temperature on the surface of Bellatrix is 21 500 K. Do you wonder how astronomers can "take the temperatures" of the stars? Astronomers determine the temperature of the stars by their colour. All stars might look white to your eyes, but astronomers use telescopes with special instruments to determine their colours.

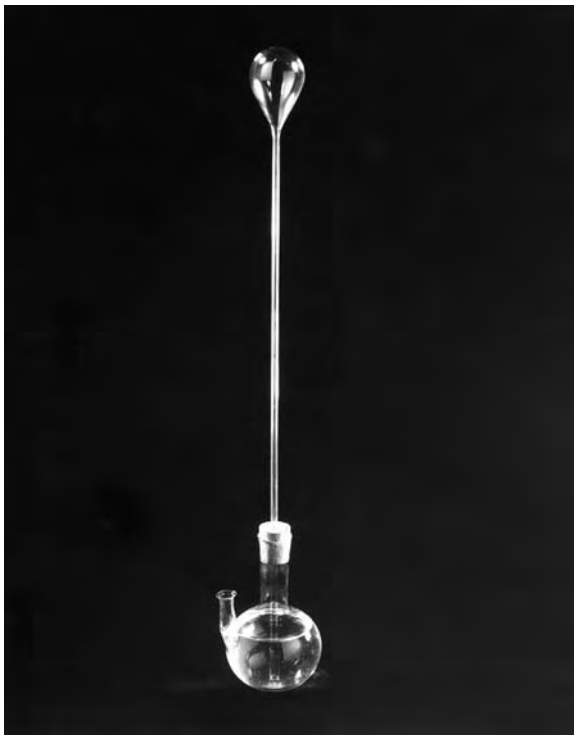
How is colour related to temperature? Think about turning on a burner on an electric stove. As it begins to heat up, it turns red. Other objects that are hotter than a burner will have other colours. As the temperature goes up, the colours go through the colours of the rainbow. The diagram on the right shows you the colours of the rainbow, called the visible spectrum, and why stars appear to be different colours. There are more "colours" on each side of the visible colours but human eyes cannot see them. However, special instruments can detect these "colours." Each section of the diagram has a curved line that shows you how much of each colour is given off by certain groups of stars. In part A, only red and a tiny bit of yellow is given off so the stars look red. These stars would have temperatures around 3000 K. In part B, more yellow is given off than any other colour so the star would look orange to yellow. These stars are around 4000 K to 5000 K. In part C, there is more blue and purple than any another colour. These blue stars are around 20 000 K. What do you think are the colours of Betelgeuse and Bellatrix?



Check Your Understanding

Checking Concepts

1. What type of information about temperature does a thermoscope provide?
2. Explain how Galileo's air thermometer showed a change in the temperature.
3. What was the first temperature scale to be widely used?
4. How does the Celsius scale differ from the Fahrenheit scale?
5. How is the Kelvin temperature scale similar to the Celsius temperature scale? How is it different?
6. Explain what it means to calibrate a thermometer.
7. Why does heat cause a bimetallic strip to bend?



Understanding Key Ideas

8. Explain the properties that a device must have in order to measure temperature.
9. Some early scientists used wine as the liquid in their thermometers. Suggest a reason for choosing to use wine.
10. Why did the scientists need to pick two things with constant temperatures in order to put scales on their thermometers?
11. Why do you think that the Celsius scale is more practical than the Fahrenheit scale?
12. What does "absolute zero" mean?
13. Explain how a thermostat can turn a furnace on and off.
14. What might be the advantages of using a thermocouple instead of a laboratory thermometer?

Pause and Reflect

A man was driving down the street and when he came to a red traffic light, he stopped. While sitting at the light, he noticed a temperature sign outside of a bank. The sign was flashing between 11° and –11°. Can you explain why the sign was showing these two numbers?

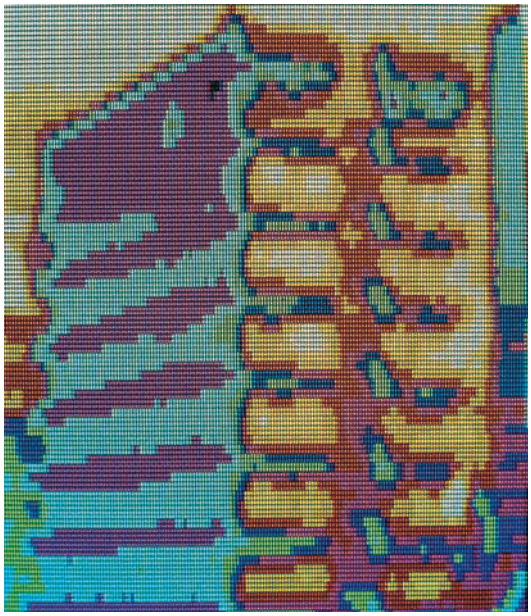
Prepare Your Own Summary

In this chapter, you investigated the temperatures of common things and ways to measure temperatures. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes.

1. Temperatures of Everyday Items and Places
2. Thermoscopes and Thermometers
3. Temperature Scales
4. Modern Temperature Measuring Devices

Checking Concepts

1. Choose five items that have different temperatures. What are the approximate temperatures of these items?
2. If the temperature of a freezer in a refrigerator was –6°C, what might happen to the food stored in it?
3. Which of the following animals would you expect to have a body temperature higher than your body temperature?
   (a) kangaroo
   (b) horse
   (c) elephant
   (d) robin
4. Why is your skin a poor instrument for measuring temperature?
5. Describe Galileo's first thermoscope.
6. In addition to developing a temperature scale, what other accomplishments did Fahrenheit make related to measuring temperatures?
7. What is the difference between the Celsius scale and the Kelvin scale of temperatures?
8. What was Lord Kelvin's major contribution to the concept of temperatures?
9. Explain how a thermogram is made.



Understanding Key Ideas

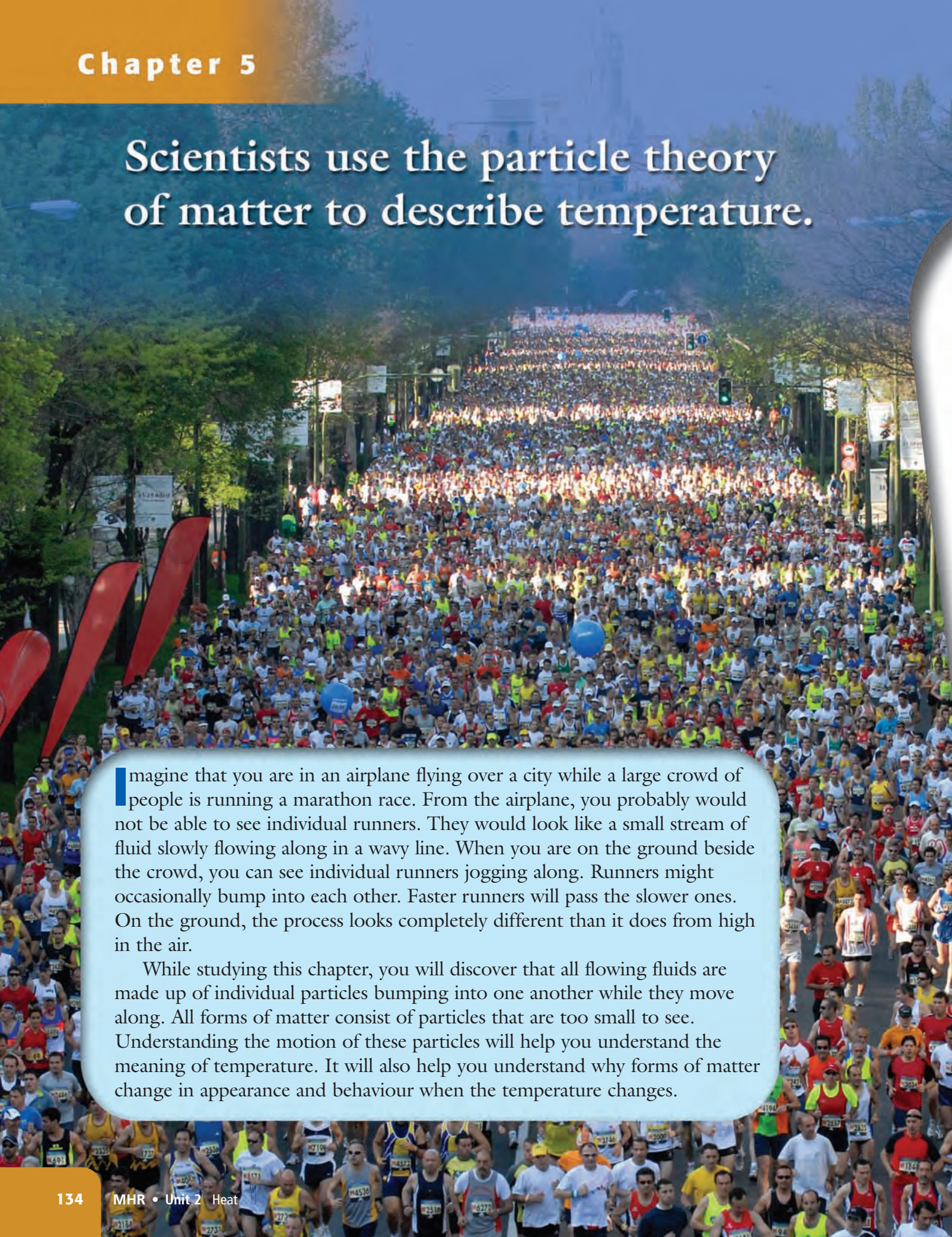
10. If you were told that an object had a temperature of –14°C, would you pick it up with your bare hands? Why or why not?
11. Explain why one person might touch an object and say it was cool while another person touches the same object and says that it is warm?
12. If a classmate told you that the coldest temperature ever recorded in Newfoundland and Labrador was –21°C, what would you tell your classmate?
13. Suppose that you were present on the hottest day that was ever reported in Canada. What would your body temperature have been? Explain your answer.
14. Many appliances in the home are heated electrically. They usually contain a thermostat that switches electricity on and off to keep the appliance at a constant temperature. Identify two examples of this use for thermostats.
15. Erin and Val go to a swimming pool on a warm summer day. Val spreads her towel in the Sun and lies down, while Erin decides to lie in the shade. After about twenty minutes, they decide to jump into the pool. Predict how warm the water will feel to each person. Explain how you arrived at your prediction.
16. Why do you think that scientists used coloured liquids in their thermometers?
17. Many people worked on the development of a temperature scale that set 0° as the freezing point of water and 100° as the boiling point of water. Why was the scale named after Celsius?
18. Why was –273.15°C on the Celsius temperature scale chosen for 0 K on the Kelvin temperature scale?
19. Bimetallic strips and thermocouples are both made from two different metals. What properties of the metals allow these devices to measure temperatures?

Pause and Reflect

Before the temperature scale that was designed using 0° for the freezing point of water and at 100° for the boiling point of water was named the Celsius scale, it was called the Centigrade scale. The prefix "centi-" means a hundredth part of something. Explain why this was an appropriate name for the temperature scale.

Chapter 5

Scientists use the particle theory of matter to describe temperature.



Imagine that you are in an airplane flying over a city while a large crowd of people is running a marathon race. From the airplane, you probably would not be able to see individual runners. They would look like a small stream of fluid slowly flowing along in a wavy line. When you are on the ground beside the crowd, you can see individual runners jogging along. Runners might occasionally bump into each other. Faster runners will pass the slower ones. On the ground, the process looks completely different than it does from high in the air.

While studying this chapter, you will discover that all flowing fluids are made up of individual particles bumping into one another while they move along. All forms of matter consist of particles that are too small to see. Understanding the motion of these particles will help you understand the meaning of temperature. It will also help you understand why forms of matter change in appearance and behaviour when the temperature changes.

What You Will Learn

In this chapter, you will

- **explain** the particle theory of matter
- **describe** the three states of matter
- **describe** the relationship between kinetic energy and temperature
- **explain** how each state of matter reacts to changes in temperature
- **use** the particle theory to explain expansion and contraction of matter

Why It Is Important

Understanding the particles that make up matter will help you understand why substances freeze, thaw, and evaporate. Knowing how materials expand and contract when the temperature changes is important for building safe structures such as buildings and bridges. Knowing how thermal energy is passed from one substance to another is necessary for designing insulation for homes and for cooking food.

Skills You Will Use

In this chapter, you will

- **use** and **read** a thermometer safely and properly for collecting data
- **compile** and **display** data using tables and graphs
- **state** a prediction based on background information

FOLDABLES™
Reading & Study Skills

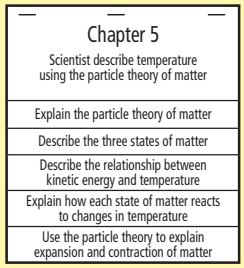
Make the following Foldable to take notes on what you will learn in Chapter 5.

STEP 1 **Stack** three sheets of 8.5″ × 11″ paper so that the back sheet is 2 to 3 cm higher than the middle sheet, and the middle sheet is 2 to 3 cm higher than the front sheet. (**Hint:** From the tip of your index finger to your first knuckle is about 2.5 cm.)

STEP 2 **Bring** the bottom of the sheets upward and **align** the edges so that all of the layers or tabs are the same distance apart. **Fold** the paper and **crease** well.

STEP 3 **Staple** the papers along the fold.

STEP 4 **Label** the Foldable with the chapter title and the five key points found in "What You Will Learn", as shown.



Organize As you read through the chapter, use the space under the tabs to record new terms and their definitions, and use the particle theory to explain temperature and its effect on matter.

5.1 Particle Theory of Matter

Did You Know?

The number of particles in one drop of water is about 3 000 000 000 000 000 000 000.

Matter is anything that takes up space and has mass. The particle theory of matter says that all matter is made up of tiny particles. The particles are always moving, have space between them, and are attracted to one another. The energy of motion is called kinetic energy. Temperature is a measure of the average kinetic energy of the particles that make up an object or a substance.

Key Terms

kinetic energy
matter
particle theory of matter
temperature

Matter is anything that takes up space and has mass. This book is matter. The water you drink is matter. Even though you cannot see it, the air you breathe is matter. Light from the Sun is not matter. It is a form of energy that your eyes can detect. Sunlight also helps plants grow but sunlight is energy and not matter.

The buildings in the photograph in Figure 5.1 are matter. Although it might be hard to believe, the buildings in photograph A are made entirely of Lego® blocks like those in photograph B. Each block had to be carefully attached to the others in exactly the right place to create these models of buildings.

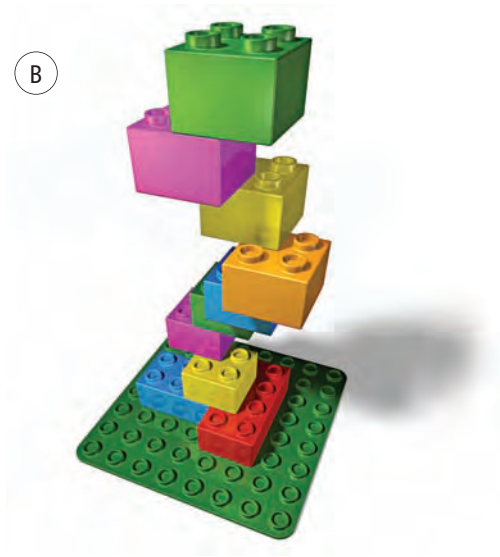


Figure 5.1 Imagine the time and care it would take to build these buildings (A) from individual Lego® blocks (B).

You could think of buildings made up of Lego® blocks as models for all forms of matter. All matter is made up of particles. The particles of matter, however, are so small that you cannot see them. The type of particles and the way they are attached to one another determines what the substance is and how the substance functions. For example, the particles that make up water are different from the particles that make up salt or sugar.

5-1A Modelling the Particle Theory

Find Out ACTIVITY

All forms of matter are made up of very small particles and these particles have spaces among them. In this activity, you will model the particle theory to find evidence of the spaces among particles.

Safety

- Ethanol is poisonous.
- Be careful to wipe up any spills.

Materials

- funnel
- water
- 2 100 mL graduated cylinders
- 250 mL graduated cylinder
- 50 mL ethanol
- marbles
- 50 mL sand
- stirring rod

What to Do

1. Copy the following data table. Predict the total volume for each trial and record your prediction in your table.

Trial	Volumes	Predicted Total Volume (mL)	Actual Total Volume (mL)
1	50 mL water 50 mL water		
2	50 mL water 50 mL ethanol		
3	50 mL marbles 50 mL sand		
4	Trial 3 plus 50 mL water		

Trial 1 Water and Water

2. Use a funnel to carefully measure 50 mL of water into each of the two 100 mL graduated cylinders.
3. Add one of the volumes of water to the other. Stir with a stirring rod. Record the total volume.

Trial 2 Water and Ethanol

4. Carefully measure 50 mL of water into one 100 mL graduated cylinder and 50 mL of ethanol into the other cylinder.
5. Add one of the volumes to the other. Stir with the stirring rod. Record the total volume.

Trial 3 Marbles and Sand

6. Add marbles to the 250 mL graduated cylinder until they reach the 50 mL mark.
7. Add sand to a dry, 100 mL graduated cylinder until it reaches the 50 mL mark.
8. Add 50 mL of sand to the marbles. Record the new volume. (Save the mixture for Trial 4.)

Trial 4 Marbles, Sand, and Water

9. Carefully measure 50 mL of water in one of the 100 mL graduated cylinders. Add the water to the mixture of marbles and sand. Record the new volume.
10. Clean up and put away the equipment you have used.

What Did You Find Out?

1. If the 50 mL of water and the 50 mL of water did not add up to 100 mL, explain why.
2. If the 50 mL of water and the 50 mL of ethanol did not add up to 100 mL, explain why.
3. If the 50 mL of marbles and the 50 mL of sand did not add up to 100 mL, explain why.
4. If the 50 mL each of marbles, of sand, and of water did not add up to 150 mL, explain why.
5. If you added the substances in Trial 3 to the cylinder in reverse order, would the total volume be greater or less? Explain.

Word Connect

The word "kinetic" comes from a Greek word, *kinetikos*, which means motion or movement. The same Greek word is the basis of the word "cinema" (moving pictures).

The Particle Theory

The concept that all matter is made of particles is called the **particle theory of matter**. The important points of the particle theory of matter are listed here.

- All matter is made up of tiny particles.
- These particles are always moving—they have energy.
- There are spaces among particles.
- There are attractive forces between the particles.
- The particles of one substance differ from the particles of other substances.

Figure 5.2 The amount of kinetic energy that a ball has will determine how hard the ball hits the glove. Fastballs can sting your hand even if you are wearing a catcher's mitt.

Kinetic Energy

All particles of matter are moving and, therefore, have energy. The energy that an object has due to its motion is called **kinetic energy**. What properties of an object affect its kinetic energy?

Imagine that you are playing baseball in the position of catcher (see Figure 5.2). Which would sting your hand more when you caught it, a slow ball or a fastball? Whether you have ever played catcher or not, you probably know that a fastball will sting your hand more than a ball that is moving slowly. As the speed of an object increases, its kinetic energy increases, making it harder to stop.

Now think about bowling as shown in Figure 5.3. When you throw a strike, the pins fly away from the ball. What would the pins do if you rolled a baseball down the bowling lane at the same speed that you roll the bowling ball? The pins would probably wobble but they might not even fall down. A bowling ball moving at the same speed as a baseball has much more kinetic energy. When any two objects are moving with the same speed, the one with the larger mass has more kinetic energy. Mass and speed affect the kinetic energy of an object.

Figure 5.3 When a bowling ball is thrown well, the pins fly in all directions. How would the pins react if hit by a rolling baseball or a golf ball travelling at the same speed?

Average Kinetic Energy

Sports and games involving the motion of balls make excellent models for studying the motion of particles. Billiards allows you to analyze the motion of many balls at the same time. When a player makes the first shot and breaks the racked balls, the balls

move out in all directions. Each ball has kinetic energy, but it is unlikely that any two balls have the same amount of kinetic energy. You could describe the energy of the balls by finding the average kinetic energy of all of the balls. An example of finding average kinetic energies is given in the following Think About It activity.

Figure 5.4 Even if you do not play billiards, you can learn a lot about motion by studying the speed and direction of the balls.

5-1B Average Kinetic Energy

Think About It

You will discover that the average kinetic energy of the particles in a substance is an important characteristic of matter. You can practise calculating the average kinetic energy of billiard balls to learn about finding averages.

Note: The unit of kinetic energy is the joule (J).

What to Do

1. Study the following example of finding an average.

   The kinetic energies of 15 billiard balls just after the racked balls were hit by the cue ball are given here.

0.95 J	1.21 J	1.10 J	0.90 J	0.82 J
0.86 J	0.79 J	1.35 J	1.08 J	1.03 J
1.05 J	0.91 J	0.77 J	0.88 J	1.11 J

   Find the average kinetic energy of all of the balls by adding the energies of all 15 balls and then dividing by the number of balls, or 15.

   0.95 J + 0.86 J + 1.05 J + 1.21 J + 0.79 J + 0.91 J + 1.10 J + 1.35 J + 0.77 J + 0.90 J + 1.08 J + 0.88 J + 0.82 J + 1.03 J + 1.11 J = 14.81 J

   $\frac{14.81\ \text{J}}{15} = 0.99\ \text{J}$

   The average kinetic energy of the balls is 0.99 J.

2. Find the average kinetic energy of the balls if their individual energies are:

0.92 J	1.09 J	1.23 J	0.94 J	0.85 J
0.89 J	0.81 J	1.04 J	1.02 J	1.14 J
1.12 J	0.72 J	0.74 J	0.85 J	0.91 J

What Did You Find Out?

1. How large is the average kinetic energy compared with the individual kinetic energies of the balls? Is it larger, smaller, or in the middle?
2. How long do you think it would take to calculate the average kinetic energy of 100 particles?

Reading Check

1. Describe the particle theory of matter.
2. When an object is moving, what type of energy does it have?
3. Name the two characteristics of an object that determine the amount of kinetic energy the object has.

Kinetic Energy and Temperature

If it is cool outdoors and you are not wearing gloves, you sometimes rub your hands together to make them warmer. Because your hands are moving, they have kinetic energy. The rubbing of your hands together causes the particles of skin on your hands to move more rapidly. How does this motion, or kinetic energy, cause your hands to feel warm? Some more clues about the connection between kinetic energy and temperature are given in the following Think About It activity.

5-1C Detect a Connection

Think About It

While analyzing the images in this activity, think about the motion of the particles that make up matter. According to the particle theory, particles are always moving, even when the object itself is not moving. You do not see the motion because the particles in the object are moving randomly and in different directions. How can you measure the motion of tiny objects that you cannot see?

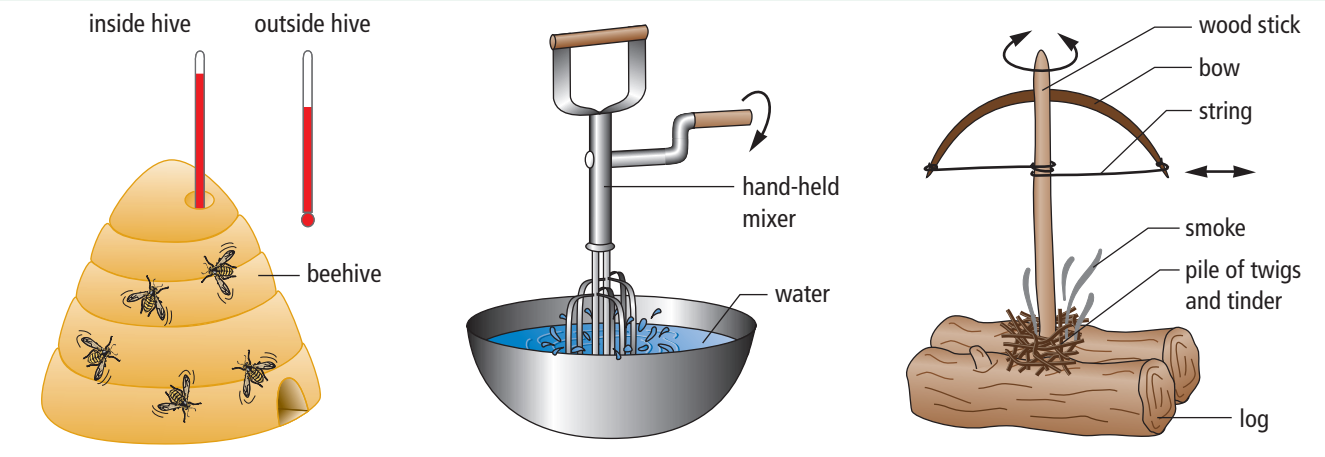
What to Do

Carefully examine each picture. Then, answer the following questions.

1. One way that bees control the temperature in their hive is by beating their wings vigorously. Explain what happens to:
   (a) the motion of the air particles in the hive
   (b) the air temperature in the hive
2. In a famous experiment, James Joule observed the temperature of water as a mechanical mixer stirred it vigorously. Explain what happened to:
   (a) the motion of the water
   (b) the temperature of the water
3. To start a fire, early people used a fire drill to twirl a stick pressed against a piece of wood.
   (a) What happened to the temperature at the pointed end of the drill?
   (b) What do you think caused the particles of wood to change temperature?

What Did You Find Out?

1. What common feature caused the changes in temperature in each example you examined?



When a large object such as a bowling ball or a billiard ball has kinetic energy, it moves from one place to another. When the particles that make up a solid object such as a billiard ball have kinetic energy, they do not move from place to place. Instead, the particles vibrate back and forth while remaining near the same location within the object. The particles are constantly colliding with one another and, therefore, changing direction.

Now think about rubbing your hands together again. When you rub your hands together, you cause the particles in your skin to vibrate faster and your hands feel warm. The temperature of your skin actually increases. Temperature is directly related to the kinetic energy of the particles in an object.

The particles in any object or substance do not all have the same amount of kinetic energy. However, you can describe their average kinetic energy just as you did with the billiard balls. Fortunately, you do not have to measure or calculate the kinetic energies of any of the particles to describe their average kinetic energy. The **temperature** of a substance is a measure of the average kinetic energy of its particles. Figure 5.5 illustrates the relationship between temperature and kinetic energy. When particles are the same size, the faster moving particles have more kinetic energy than the slower moving particles. The substance having the particles with the higher average kinetic energy has a higher temperature.

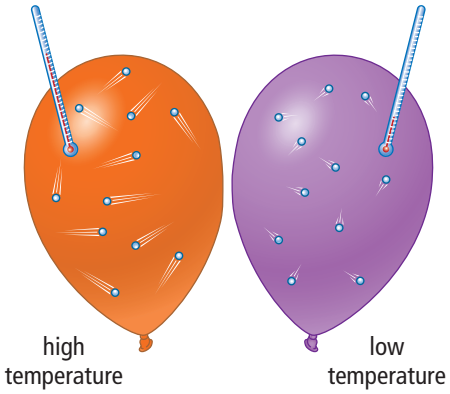


Figure 5.5 The air in the orange balloon is at a higher temperature than the air in the purple balloon because the particles have more kinetic energy.

Reading Check

1. Explain how particles in an object can be moving if the object is not moving.
2. What is the connection between the kinetic energy of the particles in an object and the temperature of the object?
3. Explain how to find the average of a set of numbers.

internet connect

You cannot see the motion of the particles in an object or substance, so it might be difficult to understand their motion. There are animations on the Internet that illustrate the motion of particles in relation to temperature. To find an animation, start your search at **www.discoveringscience.ca.**

Did You Know?

When scientists were developing the temperature scales, they had not yet discovered the relationship between temperature and average kinetic energy of particles in a substance. Temperature and energy are different quantities, measured in different units, and they cannot be equal to each other. Temperature is related to the average kinetic energy of the particles in a substance but it is *not* equal to it.

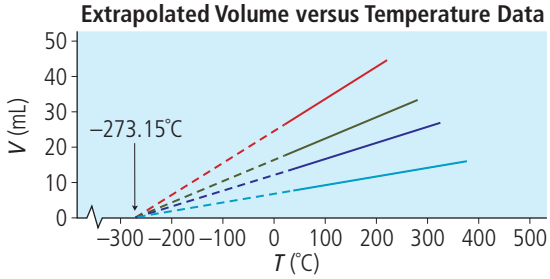
Science Watch

Absolute Zero: As Cold as It Gets

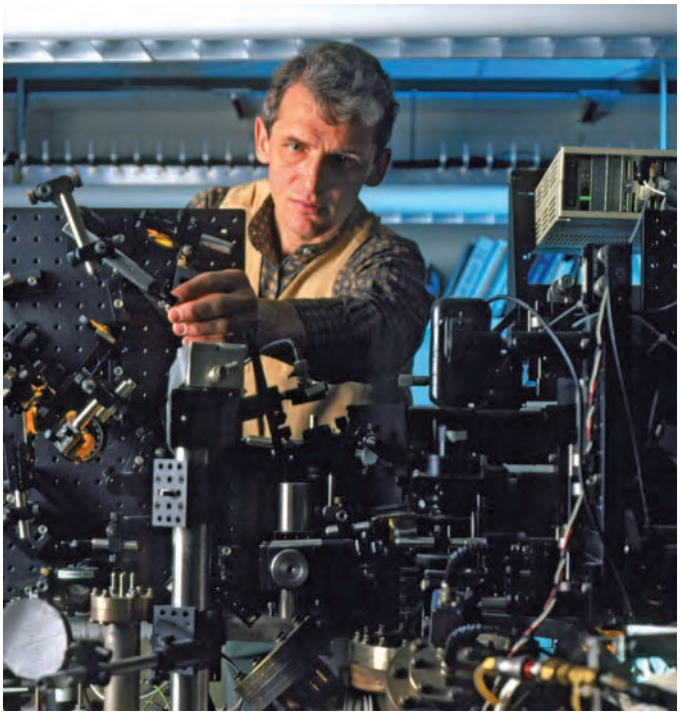
In Chapter 4, you read that the lowest possible temperature is –273.15°C. Why is it impossible for anything to get any colder than –273.15°C? You have learned that temperature is a measure of the average kinetic energy of the particles that make up a substance. Therefore, when the particles have no kinetic energy, the temperature is as low as it can possibly get.

The Kelvin scale was proposed in 1848. How did scientists of the time discover that absolute zero was –273.15°C? They did not even have refrigerators! They used a mathematical technique called *extrapolation.* Extrapolate means to extend the line in a graph past the data points. The scientists performed experiments on gases and collected and plotted the data from the experiments.

As the kinetic energy of gas particles gets lower and lower, the particles do not hit the walls of the container as often or as hard. If the walls are flexible, the container will get smaller. Therefore, as the temperature of a gas decreases, its volume also decreases. So, scientists measured the volume of samples of gases at many different temperatures. Then, they plotted the data on a graph like the one shown here. They drew a line through their data points and extrapolated the line to zero volume. No matter how large the sample was or what type of gas they used, the line ended at the same temperature, –273.15°C. The four lines on the graph below represent four different samples of gases tested under different conditions.



Today scientists want to get as close to absolute zero as possible. They have developed techniques involving magnetism and lasers that can cool particles to very near absolute zero. In 2001, three physicists, Carl Wieman, Eric Cornell, and Wolfgang Ketterle won the Nobel Prize in Physics for a project in which they brought a few very small particles down to a temperature of 0.000 000 170 K. As scientists study matter at these extremely low temperatures, they will learn more about the tiniest particles of matter and also develop new technologies. Some of the instruments used by these Nobel award-winning scientists are shown here.



Questions

1. Explain why it is not possible to cool a substance below absolute zero.
2. Is there a highest possible temperature? Do research on the Internet to find out.
3. What is the coldest temperature that you have ever experienced?

Check Your Understanding

Checking Concepts

1. State the definition of matter. Give an example of something that is not matter.
2. List the main points of the particle theory of matter.
3. How does the kinetic energy of the particles that make up a bowling ball differ from the kinetic energy of the ball as it rolls down the lane?
4. Two identical baseballs are hit with a baseball bat. One baseball is travelling at a speed of 35 m/s and the other is travelling at 23 m/s. Which baseball has more kinetic energy? Why?

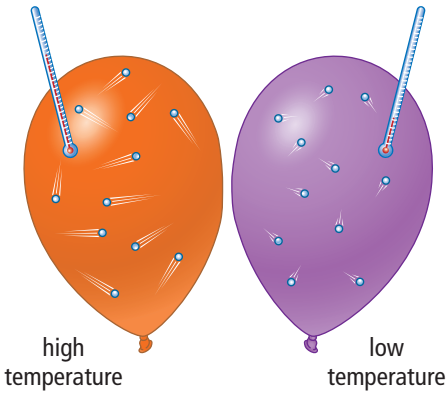
5. A billiard ball and a Ping-Pong™ ball are travelling at the same speed. Which ball has more kinetic energy? Why?
6. What is wrong with the following statement? "The temperature of an object is a measure of its kinetic energy." Rewrite the statement correctly.

Understanding Key Ideas

7. At the beginning of this section, you saw pictures of buildings made up of Lego® blocks. These were used as models of the particle theory of matter. Think of another way to model the particle theory of matter. Write a paragraph about your model.
8. Explain why rubbing your hands together makes them feel warmer. In what other way could you use motion to make yourself feel warmer?
9. One golf ball has been lying in the sun and another one has been in the shade. The particles of which ball have a larger average kinetic energy? Explain.

Pause and Reflect

The balloons from Figure 5.5 are shown again here. Analyze the image to find something that you think might be drawn in a more accurate way. Think about the number of particles in the balloons and the speed of the particles in each balloon. Think about the volumes of the balloons. Explain why the figure might be inaccurate. Draw the balloons in a way that corrects the figure.



5.2 States of Matter

The three common states of matter are solid, liquid, and gas. The particle theory explains the states of matter. Matter in any state will expand upon warming and contract upon cooling.

Key Terms

gas
liquid
solid
thermal contraction
thermal expansion

Figure 5.6 When you first look at this picture of an iceberg, you might just think of its beauty. However, by analyzing the picture, you can learn some very important features of matter.

Can you describe all of the forms of water that are shown in the photograph in Figure 5.6? The iceberg is made up of solid water. The ocean water is, of course, liquid water. The clouds in the sky are also liquid water. Clouds are made up of droplets of water that are so small that they do not fall to Earth. The presence of clouds indicates that there must also be water vapour in the air. Water vapour is the gaseous form of water. Three states of water—solid, liquid, and gas—are all present at the same time.

Did you know that water is the only substance that is naturally found in all three states at the same time on Earth? What causes some substances to be solid and others to be liquid or gaseous over the range of temperatures normally found on Earth? In this section, you will learn how to define solids, liquids, and gases. As well, you will learn how the particles of a substance cause them to be solids, liquids, or gases. Then, you will find out how changes in temperature affect matter in the three different states.

Did You Know?

When learning about states of matter, you usually read about solid, liquid, and gaseous states. However, there are two additional states of matter. When matter becomes extremely hot, the positive and negative charges in the particles come apart and form an electrically charged gas. This state of matter is called plasma. When matter becomes extremely cold—very close to absolute zero—the small particles collapse and combine with one another to form another state of matter called a Bose-Einstein condensate.

5-2A Is It a Solid, Liquid, or Gas? Find Out ACTIVITY

You will analyze some objects and substances and classify them as solids, as liquids, or as gases. Then, you will discuss any uncertainties with the class.

Materials

- rock
- marshmallow
- a square of gelatin dessert
- glass of milk
- whipped cream from an aerosol can
- jar with lid
- glass of water
- vegetable oil

Safety

Do not taste any of the objects that you are analyzing.

What to Do

1. Inspect each item and classify each one as a solid, liquid, or gas.
2. If you were not sure about any of the items, explain why you were unsure.
3. For each state of matter (solids, liquids, and gases) write the characteristics that allow you to classify an item as that particular state of matter.
4. As a class, discuss any problems you had in classifying the items or defining the characteristics of a particular state of matter.

What Did You Find Out?

1. Describe any difficulties you had in defining what makes something a solid, a liquid, or a gas.
2. Was there any object that the class could not agree on? If so, what was it?

Describing the States of Matter

When you look at the photographs in Figure 5.7, you can easily identify each one as a solid, a liquid, or a gas. However, if you were asked to describe what you mean by a solid, a liquid, or a gas without referring to a picture, would you be able to give clear descriptions?

Figure 5.7 (A) You might have heard the expression, "solid as a rock." What do you think it means? (B) Does this photograph help you to describe the shape of a liquid? (C) Many gases are invisible but this gas has a reddish-brown colour.

Did You Know?

Scientists have found evidence to show that most of the giant planet, Jupiter, just below its cloudy surface, is made up of a strange substance. It is made up of liquid metallic hydrogen. At pressures of more than 4 000 000 times that of Earth's atmosphere, hydrogen not only flows like a liquid but also conducts electric current like a metal.

A **solid** is the form of matter that has a fixed shape. The shape of a solid will not change when you put it into a container or place it on a table. You might be able to break a solid such as the rock in Figure 5.7A by hitting it with a hammer. Then, you would just have smaller pieces of a solid. A solid also has a constant volume. You could try to press on it but its volume would not change. You might be able to change the shape of a solid such as bending a piece of plastic. You might be able to squeeze air bubbles out of something like a sponge, but you are not actually changing the volume of the solid itself.

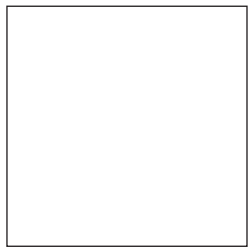
A **liquid** has no shape of its own. When you pour a liquid into a container, it takes the shape of the container and forms a flat surface in the container. Figure 5.7B shows how the liquid takes on some interesting shapes. What are the shapes of the milk and juice containers in your refrigerator? Liquids also have an unchanging volume as long as the temperature does not change. You can exert pressure on the liquid but its volume will remain almost exactly the same. You might sometimes think you have compressed a liquid but you probably just squeezed out air bubbles.

A **gas** has no shape and no volume of its own. A gas takes the shape of any container and completely fills the container. The gas in Figure 5.7C has a reddish-brown colour so you can see that it fills the container. Gases can easily expand or contract to fit the volume of any container. Figure 5.8 summarizes the characteristics of solids, liquids, and gases.

Figure 5.8 These definitions should help you identify the states of matter. Use these definitions to check your classifications in Find Out Activity 5-2A.

solid state

liquid state



gas state

Solid
- A solid has a fixed shape.
- Its shape does not change to fit its container.

Liquid
- The shape of a liquid changes with the shape of its container.
- A liquid forms a surface inside its container.

Gas
- The shape of a gas changes with the shape of its container.
- A gas does not form a surface inside its container because it fills its container completely.

If you compared the amount of mass in a specific volume of a solid, a liquid, and a gas, what would you expect? For example, how would the masses of a litre of a gas, a liquid, and a solid compare? Since the amount of space between the particles of a gas is very large, the mass in a litre of gas would be very small. The amount of mass in a litre of a solid or a liquid is much larger than the mass in a litre of a gas when the temperature and pressure are the same. The mass in a litre of solids and liquids depends on the types of substances you are comparing. For example, a ball made up of solid lead would have much more mass than a ball made up of aluminum that is the same size.

The Particle Model and the States of Matter

The particle theory of matter might help you to understand why some substances are solids, others are liquids, and still others are gases under the same conditions. Examine Figure 5.9 to see how particles combine to make solids, liquids, and gases.

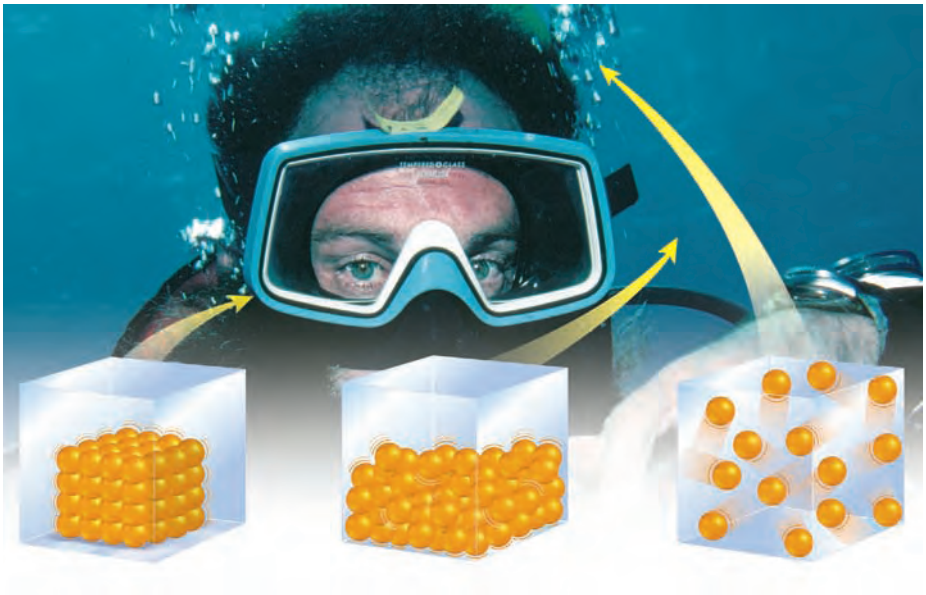


Figure 5.9 In solids, the particles are tightly packed. In liquids, the particles can slide around and past each other. In gases, the particles are very far apart. They collide with each other then bounce away.

In solids, particles are closely packed together. Each particle is attracted to the particles on each side by a strong force. The particles stay beside the neighbouring particles like children holdings hands (see Figure 5.10). The particles can move with small vibrations but they do not separate from the closest particles.

Figure 5.10 The children's hands held together represent the strong attractive forces that act between the particles in a solid. As long as they hold hands, the children can move around but they will always be holding hands with the same friends. The particles in a solid can move slightly but the forces will not allow particles to be separated from the particle beside it.

Figure 5.11 These square dancers are taking hands then letting go to take another hand. However, each person is always holding hands with someone as they move around the circle.

In liquids, particles are packed closely together and are attracted to each other by a force. However, particles can slide past each other and move around. You might picture the motion as similar to the square dancers in Figure 5.11. The dancers are constantly changing partners or moving past each other, but they are always holding hands with at least one other person.

In gases, the particles are not touching one another. There are large distances between them. The particles collide and bounce off the walls and off one another. The attractive forces between the particles are very small. You might compare particles in gases to children playing tag as shown in Figure 5.12. The children are running in all directions but are rarely touching each other.

Figure 5.12 When children play tag, they try to stay as far as possible from the child who is "it." They are each running in a different direction and never holding hands.

Did You Know?

If the amount of water that would fill this pitcher became a gas at standard atmospheric pressure, it would fill about four refrigerators.

Reading Check

1. (a) List two features of solids that help you to classify something as a solid.
   (b) List two features of liquids that help you to classify something as a liquid.
   (c) List two features of gases that help you to classify something as a gas.
2. Describe the arrangement of particles in a solid.
3. Explain one way in which the particles in a liquid differ from the particles in a solid.
4. Explain how children playing tag can make a good model for the particle theory of gases.

Expansion and Contraction of Matter

When you read about solids, liquids, and gases on page 146, you read that solids and liquids cannot be compressed. It is true that pressure has almost no affect on the volume of liquids and solids as long as the temperature stays the same. However, when you change their temperature, all forms of matter can expand and contract to some extent. In fact, many thermometers are based on the expansion of a liquid or solid with an increase in temperature as shown in Figure 5.13.

The term **thermal expansion** means that the volume of an object or substance increases when the temperature increases. When an object or substance cools, it contracts. That is, its volume decreases. The term **thermal contraction** applies to the reduction in volume with a decrease in temperature.

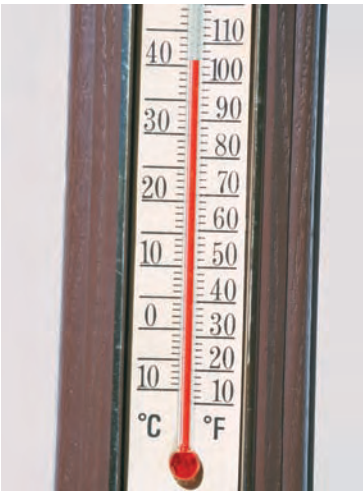


Figure 5.13 The red liquid in this thermometer expands when the temperature increases. It contracts when the temperature decreases.

Expansion, Contraction, and the Particle Theory

In Section 5.1, you read that the particles of an object or substance are always moving, so, they have kinetic energy. You also read that temperature is a measure of the average kinetic energy of the particles of a substance. If you add energy to a substance, or heat the substance, the kinetic energy of the particles increases. How does this increase in kinetic energy cause the substance to expand?

Figure 5.14 represents the particles of a gas (A) at a cool temperature and (B) at a warm temperature. The lengths of the arrows represent the speed of the particles. When the temperature of a gas increases and the kinetic energy of the particles increases, the particles collide with the walls of the container with a greater force. If the walls of the container are flexible, the increased force on the walls causes them to move out and the volume of the gas becomes greater.

A similar process occurs in liquids and in solids when the temperature of the substance increases. The particles move faster and collide with each other with a greater force. However, the attractive forces between the particles in liquids and solids prevent them from moving as far as the particles in gases move. Nevertheless, the particles collide with greater forces when they are at higher temperatures and particles push each other farther apart. As a result, the volumes increase somewhat.

You might wonder how a particle in a solid can move more rapidly and with more energy but does not move away from the

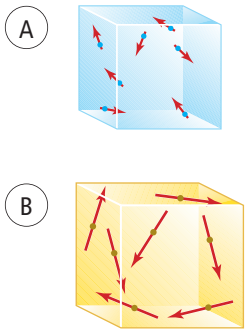


Figure 5.14 As the temperature rises and the kinetic energy of the gas particles increases, the particles collide with the walls with a greater force. This force causes the walls to move outward and the volume of the container increases.

Suggested Activity

Investigation 5-2B on page 151.

Suggested Activity

Investigation 5-2C on page 152.

particles beside it when the temperature increases. You can imagine the particles in solids as being attached to each other by springs as shown in Figure 5.15. The springs represent the attractive forces between the particles. The particles can vibrate and stretch the springs, but the springs still prevent the particles from "letting go" of each other.

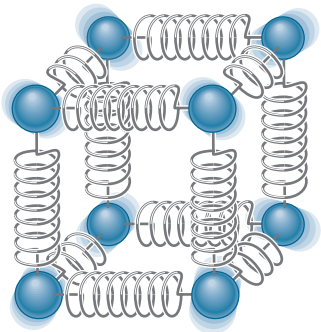


Figure 5.15 Particles are not really attached by springs, but the forces that hold them together cause the same effect that springs would cause.

The thermal expansion of solids is very small. For example, if you had a lead bar that was exactly 1.0000 m long at 0°C, it would expand to 1.0029 m long at 100°C. That is, the amount of expansion, or 0.0029 m, is about equal to the thickness of the cover of this textbook. This amount of expansion might not seem important, but for very large objects it can be critical. Engineers who design large buildings, bridges, and railroads must plan ahead for thermal expansion or the structures could be damaged. Figure 5.16 shows what can happen if railroad tracks are not designed to allow for thermal expansion. Correctly placed tracks have spaces between them as shown in Figure 5.16A. If the space is not large enough and the tracks expand on a very hot day, the tracks can bend as shown in Figure 5.16B. Bent tracks could cause a train to derail.

Suggested Activity

Investigation 5-2D on page 154.

Figure 5.16 (A) Notice the space between each piece of iron track. The space is necessary so that, when the track expands in the heat, the rails will not push on each other and cause bending. (B) This is what happens if not enough space was left between the pieces of track.

Reading Check

1. Define the term, *thermal expansion*.
2. How do the particles of a gas cause the volume of a container to increase when the temperature of the gas increases?
3. Describe a practical use for the expansion of liquids with an increase in temperature.

5-2B Bulging Balloons

Conduct an INVESTIGATION

Skill Check

- Observing
- Predicting
- Controlling variables
- Evaluating information

Materials

- 2 identical balloons
- refrigerator or freezer
- hair dryer or electric heater

To observe the expansion and contraction of a gas, it must be in a flexible container. In this investigation, you will use balloons to "contain" a gas and observe any changes in the volume of the balloons.

Question

How can you demonstrate the effect that a change in temperature will have on a gas?

Prediction

Predict what will happen to a balloon that is cooled and to a balloon that is heated.

Procedure

1. Blow up both of the balloons several times to stretch them. Then, blow up both of the balloons to the same size and tie them so that no air can escape.
2. Put one balloon in the refrigerator or freezer to cool it. Leave the other balloon at room temperature.
3. Near the end of the class period, compare the size of the two balloons.
4. Warm the cold balloon by blowing warm air from a hair dryer over it or by holding it in the warm air from an electric heater. Continue to warm the balloon until it feels much warmer than room temperature.
5. Compare the size of the balloons.

Analyze

1. Describe what you observed using the words "expand" and "contract."
2. How well do your observations support your prediction? (completely, partially, or not at all)
3. Describe any differences between what you expected to happen and what did happen.
4. In this activity, one balloon is called the *control* and the other is called the *test*. Which is which? Why?

Conclude and Apply

5. At which point in this activity were the air particles in one balloon the farthest apart? When were they the closest together?
6. Describe another situation in which you are able to observe the expansion and contraction of a gas.

5-2C Race for the Top

Skill Check

- Observing
- Predicting
- Controlling variables
- Evaluating information

Safety

- Ethanol is poisonous. Be careful to wipe up any spills.
- Be careful when handling hot water.

Materials

- 3 liquids (coloured water, ethanol, and cooking oil)
- 3 large test tubes
- 3 one-hole stoppers with 50 cm pieces of glass tubing inserted
- laboratory stand and clamps
- rubber bands
- markers
- 2 large tin cans or 500 mL beakers
- very hot water
- ice-cold water

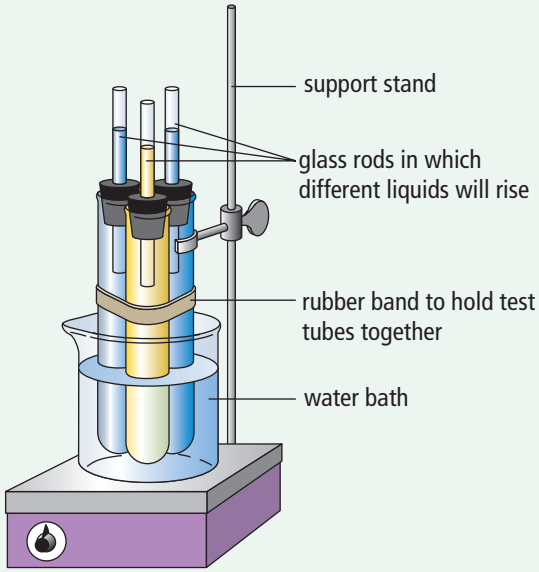
You already know that liquids expand when heated. You have used laboratory thermometers that can measure temperature because the liquid expands by a known amount. Thermometers are calibrated so that the degree marks match the amount of increase in the volume of the liquid when the temperature increases by one degree. Do all liquids behave in exactly the same way? (Your teacher may choose to demonstrate some or all of the steps for you.)

Question

Do all liquids expand by the same amount when they are heated?

Hypothesis

Make a hypothesis about the expansion of different liquids when they are heated to the same temperatures.



Procedure

1. Completely fill one test tube with coloured water, the second with ethanol, and the third test tube with cooking oil. Insert a stopper in each test tube so that there are no air bubbles and the liquid rises a few centimetres up the glass tubing.
2. Hold the test tubes together with the rubber band so that the liquids are at the same level in the glass tubing.
3. Arrange the apparatus as shown in the diagram.
4. Use the markers to mark the starting height of each liquid on the glass tubing.

5. Pour the hot water into the beaker around the test tubes. Watch the heights of the liquids closely as the liquids warm.
6. Before the liquids overflow the glass tubes, lift the apparatus out of the hot water and put it into the ice-cold water.
7. Continue to watch the height of the liquids as they cool.

Analyze

1. Did all of the liquids expand by the same amount as they warmed? If not, answer the following questions.
   (a) Which liquid expanded the most?
   (b) Did the liquid that expanded the most as it warmed also contract the most as it cooled?
2. At the end of the activity, did the liquids return to their original heights in the tubes? Did you expect them to do so? Explain.

Conclude and Apply

3. Based on your observations, do all liquids expand and contract the same amount when they are heated and cooled?
4. Explain which of the liquids that you tested would be most suitable for making a thermometer that could be used to
   (a) show small changes in temperature clearly
   (b) measure large changes in temperature without the thermometer being too large
   Explain the reasoning for your answers to (a) and (b).
5. Examine the laboratory thermometer and the home thermometer below. Have you noticed that all liquid thermometers have a large bulb of liquid at the bottom?
   (a) What do you think is the purpose of the bulb of liquid?
   (b) What part of your apparatus performs the same function as the bulb on thermometers?
   (c) Why do you think that the diameter of the tube in which the liquid rises affects the accuracy of the thermometer?

5-2D Expanding Solids

Skill Check

- Observing
- Measuring
- Evaluating information
- Explaining systems

Materials

- long copper or iron wire
- small mass with a hook (200 g or 500 g)
- metre stick
- ball and ring apparatus
- laboratory burner
- candles
- matches
- cold water

Changes in the size of solids are so small that you usually cannot see them. In this investigation, you will observe two special situations that allow you to see the effects of the expansion and contraction of solids.

Question

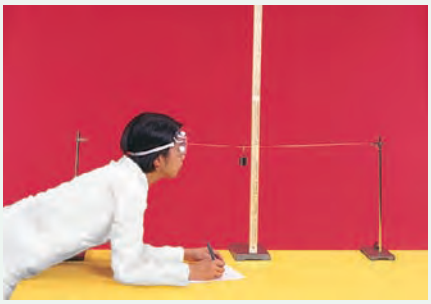
What evidence can you observe of solid materials expanding as they are warmed?

Safety

- Be careful working with an open flame and hot objects.

Part 1

The Sagging Wire



Procedure

1. Prepare a table like the one on the left for recording your data. Make at least 12 rows.
2. Stretch the wire tightly between firm supports. Place the small mass in the middle of the wire. Put the metre stick behind the mass and record its height.
3. Light the candles and use them to warm the entire length of the wire for several minutes. As you do, observe and carefully record the height of the mass after each 30 s of heating.
4. Stop warming the wire. Observe and record what happens to the height of the mass during the next 2 or 3 min.

Time of Heating or Cooling	Height of Mass Above the Table

Analyze

1. (a) If the wire sags, the mass moves down. Does this mean that the wire is getting longer or shorter?

   (b) What is happening to the length of the wire if the mass moves up?
2. If the wire sags, are its particles getting farther apart or closer together? Explain why they would do this. (Hint: Think about their motion.)

Part 2

Your teacher will do the heating in Part 2 as a demonstration.

The Ball and Ring

1. Observe whether the brass ball fits through the brass ring when both the ball and the ring are at room temperature.
2. Warm only the ring in a hot flame for 30 s. Does the ball fit through the ring when only the ring is heated?
3. Allow the ring to cool.
4. Heat only the ball for 30 s in a hot flame. Does the ball fit through the ring when only the ball is heated?
5. Heat both the ring and the ball. Does the ball fit through the ring when both the ball and the ring are heated?
6. After the ball and ring have both cooled, test once more whether the ball will fit through the ring.

Analyze

1. As a class, brainstorm possible reasons that can explain your observations. If possible, propose an experiment that will test your ideas.

Conclude and Apply

2. How did the demonstration give evidence that solids can expand? Explain what you did to cause the expansion and which part of the apparatus (the ball, the ring, or both) expanded.
3. Explain precisely what you think happens to the particles that make up the apparatus when the ball and ring are heated. How does this change in the individual particles, due to heating, bring about a change in the overall structure of the ball and ring? How does the change in the structures cause the outcomes that you observed when testing whether the ball would fit through the ring?
4. What do you think happens to the particles when the apparatus is cooled?

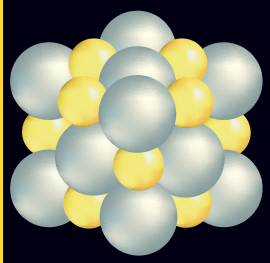
NATIONAL GEOGRAPHIC

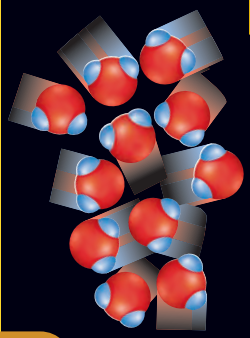
VISUALIZING STATES OF MATTER

Matter on Earth exists naturally in four different states—solid, liquid, gas, and plasma—as shown here. The state of a sample of matter depends upon the amount of energy its particles possess. The more energy that matter contains, the more freely its particles move, because they are able to overcome the attractive forces that tend to hold them together.

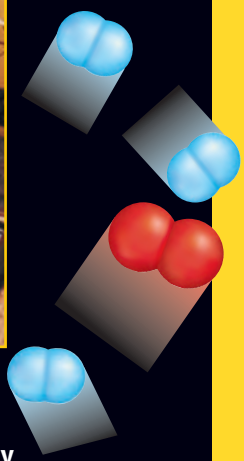
D PLASMA Electrically charged particles in lightning are free moving.

A SOLID In a solid such as galena, the tightly packed particles lack the energy to move out of position.





B LIQUID The particles in a liquid such as water have enough energy to overcome some attractive forces and move over and around one another.



C GAS In air and other gases, particles have sufficient energy to separate from each other completely and move in all directions.

Check Your Understanding

Checking Concepts

1. How are the three states of water unique when compared to other substances?
2. State one way in which solids and liquids are similar and one way in which solids and liquids are different.
3. State one way in which liquids and gases are similar and one way in which liquids and gases are different.
4. According to the particle theory of matter, why can the particles of a liquid slide past one another but the particles of a solid cannot? Why must the particles of a solid remain beside each other?
5. Compare the attractive forces among the particles of gases, liquids, and solids.
6. Compare the thermal expansion of gases to the thermal expansion of solids and liquids. How are they similar and how do they differ?
7. Explain how a solid can expand while the individual particles in the solid always remain beside the same particles.
8. Give one reason why it is important for engineers who design buildings and bridges to understand thermal expansion and thermal contraction of materials.

Pause and Reflect

On the road surface of bridges, you often see structures like the one in the photograph on the right. Why do you think these structures are built into the roadways of bridges? Predict whether this photograph was taken in the winter or in the summer. Explain your reasoning.

Understanding Key Ideas

9. Describe how you would use Styrofoam™ balls to model the three states of matter. Use sketches if you would like to.
10. A metal lid on a jar is stuck on very tight. Use the particle theory to explain whether heating or cooling the lid would make it easier to remove the lid.
11. Imagine that you were given a balloon and a bottle. Design an activity that would demonstrate the thermal expansion of gases.

5.3 Changes of State

The changes of state are melting, freezing, evaporation, condensation, sublimation, and deposition. Each pure substance has its own unique freezing point and boiling point. The strength of the attractive force among particles determines the freezing and boiling points of a pure substance.

Key Terms

boiling point
change of state
condensation
deposition
evaporation
freezing
heating curve
melting
melting point
sublimation

Have you ever heard a car owner talk about "winterizing" the car? To winterize a car simply means to prepare it for winter. One of the most important things to do is to be sure that the water in the radiator will not freeze. The water circulates through the engine to keep it cool while the engine is running. When the car is not running, however, the water in the radiator will become as cold as the outdoor temperature. If the water freezes, it will crack the radiator and possibly even the engine. The repair is very expensive. Therefore, car owners add antifreeze to the water in the radiator as shown in Figure 5.17. The car owner or auto mechanic can also check the antifreeze (Figure 5.17B) to see how cold the weather can become before the coolant will freeze.

Did You Know?

Antifreeze contains ethylene glycol, which is very toxic to animals and people. It also has a sweet taste, which will tempt animals to lick up spilled antifreeze. Car owners should be extremely careful about cleaning up spills and carefully storing antifreeze. Also, humane societies are urging governments to pass laws to make manufacturers add a bitter tasting chemical to antifreeze to prevent animals from drinking it.

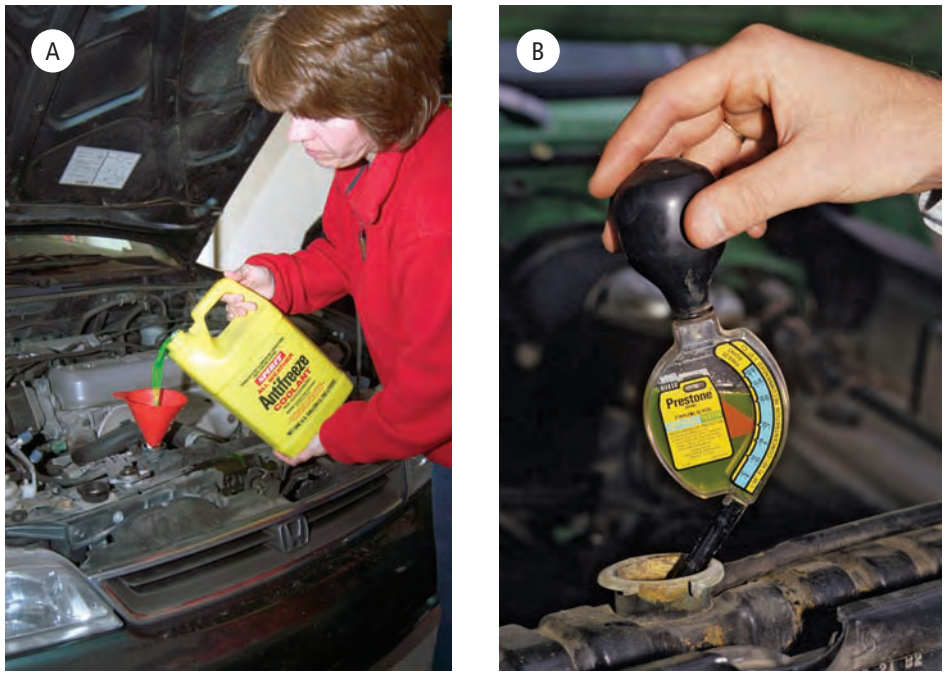


Figure 5.17 (A) The car owner is adding antifreeze to the car radiator. (B) To test the coolant, you squeeze the bulb then put the end into the coolant and release the bulb, drawing coolant into the tester. The dial will tell you the lowest temperature at which the coolant will still be liquid.

5-3A How Low Can It Go?

Find Out ACTIVITY

The instrument shown here is called a sling psychrometer. It has two thermometers, a dry bulb and a wet bulb thermometer. The technician using it, wets the cloth around the bulb of the wet bulb thermometer, holds it by the handle, swings it around rapidly, and then quickly reads the temperature on both thermometers. The motion causes the moisture in the cloth to evaporate at the maximum rate. The difference in the readings of the dry bulb and wet bulb thermometers allows the technician to calculate the relative humidity and the dew point.

In this Activity, you will observe the effects of evaporation of two different liquids on the temperature reading of a wet bulb thermometer. You will not swing the thermometers around but instead you will use an electric fan to increase the rate of evaporation. You might be surprised to discover how evaporation affects the temperature of an object. Try it and see.

Materials

- laboratory thermometer
- electric fan
- 2 strips of cloth or paper towel
- room-temperature water
- room-temperature alcohol

Safety

Pure alcohols are harmful to the body. Do not taste these chemicals and do not breathe in their vapours. Do not use alcohols near open flames as the alcohol vapours may catch fire or explode.

What to Do

1. Measure and record the temperature of the liquid water and alcohol.
2. Wrap the cloth strip around the thermometer bulb and soak it in the water. Hold the thermometer near the fan to speed up evaporation from the wet cloth. Record the temperature every 30 s until it stops changing.
3. Repeat step 2 using a second cloth strip and alcohol.
4. To compare your observations for the two liquids, draw a graph with temperature on the vertical axis and time on the horizontal axis. Plot both sets of data on the same graph.

What Did You Find Out?

1. In which liquid were the particles evaporating faster? How do you know?
2. Which of the two cloths would take longer to dry completely? What would happen to the temperature of the cloth after all of the liquid had evaporated?
3. In which liquid do you suppose the particles have a stronger attraction for one another? Why do you think so?

Science Skills

Go to Science Skill 1 for help with graphing.

Figure 5.18 You often see moisture on the outside of a glass of ice water. Why do you *not* see this on a glass or cup of a hot drink?

Describing Changes of State

A glass of ice water or other iced drink, like the one in Figure 5.18, is a common sight. You put ice in the drink to cool it. As the ice melts, the drink becomes cooler. Often, water vapour from the air condenses on the outside of the glass.

The melting of ice and the condensing of water vapour are called changes of the state of water. All substances can exist as solids, liquids, or gases. The gaseous form of water is often called vapour. However, for most substances, scientists use the term "gaseous state" instead of vapour. The change from any of the three states to any other state is called a **change of state.** Each change of state has a specific term that describes that change.

- **Melting** is the change from the solid state to the liquid state.
- **Freezing** is the change from the liquid state to the solid state.
- **Evaporation** is the change from the liquid state to the gaseous state.
- **Condensation** is the change from the gaseous state to the liquid state.
- **Sublimation** is the change from the solid state to the gaseous state.
- **Deposition** is the change from the gaseous state to the solid state.

These definitions are summarized in Figure 5.19.

Suggested Activity

Investigation 5-3C on page 166.

Connection

Section 7.1 has information on pure substances.

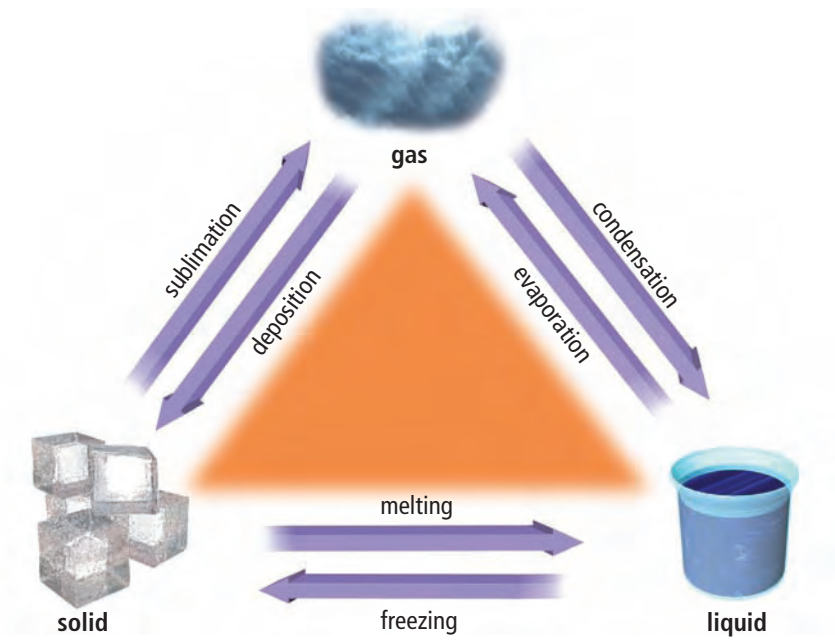


Figure 5.19 This diagram summarizes all of the changes of state.

Before you read the last paragraph, did you know that substances could go from the solid state directly to the gaseous state, or sublime? You might not have realized it but you have probably seen evidence of sublimation before. The substance that is called dry ice is really solid carbon dioxide. It is extremely cold, so you should never handle it with your bare hands. Your skin would freeze in just a few seconds. However, dry ice is often used for special effects in plays or at parties.

Under standard conditions, dry ice does not melt but it sublimes directly into carbon dioxide gas. If you put it in water, it looks as though the water is boiling. However, the dry ice is turning into gaseous carbon dioxide under water and making bubbles.

You might have seen effects such as those shown in Figure 5.20. The effects are created with dry ice, but the foggy substance that you see is not carbon dioxide gas. Carbon dioxide gas is colourless and, therefore, invisible. However, the carbon dioxide gas cools the air so much that water vapour in the air condenses to form the fog.

Figure 5.20 This halloween pumpkin looks like steam is coming from its mouth. Actually, there is dry ice inside the pumpkin. As the dry ice sublimes, it cools the air and causes water vapour to condense.

Melting Points and Boiling Points

You usually think of metals such as tin and lead as being solids. As well, you probably think of oxygen and nitrogen as being gases. These are the states in which you find these substances at room temperature. Nevertheless, if you heat tin and lead to very high temperatures, they will become liquids and then gases. If you cool oxygen and nitrogen to very low temperatures, they will become liquids and then solids.

Most pure substances have specific temperatures at which they melt and boil. The temperature at which a substance changes from a solid to a liquid is called its **melting point.** The temperature at which a substance changes from a liquid to a gas is called its **boiling point.** Table 5.1 lists some melting and boiling points for a few common substances. Remember, below its melting point, a substance is solid. At temperatures between its melting point and boiling point, a substance is a liquid. Above its boiling point, the substance is a gas.

Did You Know?

Water is a unique substance. The boiling point (100°C) and the melting point (0°C) of water are much higher than those of nearly all other substances that have particles about the same size as water particles. What does this information tell you about the attractive forces that hold particles of water together?

Table 5.1 Melting Points and Boiling Points of a few Pure Substances

Substance	Melting Point (°C)	Boiling Point (°C)
Oxygen	–219	–183
Nitrogen	–210	–196
Rubbing alcohol	–88	82
Mercury	–39	357
Water	0	100
Sulfur	115	445
Tin	232	2602
Lead	328	1740
Aluminum	660	2519
Table salt	801	1413
Silver	962	2162
Gold	1064	2856
Iron	1535	2861

5-3B State the State

Think About It

Different pure substances have different melting and boiling points. Scientists measured and used these temperatures to identify substances long before they could explain the differences. You can probably guess that modern explanations involve the strength of the forces that hold the tiniest particles of a substance together.

What to Do

Use the information in Table 5.1 to answer each of the following questions.

1. In what state (solid, liquid, or gas) would each substance be at the given temperature?
   (a) oxygen at –50°C
   (b) aluminum at 800°C
   (c) table salt at 800°C
   (d) gold at 3000°C
   (e) iron at 2000°C
2. What change of state, if any, would each substance go through during the given temperature change?
   (a) mercury cooling from –10°C to –45°C
   (b) silver cooling from 1000°C to 950°C
   (c) tin warming from 2200°C to 2300°C
   (d) mercury warming from 300°C to 350°C
   (e) iron cooling from 1600°C to 1500°C

What Did You Find Out?

Compare the melting points of aluminum and tin. Which metal do you suppose has stronger forces holding its particles together? Explain your reasoning.

Reading Check

1. What is another name for water vapour?
2. What change of state is opposite to:
   (a) evaporation
   (b) melting
   (c) deposition
3. Define the term, *boiling point*.
4. At what temperature does sulfur boil?

Changes of State and the Particle Theory

In a solid substance, the particles are held tightly together. As you saw in Figure 5.15 on page 150, the particles have kinetic energy, so they vibrate. However, they remain attached to each other by forces that are represented by springs. As you add more energy in the form of heat, the kinetic energy of the particles increases and the temperature increases. Eventually, you reach a temperature at which the kinetic energy of the particles is great enough to break the attractive forces, or springs, that are holding the particles together (see Figure 5.21). This temperature is the melting point of the substance. As the particles break away from one another and have enough energy to slide past each other, the substance becomes a liquid.

As a liquid is heated, the particles gain kinetic energy. Eventually, many particles have enough energy to break away from the attractive forces of the other particles and escape from the surface of the liquid as shown in Figure 5.22. These high-energy particles are now in the gaseous state.

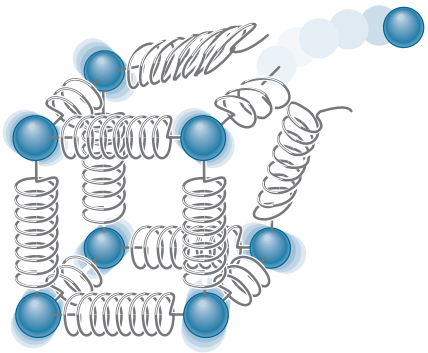


Figure 5.21 The forces that hold particles together in the solid state are quite strong. Nevertheless, particles can gain enough kinetic energy to break away from their neighbouring particles.

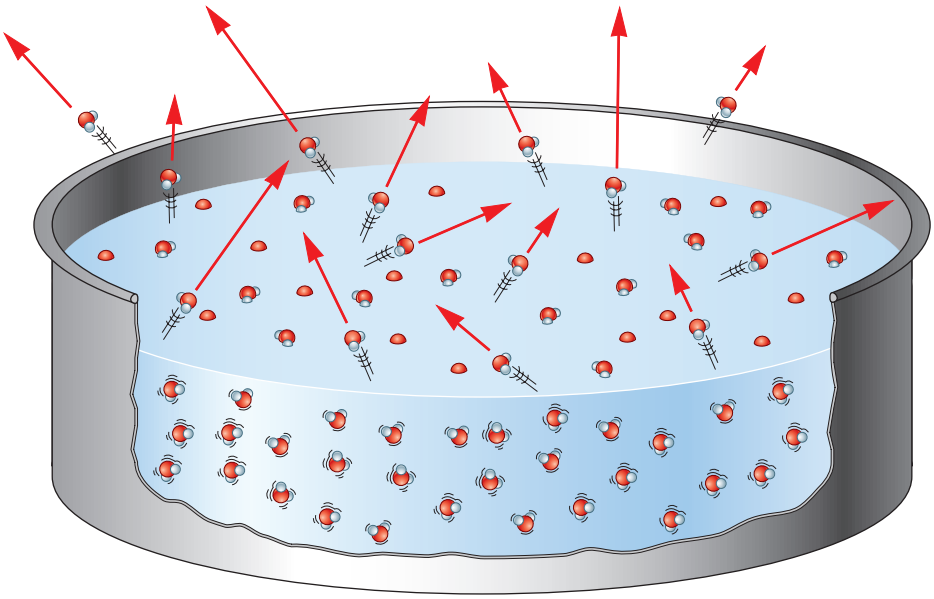


Figure 5.22 This diagram models the activity of particles as a substance evaporates (that is, as it changes from the liquid state to the gaseous state).

Did You Know?

Nearly all substances contract when they freeze, or change their state from a liquid to a solid. Water, however, expands when liquid water freezes and becomes ice. That is the reason that ice floats on water instead of sinking.

Why do different substances have such different melting points and boiling points? The melting point and boiling point of a substance depend on the strength of the attractive forces holding the particles together. If the forces are very strong, large amounts of energy are needed for a particle to break away from its neighbouring particles.

In order for the particles of a substance to have large amounts of energy, the temperature must be high. Therefore, the particles of substances that have high melting points and boiling points have very strong forces holding the particles together. For example, the melting point of table salt is 801°C while the melting point of sulfur is 115°C. Therefore, the attractive forces holding particles of table salt together are much stronger than the attractive forces between particles of sulfur.

Heating Curves

You can summarize the processes of changing states by using a heating curve. A **heating curve** is a plot of temperature and time. Energy is continuously being added to the substance. In Figure 5.23, a heating curve is drawn above diagrams that show what is happening during the various periods of time as energy is continuously being added to a substance.

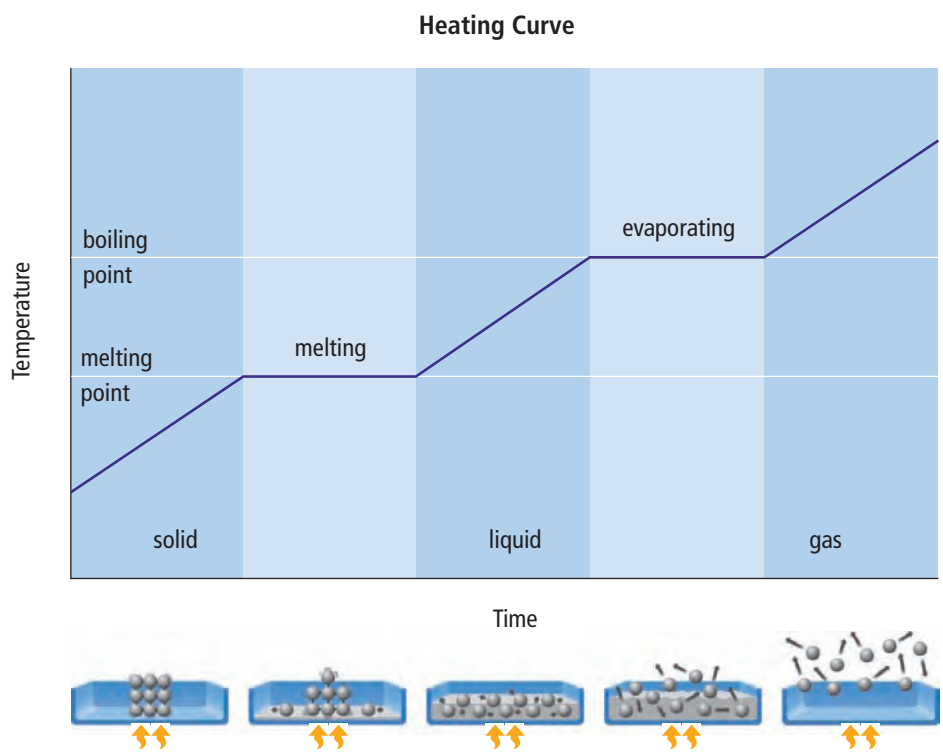


Figure 5.23 The diagrams below the graph show how the particle theory explains what is happening as heat is being added to a substance during a period of time. The yellow arrows indicate that heat is entering the container.

To understand the heating curve, follow it from the time that the heating began on the left, to the end of the process on the right. The particles representing a solid are in a container that is being heated. The yellow arrows at the bottom of the container represent heat entering the system. When the process begins, the object is in its solid state and the temperature is low. As heat is added to the object, its temperature rises because the heat is giving the particles more kinetic energy. When the temperature reaches the object's melting point, the energy going into the object gives the particles enough energy to break away and start forming a liquid. Notice that the temperature stops going up for a while. During this time, all of the heat entering the object is used to overcome the attractive forces holding the particles together. They are not gaining kinetic energy. Eventually, the entire object has melted and is a liquid.

Now the heat that is entering the object gives the liquid particles more kinetic energy and the temperature rises again. A similar situation occurs when the liquid reaches its boiling point. Once again, the temperature stops going up for a while. All of the energy going into the liquid is used by the particles to break away from the liquid and go into the gaseous state. Finally, when all of the liquid has evaporated, heat entering the system increases the kinetic energy of the gas particles. The temperature once again rises.

Did You Know?

Some species of bacteria are able to live in water temperatures of 90°C and in water as acidic as vinegar.

Reading Check

1. What condition must occur for a solid to start melting?
2. Describe evaporation using the particle theory of matter.
3. Explain how heat can be added to a substance but the temperature of the substance remains the same.

Did You Know?

The white trails behind jet planes in the sky are often called jet trails. The correct term is contrail because they are a result of the condensation of water in the exhaust of the jet engines. The jet plane's exhaust is very hot and contains a lot of water vapour. When the hot vapour mixes with the cold air at these high altitudes, it condenses and forms a contrail.

5-3C The Plateau Problem

Core Lab

Skill Check

- Observing
- Controlling variables
- Graphing
- Working co-operatively

Safety

- Use oven mitts, hot pads, or tongs to handle the beaker of boiling water.
- Unplug the hot plate at the end of the investigation and let it cool before putting it away.

Materials

- 2 laboratory thermometers
- stirring rod
- hot plate
- kettle
- 2 beakers (250 mL)
- clock or watch
- crushed ice
- ice-cold water
- hot water (almost boiling)

Puddles of liquid water on the road can freeze on a wintry night but this does not happen instantly. Water boiling in a kettle is turning into water vapour but this takes time. What is happening while the water is changing state?

Question

What happens to the temperature of water while it changes state?

Hypothesis

Think about familiar situations in which ice is melting or liquid water is boiling. Then, form two hypotheses by completing the following two statements. Add reasons for your hypotheses.

(a) While water melts from solid ice to liquid water, the temperature will (drop/stay the same/increase), because…

(b) While water boils from a liquid to a gas, the temperature will (drop/stay the same/increase), because…

Procedure

1. Prepare a table for data like the one shown here. You will need space for at least five observations (more if time permits).

Time (min)	Temperature of Melting Ice (°C)	Temperature of Boiling Water (°C)

2. Fill one beaker with hot water from the kettle and put it on the hot plate to boil.
3. In the other beaker, make a slush of crushed ice and a little cold water.
4. With a stirring rod, stir the contents of each beaker for several seconds. Then, measure and record the temperature. Lift the thermometer off the bottom of the beaker to ensure that you are measuring the temperature of the contents and not the container.

5. Repeat the temperature measurements every 3 min. For a fair test, make sure that you stir and measure exactly the same way each time. Record each result.
6. Stop heating the boiling water *before* it all boils away. Unplug the hot plate, and carefully set aside the hot beaker to cool.

Analyze

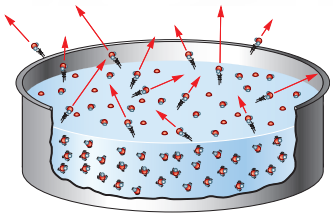
1. In this activity, you measured time and temperature.
   (a) What was your dependent variable? (Which value was unknown until after you made an observation?)
   (b) What was your independent variable? (What value did you select before making an observation?)
2. Draw two line graphs to show your temperature–time observations: one for the melting ice and one for the boiling water. Instead of joining the points dot-to-dot, draw a smooth line or curve that passes through or between the points (a best-fit line).
3. On your hot-water graph, mark the part where
   (a) the water was hot but not yet boiling
   (b) the hot water was boiling vigorously (called a "full rolling boil" in cooking)
4. Label any plateaus (flat, horizontal segments) on your graph.
5. Compare the temperature of your melting slush with the "official" temperature you saw in Chapter 4.
   (a) If the two temperatures are almost the same, any small differences might be caused by errors in your equipment or measurements. Suggest at least two specific errors of this sort that might occur.
   (b) If the two temperatures are quite different, the conditions in your laboratory or your sample might be responsible. Suggest at least two specific conditions that might cause this type of error.
6. Imagine that you combined both parts of this investigation. Sketch a third graph that shows what would probably happen if you heated one sample from ice to water and then to water vapour.
7. On the temperature scale of your third graph, mark the melting point and the boiling point of your samples, according to your observations.
8. Combine all the results from your class to find the average melting point and the average boiling point for water. Are they closer to the expected values than your individual group values? If they are closer, explain why.

Conclude and Apply

9. From your observations, write a clear answer to the question at the beginning of this investigation.
10. How well do your observations support your hypothesis?
11. (a) Identify any problems you had with the apparatus, procedure, or the way that you organized and worked together in your group.
    (b) Describe one improvement that your group could make the next time you work together.

Wild, Weird, Wonderful

www Science



Evaporative Cooling

When you are playing a sport or doing hard physical work, you usually sweat a lot. Is sweating just annoying or is it doing something useful for your body? Actually, sweating helps cool your body. The process is called evaporative cooling.

Review the process of evaporation by analyzing the illustration in Figure 5.22 shown on page 163. Recall that the kinetic energies of the individual particles in a substance such as liquid water are all different. Even when water is well below the boiling point, some of the particles have a large amount of kinetic energy. These particles can escape from the liquid water. What happens to the average kinetic energy of the particles remaining in the liquid state? The following calculation will help you answer the question.

Before Evaporation

Kinetic energy of particles:

1.13 J 0.87 J 0.94 J

0.99 J 0.91 J 0.88 J

0.78 J 0.82 J 0.73 J

0.85 J 1.28 J 0.94 J

1.34 J 1.02 J 0.97 J

Average kinetic energy: 0.96 J

After Evaporation

The four particles with the most kinetic energy evaporate.

Kinetic energies of remaining particles:

0.99 J 0.91 J 0.73 J

0.78 J 0.82 J 0.94 J

0.85 J 0.94 J 0.97 J

0.87 J 0.88 J

Average kinetic energy of particles remaining: 0.88 J

The average kinetic energy of the particles remaining after the most energetic particles evaporated is lower than it was before the particles evaporated. Therefore, the temperature of the remaining liquid is lower—it is cooler!

Evaporative cooling is very effective and useful. Sweating makes you cooler. Not all animals sweat but they have other ways to make water evaporate from their bodies. You have probably seen dogs panting with their tongues hanging out. Evaporation from their tongue and their breath cools them.

Some animals lick themselves and the moisture they leave on their skin or fur evaporates and cools them. The wood stork, shown here, and the black vulture urinate on their legs. The evaporation of their urine cools their legs and cools the blood flowing just under their skin.

Elephants spray water on their bodies.

Check Your Understanding

Checking Concepts

1. Explain the meaning of the phrase "change of state."
2. How does sublimation differ from evaporation?
3. Refer to Table 5.1 to answer the following questions.
   (a) What is the state of nitrogen at –200°C?
   (b) In what state is rubbing alcohol at 90°C?
   (c) In what temperature range is tin a liquid?
4. Use the particle theory to explain melting.
5. How does the particle theory explain why different substances have different melting and boiling points?
6. What is a heating curve?

For question 8

Understanding Key Ideas

7. People often put salt on icy sidewalks or roadways. Give a possible explanation for why salt might cause ice to melt.
8. When you are holding a cold glass of water or other cold drink, the outside of the glass often becomes wet. Where did the liquid water come from?
9. Compare the strengths of the attractive forces between the particles of water and between particles of table salt.
10. A cooling curve is the opposite of a heating curve. When you start making observations, the substance is a gas and the temperature is warm. The substance loses energy, or cools, over a period of time. Sketch a cooling curve for rubbing alcohol. (Hint: the boiling point for rubbing alcohol is 82°C and the melting point is –88°C.)
11. When a liquid is heated, why do all the particles not break away and become gaseous at the same time?

Pause and Reflect

In the introduction to this section, you read about car owners adding antifreeze to the coolant in the radiators of their cars. Explain how you think that antifreeze prevents the coolant in a car from freezing.

Chapter Review

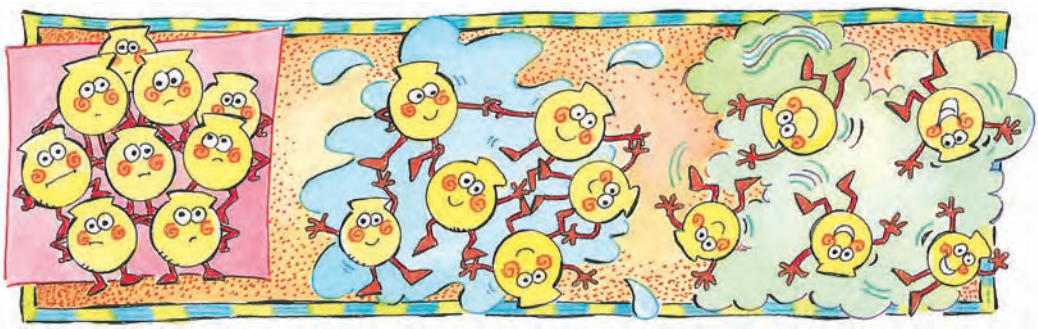
Prepare Your Own Summary

In this chapter, you investigated the particle theory of matter and the states of matter. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. The Particle Theory of Matter
2. Temperature and the Kinetic Energy of Particles
3. States of Matter
4. Expansion and Contraction of Matter
5. Changes of State
6. Melting Points and Boiling Points

Checking Concepts

1. In order for an object to have kinetic energy, it must be doing what?
2. What is a measure of the average kinetic energy of the particles that make up an object or a substance?
3. Explain how you can decide whether a substance is a solid, a liquid, or a gas.
4. Make a sketch to show how the particle theory can account for the three common states of matter. Explain your sketch.
5. How does an increase in the temperature of an object affect its volume? Which state of matter is affected the most?
6. How does the particle theory of matter explain the ability of a liquid to flow?
7. Name the following changes of state.
   (a) from a liquid to a solid
   (b) from a solid to a gas
   (c) from a gas to a liquid
8. How does the particle theory of matter explain evaporation?
9. What can you say about the forces among the particles of a pure substance if the melting temperature is –40°C?
10. What is happening to the temperature of a pure substance while it is melting?
11. The figure below can be used as a model to represent some concepts that you learned about in this chapter.
    (a) These figures are models for what concepts?
    (b) Explain how each part of the figure models the concept.
    (c) Are there any changes that you would suggest that would make the figure a better model? If so, what are those changes?



Understanding Key Ideas

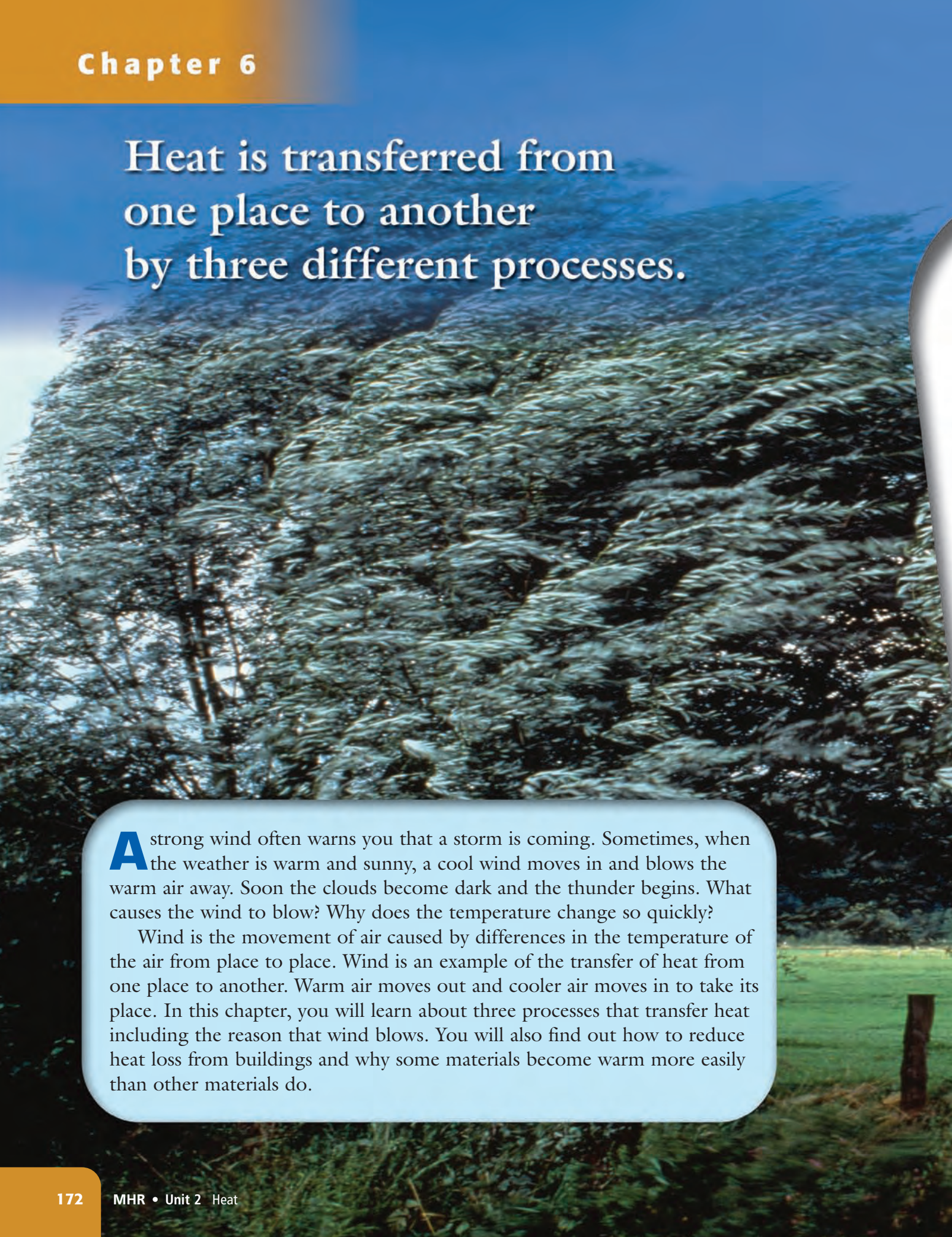
12. Explain how Lego® blocks can be used to model the particle theory of matter.
13. If two golf balls are flying through the air, how can you tell which one has more kinetic energy?
14. Imagine you fall off a bicycle and your arm rubs against the ground. The injury is sometimes called a "burn." Explain why this could be a suitable description.
15. A classmate says that if something takes the shape of the container, it must be a liquid. How would you respond to that statement?
16. Mercury is the only metal that is a liquid at room temperature. All other metals are solids at room temperature. What can you say about the interactions among the particles of mercury when compared with the particles of other metals?
17. Imagine that you filled a glass to the very top with water directly from the refrigerator. You put it on the table and then answered the telephone. After a long conversation, you discover that there is water all around the glass on the table. Explain what happened.
18. Two drinking glasses are stuck together, one inside the other. Write a recommendation for a way to remove the outer glass without breaking either glass. Explain why your method works.
19. On a winter day, the wind blows briskly all day. At the end of the day, you notice that there is much less snow on your driveway than there was in the morning. However, you did not see any moisture on the pavement all day. Explain what happened to the snow.
20. If you wanted to heat a substance to 450°C, would you use a tin container or an aluminum container? Explain your reasoning.
21. Imagine that you put some eggs in a pot of water on the stove and turn it on to boil the eggs. Then, you go to your room to do homework. You were working so hard that you forgot that you had put the eggs on to boil. While you were doing homework, all the water boiled away and the eggs were badly burned. Explain why eggs do not burn when they are in boiling water but they do burn after the water boils away.

Pause and Reflect

Examine the photograph of the sidewalk shown here. Give a possible explanation why the sidewalk buckled and broke in this way.

Chapter 6

Heat is transferred from one place to another by three different processes.



A strong wind often warns you that a storm is coming. Sometimes, when the weather is warm and sunny, a cool wind moves in and blows the warm air away. Soon the clouds become dark and the thunder begins. What causes the wind to blow? Why does the temperature change so quickly?

Wind is the movement of air caused by differences in the temperature of the air from place to place. Wind is an example of the transfer of heat from one place to another. Warm air moves out and cooler air moves in to take its place. In this chapter, you will learn about three processes that transfer heat including the reason that wind blows. You will also find out how to reduce heat loss from buildings and why some materials become warm more easily than other materials do.

What You Will Learn

In this chapter, you will

- **explain** the difference between heat and temperature
- **describe** the three mechanisms of heat transfer which are conduction, convection, and radiation
- **define** specific heat capacity
- **compare** the specific heat capacities of some common materials

Why It Is Important

Understanding specific heat capacity of substances will help you know which types of hot objects are more likely to burn your skin. You will also know why water is best for treating burns. Specific heat capacities will also help you understand weather conditions.

Skills You Will Use

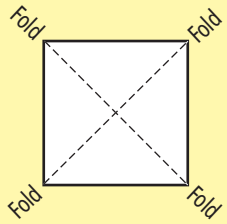
In this chapter, you will:

- **observe** the rate at which different liquids warm
- **control** variables that will may affect experimental results
- **explain** some weather systems

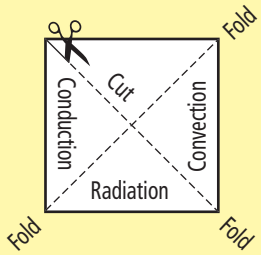
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 6.

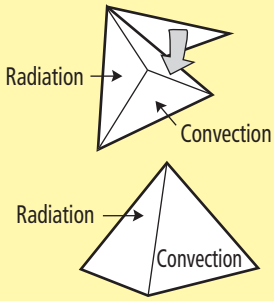
STEP 1 **Fold** a large square of paper diagonally to form an X.



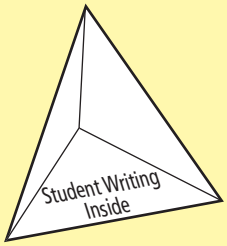
STEP 2 **Cut** along one of the fold lines, stopping at the centre intersection point. This cut will form two triangular sections. **Label** the Foldable as shown.



STEP 3 **Fold** and glue the blank triangular section under the one labelled "Conduction" to form a three-sided pyramid.



STEP 4 **Lay** the pyramid on its side to write notes inside the triangular sections.



Organize As you progress through the chapter, take notes and record new terms related to radiation, conduction, and convection on the inside of the pyramid. Additional notes can hang from the sides of the pyramid to make a mobile.

6.1 Processes of Transferring Heat

Conduction occurs when particles in an object vibrate in place but collide with neighbouring particles passing kinetic energy to them. Convection occurs when warm fluids move from one place to another. Radiation occurs when electromagnetic waves carry energy from a source to another object. The object then absorbs the energy of the electromagnetic wave.

Key Terms

conduction
convection
convection currents
radiation

Figure 6.1 Lizards often bask in the Sun to absorb the radiant energy, which increases their body temperature.

Did You Know?

One type of lizard that lives high in the Andes Mountains in South America is especially efficient at absorbing radiant energy from the Sun. The lizard will crawl out of its burrow in the morning when the air temperature is as low as –5°C. It will climb up on some vegetation and orient its body so that its back is directly toward the Sun. After two hours of basking, the lizard's body can reach temperatures higher than 30°C even though the air temperature is near the freezing point.

Lizards belong to the class of animals called reptiles. Reptiles do not generate enough heat to keep their bodies at a constant temperature. For many years, biologists thought that the body temperature of reptiles was always the same as the temperature of the air around them. However, more research showed that reptiles have some clever ways to warm their bodies to temperatures higher than the temperature of the surrounding air. The lizard shown in Figure 6.1 is basking in the Sun. The lizard's body absorbs the radiant energy of the Sun and becomes warmer. If its body becomes too warm, the lizard might take a dip in a nearby pond to cool off.

Radiation is one of the three processes that transfer heat from one place to another. In this section, you will learn about all three processes: conduction, convection, and radiation.

6-1A Currents in a Pie Pan

Find Out ACTIVITY

When you heat a pan of water, how does all of the water get hot instead of just the water on the bottom of the pan? In this activity, you will observe the movement of water, or currents, when the water is heated.

Safety

- Use care when handling hot items.
- Do not touch an electric plug if your hands are wet.

Materials

- aluminum pie pan
- hot plate
- stirring rod
- liquid hand soap or shampoo (that appears pearly, not transparent)
- food colouring (any colour)
- water

What to Do

1. Fill the pie pan about half full of water.
2. Add about two tablespoons of hand soap or shampoo.
3. Stir gently to mix the soap and water but do not make bubbles.
4. Place the pie pan on a hot plate.
5. Wait until the solution is motionless then turn the hot plate on the lowest setting.
6. Observe the movement of the solution as it begins to heat.
7. When you see movement, add a drop of food colouring and watch the pattern in which it moves. Repeat this process several times.

What Did You Find Out?

1. Describe the motion of the water solution as it was heating.
2. Suggest a possible reason why the water followed the pattern of movement that you observed.
3. Suggest a way in which the movement of air (wind) might be similar to the movement of the water that you observed.

Did You Know?

If you completed the activity above, you might have seen circular motion in several small areas of the solution. These units are called convection cells. The process that caused these convection cells to form also causes the formation of certain types of clouds such as the tall cumulus clouds in the photograph on the right. A similar process occurs on the surface of the Sun causing visible cells (see page 104).

Conduction

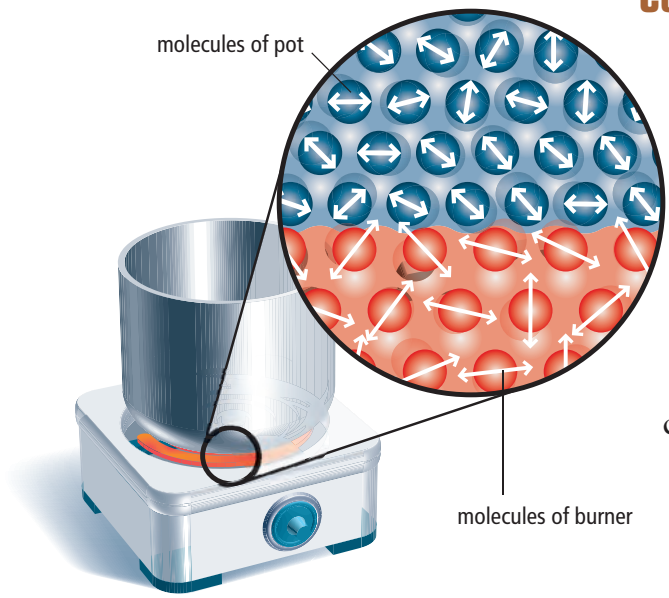


Figure 6.2 The length of the arrows on the particles in the stove burner and the bottom of the pan indicate the relative amount of kinetic energy that they have. The burner heats the pan by conduction caused by the collisions between particles in the burner and particles in the pan.

Conduction is the transfer of thermal energy that occurs when warmer particles come in contact with cooler particles and transfer energy to the cooler particles. An example is shown in Figure 6.2. When you put a pan on a hot burner on the stove, the particles in the burner are hot and the particles in the bottom of the pan are cool. The hot particles in the burner collide with the cooler particles in the pan and transfer some kinetic energy to them. As a result, the particles in the pan become warmer.

When particles on the surface of an object are heated by any type of heat source, they begin to vibrate with more kinetic energy. They then collide with the nearby particles and transfer kinetic energy to them as shown in Figure 6.3. This process continues with each particle colliding with other nearby particles until additional kinetic energy has been transferred to all of the particles in the object. Heat has been conducted throughout the entire object or substance.

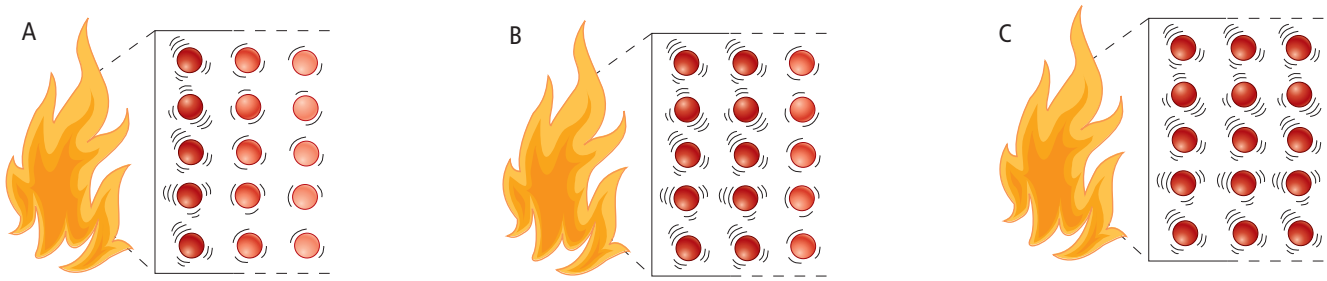


Figure 6.3 (A) Particles near a heat source absorb energy from the source and begin to move faster and, therefore, have more kinetic energy. (B) When the hot molecules on the surface collide with the neighbouring particles, they give some of their own kinetic energy to the nearby particles. (C) The collisions continue and heat is transferred throughout the object.

The important thing to remember about conduction is that the individual particles in a substance remain in place. The energy is passed from one particle to the next by collisions. Therefore, the energy is transferred through the substance but particles do not leave their original position. Conduction occurs mostly in solids.

Reading Check

1. What is necessary in order for conduction of heat to occur between two objects?
2. Does conduction occur in objects that are solids, liquids, or gases? Explain why.
3. How is heat transferred from one side of a solid object, such as the bottom of a skillet, to the other side of the object, such as the inside of the skillet?

Convection

Convection is the process in which a warm liquid or gas moves from one place to another, carrying heat with it. Figure 6.4 shows you how convection occurs. The candle flame heats the air around it. As you know, when a gas such as air is warmed, it expands. In the warm air, the particles are farther apart. Therefore, each small volume of warm air has fewer particles and is lighter than it was when it was cool. Therefore, the warm air rises. If nothing else happened, the rising air would leave an empty space below it. However, the heavier, cool air moves in to fill the place that the warm air left. As the warm air rises, it cools and, once again, becomes heavier. Eventually the cooled air drops back down again. These patterns of movement are called **convection currents**.

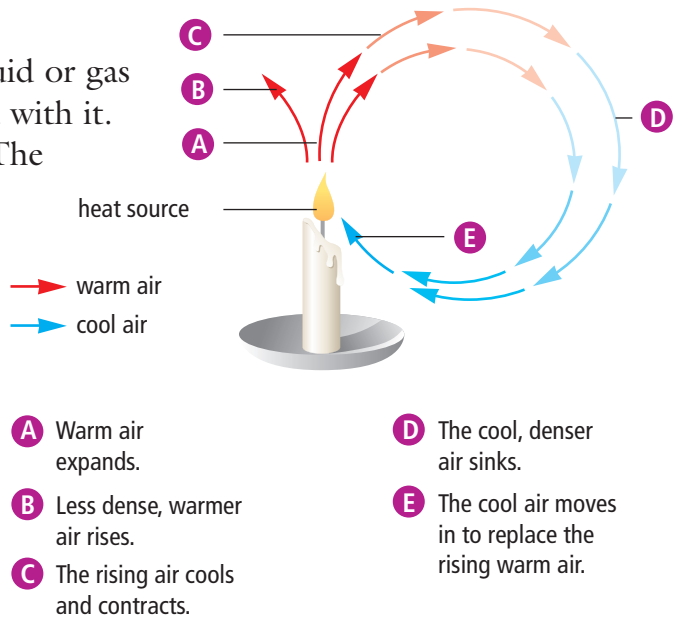


Figure 6.4 As the air near the flame becomes warmer, it rises, cools, and then drops back down again.

Wind is a form of convection current. The Sun heats Earth's surface unevenly and the air above the warmer parts of the surface rises. Cooler air moves in to replace it. Figure 6.5 summarizes the process that causes wind. The Sun warms part of Earth's surface more than another for many reasons. For example, near the equator the Sun's rays strike the surface more directly, and therefore, Earth's surface becomes warmer than it does farther from the equator. As you know, the nature of some surfaces causes them to absorb solar energy more readily. Bare ground becomes much warmer than water or a ground surface covered with vegetation. Snow covered ground reflects most of the sunlight away. Regardless of the cause of heating Earth's surface, the air above the warmer surface becomes warm by conduction. When the bottom layer of air warms, it expands and then rises. Cooler air, which is more dense and heavier,

moves in to replace the air that rose. At the same time, the rising air expands and cools. If the air was moist, the cooling causes the moisture to condense and results in rain. The cool air eventually begins to drop back to Earth. The result is a very large, circular convection current.

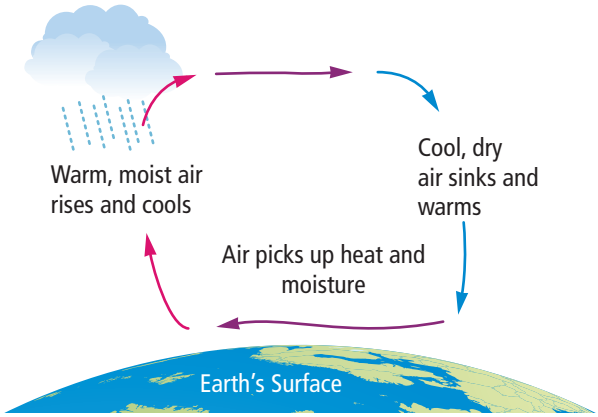


Figure 6.5 Wind is a type of convection current. You only feel the wind that is blowing along the surface of Earth. It appears to be blowing in one direction. However, the surface wind is part of a circular movement of air in the atmosphere.

Convections currents also occur in liquids. For example, when you heat water over a Bunsen burner, the water on the bottom of the beaker is heated by conduction because it is in contact with the hot beaker. As soon as the water begins to warm up, it expands and rises to the top. Cooler water moves down and becomes heated. The water circulates up and down in the beaker, as shown in Figure 6.6. If you continue to heat the water after it has all been heated to 100°C, it will begin to boil.

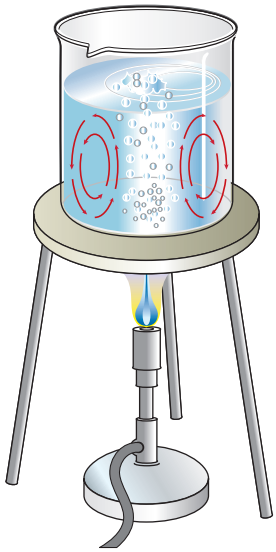
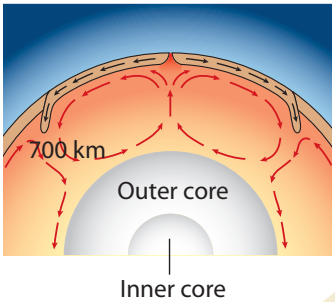


Figure 6.6 The arrows show the pattern followed by convection currents in the water.

Did You Know?

Geologists have evidence that shows that the continents and large oceanic plates have moved great distances over Earth's surface over millions of years. They believe that the motion is caused by convection currents in the molten fluid in the centre of Earth. In the diagram below, the red arrows show convection currents in the molten magma, the liquid layer below Earth's crust. The smaller black arrows show the movement of Earth's crust, which includes the continents.



Suggested Activity

Investigation 6-1E on page 188.

internet connect

There are animations on the Internet that illustrate convection currents. To find an animation, start your search at **www.discoveringscience.ca.**

6-1B Displaced Drops

Find Out ACTIVITY

You can create a small-scale model of convection. You will use water of different temperatures and food colouring to follow the movement of the water.

Materials

- 250 mL beaker
- 2 100 mL beakers
- stirring rod
- dropper
- room-temperature water
- ice water
- very hot water
- food colouring (two different colours)

Safety

- Handle the hot water with care.

What to Do

1. Add room-temperature water to the 250 mL beaker until it is about three quarters full.
2. Put some ice water in one 100 mL beaker and put some hot water in the other 100 mL beaker.
3. Add one colour of food colouring to the ice water and the other colour to the hot water. Mix thoroughly with the stirring rod.
4. Predict what will happen when you drop cold water into the room-temperature water and when you drop hot water into the room-temperature water. Record your predictions.
5. Fill the dropper with ice water. Hold the dropper just above the surface of the room-temperature water and gently squeeze out one drop of cold water.
6. Observe the movement of the cold water.
7. Repeat steps 5 and 6 several times. Draw a diagram showing the pattern of movement of the cold water.
8. Repeat steps 5 through 7 with the hot water.

What Did You Find Out?

1. Explain your reasoning for your prediction about the motion of the cold water in the room-temperature water. Was the observed motion the same as your prediction? If not, suggest a possible explanation.
2. Explain your reasoning for your prediction about the motion of the hot water in the room-temperature water. Was the observed motion the same as your prediction? If not, suggest a possible explanation.

Reading Check

1. In convection, what carries heat from one place to another?
2. Why can convection *not* occur in a solid?
3. Give an example of a common form of convection current.

Suggested Activities

Investigation 6-1F on page 189.

Radiation

On a bright sunny day, when you turn your face to the Sun, you can feel its warmth on your skin. Did you know that the radiant energy from the Sun travels about 150 million kilometres through empty space to reach Earth and to warm your face?

Figure 6.7 Light and warmth from the Sun always seem to be present. They appear to reach Earth instantaneously. However, it takes about 8 min for the light energy to travel from the Sun to Earth.

Until now, all of the concepts that you have learned about heat have involved the motion of particles. Transferring heat involved collisions between particles or the movement of warm particles from one place to another. How can the Sun's energy heat objects on Earth when there is so much empty space between them? There are no particles to collide with one another. The answer to the question is that radiant energy is carried by waves and not by particles. When matter absorbs radiant energy, the energy carried by the waves is converted into kinetic energy of the particles in the matter that absorbed it.

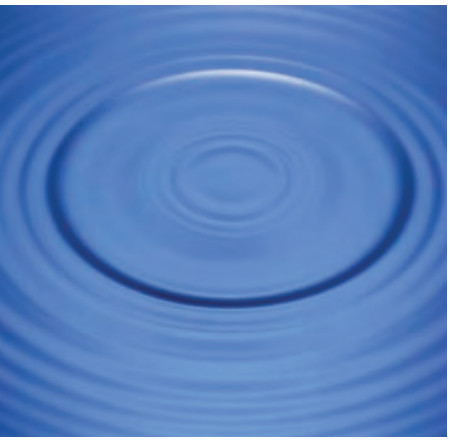


Figure 6.8 When a rock hits the surface of the water, it pushes water particles down and to the side. Each particle of water that is moved pushes on the particles beside it. These motions create the waves that you see on the surface of the water.

Waves

To understand how waves can transmit energy, think about a type of wave that you can see—a water wave. You know that if you drop a stone into a pond, ripples, or water waves, will radiate out from the point at which the stone hit the water. The kinetic energy of the stone was converted into kinetic energy of the water. If something is floating on the water, it will move up and down with the water waves. The floating object will receive kinetic energy from the water. For example, the girl in the

Figure 6.9 You can show that waves transmit energy by making waves in an aquarium and watching a floating object move.

photograph in Figure 6.9 is giving kinetic energy to the rubber ducky without touching it. She is moving her hand up and down in the water. The waves that the girl is creating with her hand are travelling through the water to the rubber ducky causing it to bob up and down. The kinetic energy of the girl's hand is giving kinetic energy to the rubber ducky without touching it.

Light waves and some other forms of waves are called electromagnetic waves. You cannot see electromagnetic waves because they are not made of matter as are water waves. Electromagnetic waves are made of electric and magnetic energy. They can carry energy through empty space or through air. **Radiation** is the transfer of energy carried by electromagnetic waves. Whenever you feel heat from the Sun, from a fire, or from a hot burner on a stove, electromagnetic waves are carrying the energy from the hot object to your skin.

There are many types of electromagnetic waves. They are divided into groups depending on their use or some other characteristic. The main groups are listed here.

- *Radio waves* are used to carry radio and television signals.
- *Microwaves* carry information to and from satellites.
- *Infrared waves* are most responsible for transmitting heat.
- *Visible light* are the electromagnetic waves that your eyes can detect.
- *Ultraviolet waves* are the type of waves that come from the Sun and cause sunburns.
- *X-rays* are used to make images of your bones.
- *Gamma rays* come from the radioactive sources and can do serious damage to living tissues.

Did You Know?

Tsunami waves transmit the energy from earthquakes on the ocean floor to continents that are hundreds of kilometres away. When the tsunami waves reach land, they can do serious damage to buildings and living beings on the land.

Did You Know?

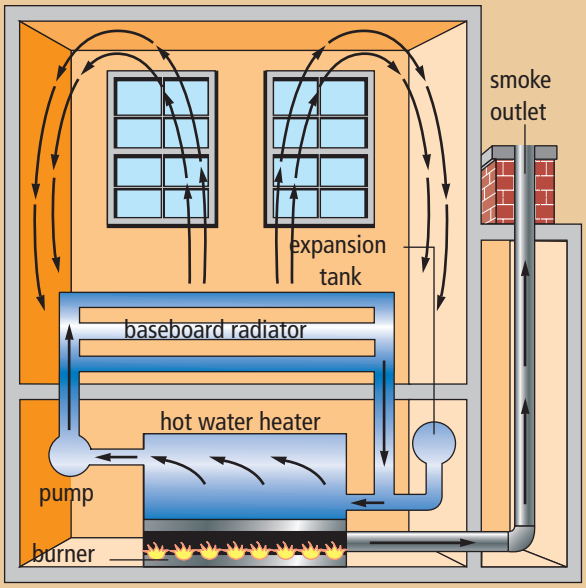
The microwaves that heat food in a microwave oven are a type of electromagnetic wave.

6-1C Energy Transfers and Home Heating Systems

Think About It

Each of the types of energy transfer—conduction, convection, and radiation—occur at one or more places in the process of heating a home. The diagram shown here illustrates the processes that occur in a hot water, home-heating system. The discussion beside the diagram describes the steps in the process. Your job is to identify and describe each step in the process in which a specific type of energy transfer is taking place.

Hot Water Heating System



Oil, gas, or another fuel burns in a furnace, heating water in the boiler. An electric motor drives the pump that circulates the hot water through the system of pipes and baseboard radiators. While the hot water flows through the baseboard radiators, it heats flat metal fins (not shown in the diagram) which, in turn, heat the nearby air. The hot air circulates throughout the room. A thermostat controls the flow of the water through the system of pipes and radiators, turning it off when the room is warm enough.

What to Do

1. Read the description of the home-heating system in detail.
2. Draw a diagram of the system in your notebook.
3. On the diagram, label each step in which an energy transfer is taking place.
4. Describe the process that is taking place at each point where there is a label in your diagram.

What Did You Find Out?

1. How many places in the home-heating system did an energy transfer occur?
2. Why are there fins on the pipes that run through the baseboards?
3. Explain why the radiators are placed along the baseboard instead of near the ceiling.
4. Radiators are often placed below windows. Why do you think that heating systems are designed in this way?
5. Baseboard heaters are usually placed on outside walls and not inside walls of a house. Why do you think that outside walls are the appropriate places for baseboard heaters? (An outside wall is between a room and the outdoors. An inside wall is between two rooms inside the house.)

Absorbing Radiant Energy

Examine the objects in Figure 6.10. What happens when light hits these objects? Light goes right through glass and reflects off of a mirrored surface. These surfaces absorb only a small amount of the light energy. The aluminum foil and the white paper absorb a little more energy but much of the energy is reflected away from the surface. The black paper absorbs more light than any of the other objects.

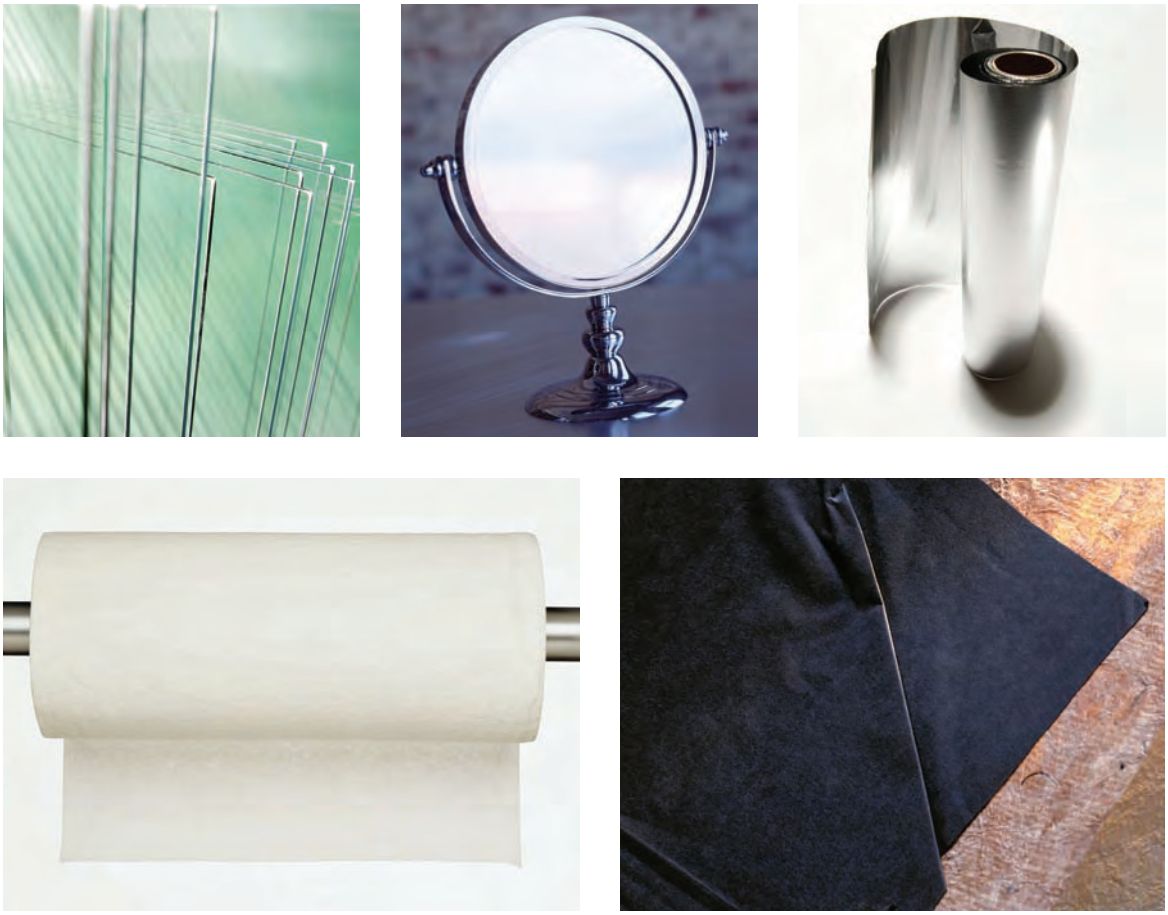


Figure 6.10 Light and other types of electromagnetic radiation interact differently with each of these different types of materials.

Infrared radiation and all other forms of electromagnetic waves react to surfaces in much the same way that visible light reacts. When the surface of an object absorbs the electromagnetic wave energy, it becomes warmer. When the surface reflects the waves or when the waves go right through an object as light goes through glass, the object does not absorb the energy and does not become warmer. An object will receive the energy transmitted by electromagnetic waves only if it absorbs the electromagnetic waves.

6-1D Absorb That Energy

Core Lab
Find Out ACTIVITY

How can you compare surfaces to see which one absorbs radiant energy (electromagnetic waves) the most efficiently? What will you measure?

Safety

- Use care when handling hot items.
- Do not touch the electric plug if your hands are wet.

Materials

- 2 empty, clean soft drink cans
- 2 thermometers
- light (at least 100 W)
- ruler
- dark- and light-coloured cloth or dark- and light-coloured paint
- aluminum foil
- 200 mL cooking oil
- tape or rubber bands

What to Do

1. Think about summer sunlight beating down on different materials. Use your own experience and what you have learned by reading this chapter to make the following predictions. Which type of surface absorbs radiant energy best?

   (a) dark or light

   (b) shiny or dull
2. From the list of materials, choose two materials to compare. Cover soft drink cans with the materials that you chose.
3. Pour 100 mL of cooking oil into each can. Place the cans 10 cm from the light as shown in the photograph.

4. Place a thermometer in each can, and then, read and record the initial temperature of the oil in each can.
5. Turn on the light. Then, read and record the temperature of the oil in each can every 5 min for at least 15 min.

What Did You Find Out?

1. Compare the temperature change of the oil in the two cans. Do your observations support your predictions?
2. If several groups tested the same prediction, how well did their results agree?
3. Combine the results of the entire class and come to an agreement about answers for both comparisons.
4. What factors other than the one that you tested could be affecting the temperature change of the oil in the cans?
5. According to scientific theory, the same materials that absorb radiant energy efficiently should also emit the radiant energy efficiently. Suppose that you have pairs of similar objects with different surfaces as listed below. Which type of surface radiates energy better and therefore, cools down more quickly?

   (a) a light-coloured surface or a dark-coloured surface

   (b) a dull surface or a shiny surface

Knowing which surfaces emit radiant energy the most rapidly is important for aircraft engineers. When flying extremely fast, the air friction rubbing against the surface of an airplane creates a large amount of heat. The airplane that holds the speed record of more than three times the speed of sound is the SR-71 Blackbird shown in Figure 6.11. The surface becomes extremely hot when it is flying at top speed. Engineers knew that the type of surface that absorbs heat most easily also emits heat the most easily. Therefore, the engineers decided to make the surface of the SR-71 Blackbird a dull black so that it would radiate heat away as rapidly as possible.

Figure 6.11 The SR-71 Blackbird has flown as fast as 3500 km/h. Although the black surface of the airplane radiates heat away as fast as possible, the surface gets so hot that the airplane expands several centimetres due to thermal expansion.

Reading Check

1. How can you transfer energy from your hand to an object without touching the object?
2. What can carry energy through empty space?
3. When radiant energy reaches an object, what must happen in order for the object to become warmer?

Heating Homes

One of the earliest forms of home heating was an open fire in a fireplace. Radiant heat from the fire heated objects with a direct line to the fire. Convection currents in the air spread the heat throughout the room. However, fireplaces warm only one room efficiently. Some large homes had fireplaces in several rooms.

Many years ago, homes in Newfoundland and Labrador were often heated with a wood stove similar to the one shown in Figure 6.12A. Stoves were often black which made them efficient radiators of heat. The room in which the stove was located could be very warm on even the coldest days. However, the transfer of heat to other parts of the house was very poor. Just before bedtime, people would put coals in a bed warmer like the one in Figure 6.12B. They would slide the bed warmer between the sheets and warm the bed.

Figure 6.12 (A) On cold winter evenings, families would sometimes gather around the wood stove and talk about the day. (B) When it was time for bed, they would put hot coals from the stove into a bed warmer like this. They closed the lid and took the bed warmer to the bedrooms and slid it between the covers. When the bed covers were toasty warm, they would hop right into bed.

Did You Know?

A man in Colliers, Newfoundland and Labrador invented and manufactures the solar panels that are shown in the photograph. A fan draws cool air from an inside room and sends it into the 15 cylindrical columns. The curved plastic covering focuses the Sun's rays on the dark-coloured columns. As the air passes through the columns, it is warmed by the solar radiation. Warm filtered air is then directed back into the room.

During the first half of the 1900s, people began to install furnaces in basements with ducts running to all of the rooms. Coal was burned in most of the early furnaces. In the mid 1900s, many furnaces were converted to oil or gas. Air was drawn into the furnace and heated and fans would blow the warm air through the ducts and into the rooms. This system is sometimes called forced air heating. In some houses, water was used to transfer water from the furnace to the rooms. A system of pipes carried water into the furnace where it was heated. Pipes passed through all of the rooms where the heat was transferred to the room air. These two systems — forced air and hot water heating — are still used in most homes.

As the cost of fuel increases and pollution from the burning of fuel threatens the environment, people are looking for new technologies. One of these technologies, called an air-to-air heat pump, works very much like a refrigerator. A fluid is contained inside a system of pipes as shown in Figure 6.13. In the summer, the fluid absorbs heat from the inside of the house and pumps it to the outdoors. In the winter, the heat pump is reversed. It absorbs heat from the outside air and pumps it into the house. You are probably wondering how a fluid can remove heat from cold air. The fluid and the system of pipes have some very special characteristics. When a fluid is allowed to expand rapidly and evaporate from a liquid to a gas, it absorbs heat from the surroundings. To remove the heat, the gas is compressed and converted back into a liquid. This process causes the heat to be released.

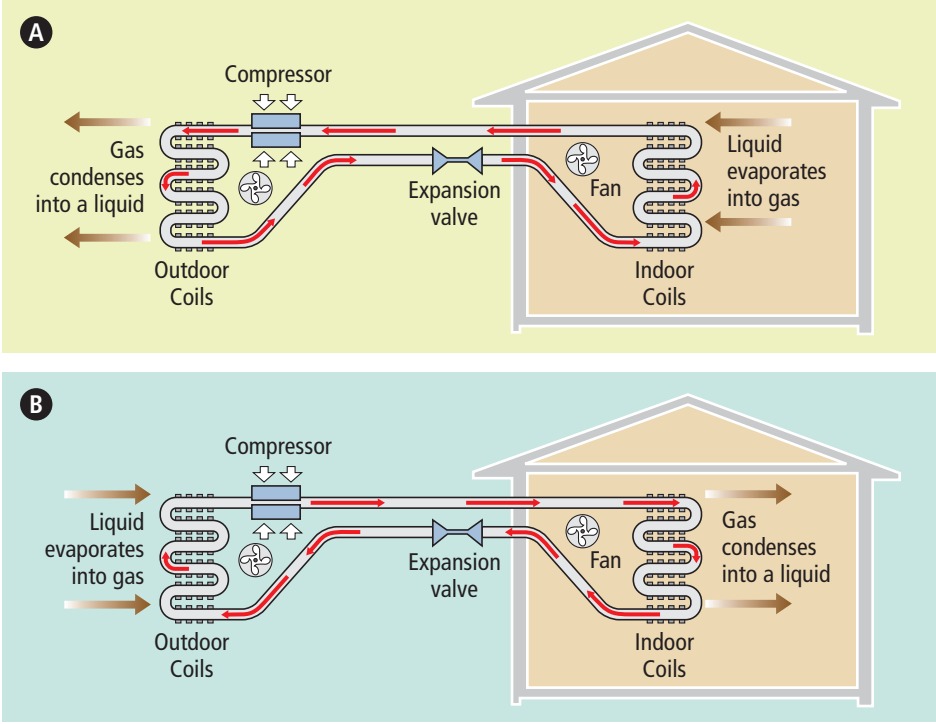


Figure 6.13 (A) In the summer, the coolant goes from the expansion valve into the house. When the coolant expands, it evaporates and draws heat from the room air. It then goes outside and through the compressor. When the coolant is compressed, it releases heat to the outdoors. (B) In the winter, the system is reversed. It absorbs heat from the outside air and releases it inside the house.

A geothermal heat pump is similar to an air-to-air heat pump. Instead of exchanging heat with the outside air, it exchanges heat with the ground. Although it is much more expensive to install, it is more efficient. Just a few metres below the surface of the ground, the temperature stays the same throughout the year. The temperature underground is cooler than the air in the summer and warmer than the air in the winter. As shown in Figure 6.14, a series of pipes are buried in the ground near a house or other building. In the summer, heat is pumped from the house to the ground. In the winter, heat is pumped from the ground to the house. Geothermal heat pumps have been installed in more than 30 000 buildings in Canada. The new Forest Centre building (see Figure 6.15) at Sir Wilfred Grenfell College in Corner Brook is the first building in Canada, other than a residential house, to use geothermal heat pump for heating and cooling.

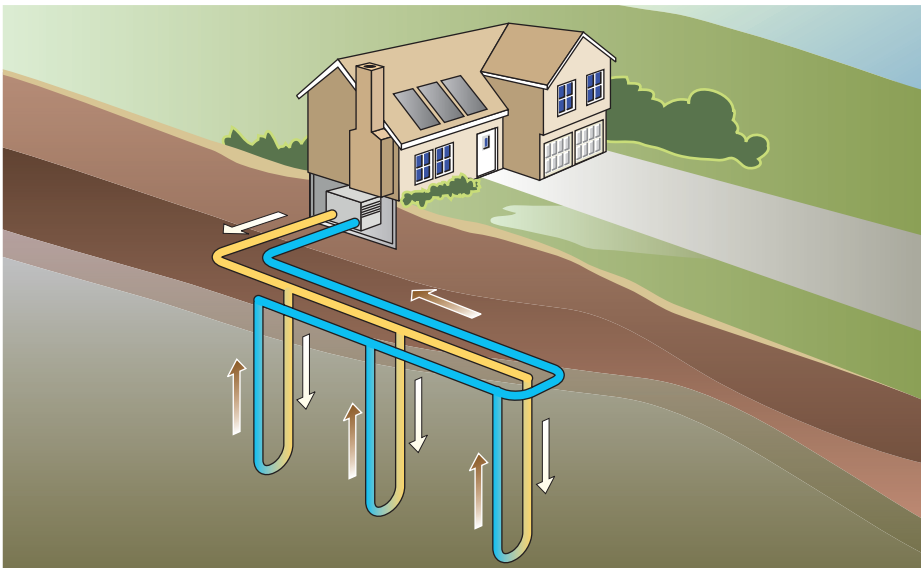


Figure 6.14 Pipes buried deep in the ground remove heat from the ground in the winter and pump it to the house. In summer, the heat pump takes heat from the house and deposits it in the ground.

Figure 6.15 The Forest Centre is on the Campus of Grenfell College, a college of Memorial University. The Centre uses cutting-edge technology of a geothermal heat pump for its heating and cooling

6-1E Blowing in the Wind

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Modelling
- Explaining systems
- Communicating

Safety

- Handle matches carefully.
- Wear thermal gloves when handling the beakers with the burning paper.
- Keep loose clothing away from flames and long hair tied back.

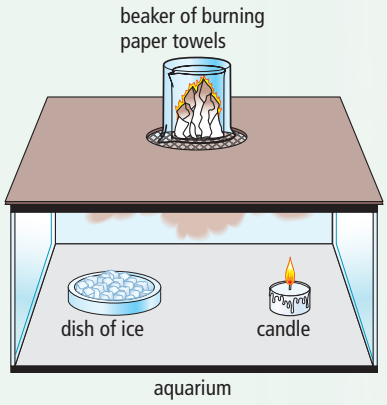
Materials

- aquarium with a screen top
- 100 mL beaker
- 1000 mL beaker
- Petri dish
- scissors
- piece of cardboard larger than the aquarium lid
- ice
- short, fat candle
- matches
- paper towels
- tape

Wind is caused by the uneven heating of Earth's surface. You can imitate those conditions in an aquarium. By creating smoke, you can observe the pattern of motion of the air. Your teacher might choose to do all or part of this investigation as a demonstration.

Question

How does a temperature difference on the Earth's surface cause a convection current in the air?



Procedure

1. Cut the cardboard so that it is just a little larger than the aquarium lid. In the centre of the cardboard, cut a hole that is slightly larger than the 1000 mL beaker.
2. Put ice in the Petri dish and place it at one end of the aquarium.
3. Place the candle at the other end of the aquarium.
4. Light the candle.
5. Put the screened lid on the aquarium and put the cardboard on top of the lid.
6. Fold up a small piece of paper towel and put it in the 100 mL beaker. Place the beaker on the screened lid in the centre of the hole in the cardboard.
7. Light the paper towel. Turn the 1000 mL beaker upside down and place it over the beaker with the lighted paper towel to cause the smoke to go into the aquarium.
8. For several minutes, observe and record what happens inside the aquarium.

Analyze

1. Draw a labelled diagram showing the motion of the smoke in the aquarium.
2. How does the ice affect the air around it?
3. How does the candle affect the air around it?
4. Based on the condition of the air near the ice and the air near the candle, explain the overall motion of the air.

Conclude and Apply

5. How does the motion of the air in the aquarium model wind?
6. Describe the conditions in nature that are similar to the conditions in the aquarium.

6-1F Convection in Water

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Controlling variables
- Modelling
- Explaining systems

Uneven heating of water can cause convection currents just as uneven heating does in gases. In this investigation, you will heat water unevenly and observe the movement of water by adding drops of food colouring. Your teacher might choose to do this investigation as a demonstration.

Safety

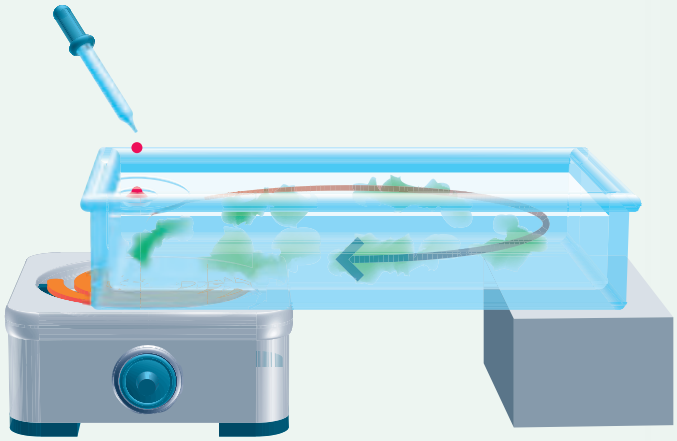
- Handle the hot tray with oven mitts.
- Do not touch the electrical plugs if your hands are wet.

Materials

- hot plate
- block of wood (same height as hot plate)
- large glass baking pan
- water
- food colouring

Question

When water is heated in one place, how is the heat distributed throughout the entire volume of water?



Procedure

1. Place one end of the glass baking pan on the hot plate and the other end on the block of wood as shown in the figure.
2. Pour water into the baking pan until it is almost full.
3. Turn the hot plate on low and let the water begin to warm.
4. Add a drop of food colouring to the water above the hot plate as shown in the figure.
5. Observe the motion of the colouring and record your observations.
6. Repeat step 5 several times until you can determine a pattern of motion of the water.
7. Wipe up any spills and wash your hands thoroughly.

Analyze

1. What happened to the drop of food colouring that was dropped into the water above the hot plate?
2. Describe the overall motion of the water in the baking pan.

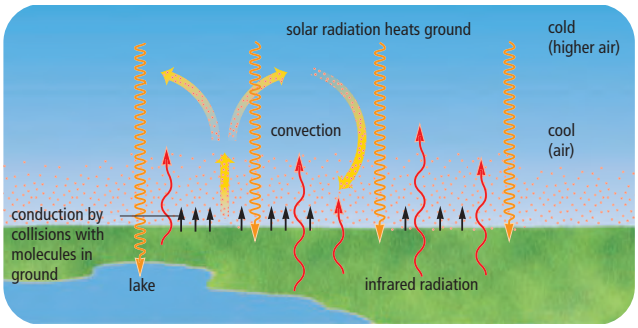
Conclude and Apply

3. Use your knowledge of convection to explain why the water moved as you described it in Analyze step 2.

Science Watch

Earth's Energy Budget

The three types of energy transfer—conduction, convection, and radiation—are all important in keeping temperatures around the world close to the average temperatures that support life. The first diagram shows the basic processes. Solar radiation (wavy orange arrows going down), which is mostly visible light, passes through the atmosphere and is absorbed by land, water, and anything on Earth's surface. The land and water are heated by the solar radiation. The land and water heat the layer of air in contact with the ground and water by conduction (short straight black arrows). The heat is spread through the lower atmosphere by convection (wide yellow arrows). Because they are warm, the land and water also emit infrared radiation. Specific gases in the air such as carbon dioxide absorb some of this radiation. The absorption of the infrared radiation warms the air.



If all of the heat that came to Earth by solar radiation stayed on Earth, the temperature would soon rise to such high temperatures that no life could survive. In order for Earth's average temperatures to remain the same, Earth must loose the same amount of heat that it gains. This energy is lost by emitting infrared radiation back out into space.

Before all of the energy in solar radiation returns to space, it is used for many purposes. The next diagram shows a few of the uses of this energy. Sunlight is absorbed by trees, grass, and other plants. The energy is used to help them grow and store nutrients. Animals eat the plants to gain energy to grow and carry out life processes. Trees and plants are also used to build houses. The coal, oil, and gas that humans take from the ground and use for fuel were once living organisms that used energy from the Sun. After all of these processes have been completed, the energy is eventually radiated back out into space.

Currently, humans are releasing more and more carbon dioxide into the atmosphere by several means including burning fuels in cars and in furnaces, and in the generation of electric energy. The levels of carbon dioxide in the atmosphere are increasing. As a result, the carbon dioxide is capturing more of the infrared radiation and preventing it from escaping back out into space. This process is one of the reasons why global warming is happening. Understanding global warming should help people to prevent it from continuing.

Questions

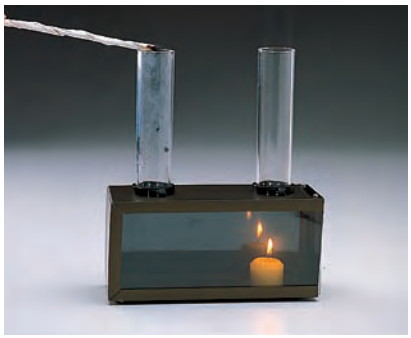
1. What is the source of the radiation that heats the air?
2. Why is it critical for Earth to emit as much heat by radiation as it receives from the Sun?
3. The levels of carbon dioxide in the atmosphere are increasing. How will this affect the atmosphere? Explain why it will have this effect.

Checking Concepts

1. When one part of a solid object is heated, how is the heat transferred to the rest of the object?
2. How is convection different from conduction?
3. Use the particle theory to explain conduction.
4. What causes the wind to blow? Use the terms "conduction," "convection," and "radiation" in your explanation.
5. Explain how energy can be transferred through empty space where no particles are colliding.
6. Visible light and infrared rays are two types of what form of energy?
7. When a solid object absorbs infrared rays, what happens to the particles in that object?

Understanding Key Ideas

8. The apparatus shown here is used to demonstrate convection. A closed container has glass sides and two glass chimneys. A candle is placed right below one of the chimneys and is lighted. A piece of burning paper is held over the other chimney. Describe the pattern of smoke from the burning paper that you would expect to see. Explain why the smoke would follow the pattern that you described.

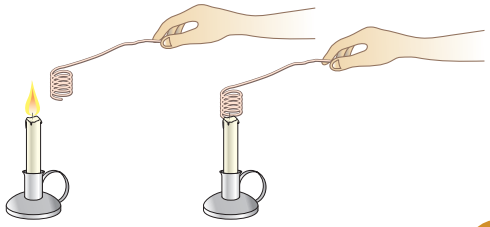


9. This diagram shows heat being transferred by conduction, convection, and radiation. Explain how and where each of the types of heat transfer is occurring.

10. Imagine that you are holding one end of a long rope and the other end is tied to a wall. A bell is tied to the middle of the rope. How could you demonstrate the transfer of energy to the bell without touching it? A rope such as this is often used as a model of radiant energy waves. Explain how waving the rope can be a model for transferring radiant energy.

Pause and Reflect

In the following diagram, a candle is burning. Someone is holding a coil made of copper wire. When the coil is placed around the candlewick, the flame goes out. Based on what you know about heat transfer, suggest a possible explanation for the reason that the flame goes out.



6.2 Conductors and Insulators

Although all solids can conduct heat, some do so much faster than others. They are called conductors. Substances that conduct heat very poorly are called insulators. For some applications, such as cooking, you need good conductors. When you want to keep hot things hot or cold things cold, you need to insulate them. Good insulation that is properly applied when a house is being built can save a lot of fuel and expense.

Key Terms

thermal conductivity
insulators

Some cooks feel that a cast iron skillet like the one in Figure 6.16A is the best type of skillet for frying. Some people even use them in the oven for baking corn bread. Most people, however, use a steel or aluminum skillet similar to the one in Figure 6.16B. If both of these skillets were on a stove burner and something delicious was cooking in each, which one would you have to be especially careful with when handling it?

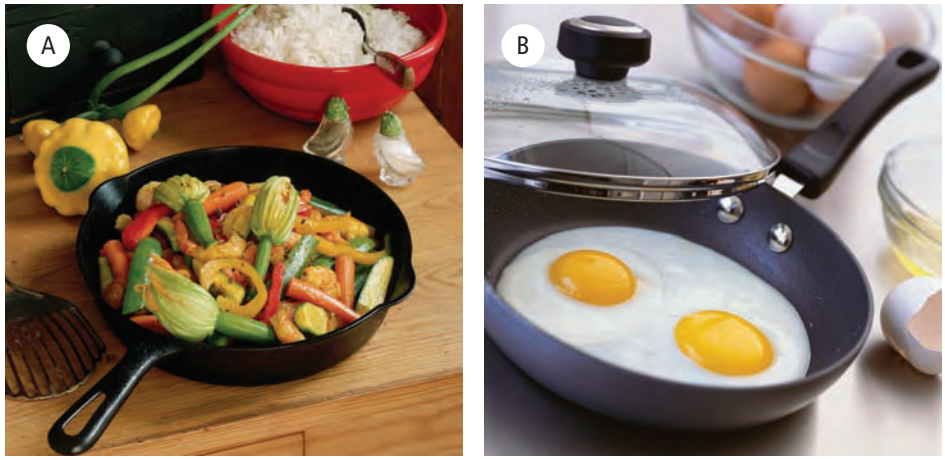


Figure 6.16 If you cook with a cast iron skillet (A), do not touch the handle without using an oven mitt or a hot pad. Most other skillets (B) have insulated handles.

Did You Know?

The bottom of the Space Shuttle is covered with special tiles that conduct heat extremely slowly. These tiles are critical because the friction between the tiles and the air when the shuttle re-enters the atmosphere makes the tiles extremely hot—as high as 1650°C. The astronauts inside of the shuttle are protected from the heat because the tiles radiate heat and conduct it back to the air faster than they conduct heat to other parts of the shuttle.

In the last section, you learned that solids transfer heat when hot particles collide with particles beside them. Skillets conduct heat from the burner to the food that is cooking in them. They also conduct heat to the handle. However, some materials conduct heat more readily than others. The handle of the cast iron skillet becomes very hot because cast iron conducts heat fairly well. The handle of the other skillet, however, is not metal. Plastic and other non-metal materials are often used for handles on cookware because they do not conduct heat as well as metals do. In this section, you will learn about materials that conduct heat efficiently and those that do not.

6-2A The Super Stirrer

Find Out ACTIVITY

For some uses, you would want an object that conducts heat very well. For other uses, you would want an object that does not conduct heat well. If you wanted a stir stick for a hot drink, what type of material would you choose?

Safety

- Handle the hot water with care.

Materials

- plastic (from a pen)
- copper wire
- long iron nails
- wooden craft sticks or wooden pencil

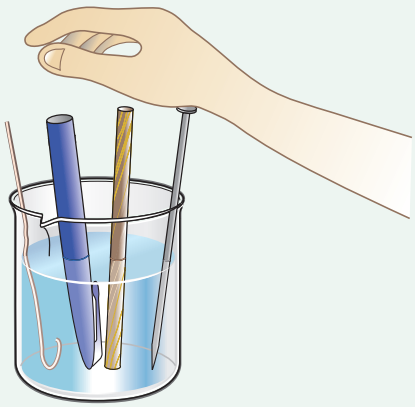
  (Each of the above items should be nearly equal in length.)
- cup or beaker of very hot water

What to Do

1. The items you are going to test for their ability to conduct heat are made of plastic, copper, iron, and wood. Predict which of the categories each material will fit in.

   a) good conductor of heat

   b) poor conductor of heat



2. Your teacher will pour a cup of very hot water for you. Place one end of each sample in the hot water. Wait for one minute.
3. The inside of your wrist is sensitive to heat. Touch the inside of your wrist to the top of each sample to determine which one is the warmest. This one is the best conductor of heat. Remove it from the cup and record which material is the best conductor of heat. Leave the other samples in the hot water for one more minute.
4. Repeat step 3 to find the second-best conductor of heat.
5. Continue to repeat step 3 until you have ranked all of the samples in order from the best conductor to the poorest.

What Did You Find Out?

1. Explain which of your samples would be the best for making:

   a) a stir stick

   b) the bottom of a frying pan

   c) the handle of a frying pan

   d) a container for delivering hot pizza
2. How might the particles in your best conductor differ from the particles in the poorest conductor of heat?

Suggested Activity

Investigation 6-2B on page 199.

Figure 6.17 The copper bottom on some types of cookware is not just for appearance. Copper is an excellent conductor of heat.

internet connect

Glass, stoneware, and ceramic cookware are poor conductors of heat. Why do you think that people cook with these products? You can find some important information about cookware on the Internet. Start your search at **www.discoveringscience.ca.**

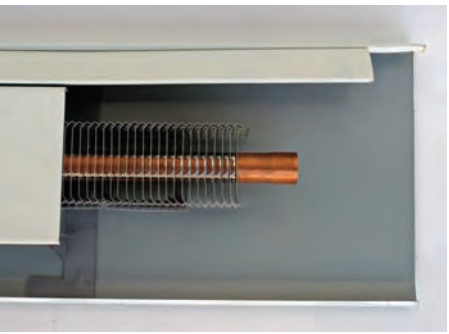


Figure 6.18 Baseboard heaters and radiators heat air by conduction with the air particles that come in contact with the metal surface. The hot air distributes the heat throughout the room by convection.

Cookware

You have probably noticed that most of the best conductors of heat are metals. However, all metals do not conduct heat at the same rate. The rate at which a substance conducts heat is called its **thermal conductivity.** Some metals are better conductors (have a higher thermal conductivity) than are other metals. This knowledge is important when designing or choosing an item that needs to conduct heat well.

Have you ever seen a pan with a copper bottom like the one in Figure 6.17? Did you wonder why the pan was made of two different metals? Copper is a very good heat conductor so it heats quickly and evenly. However, copper reacts with some foods such as tomatoes. The copper would combine with the food that was being cooked and would make it toxic. Therefore, copper is often used for the bottom of the pan but a non-reactive metal such as stainless steel is used to line the pans. Stainless steel does not conduct heat as well as copper so a pure stainless steel pan is not as good as copper is for some types of cooking.

Aluminum is similar to copper. It is a good conductor of heat but will also react with tomatoes and a few other ingredients that are often used in cooking. Aluminum pans must be either lined with a non-reactive metal or treated in a special way to prevent reactions. Good cooks must understand heat conductivity and know which metals are best to use in cooking.

Radiators

Some homes are heated by hot water running through a system of pipes in the rooms. Some hot water heating systems use baseboard heaters while others use large radiators as shown in Figure 6.18. The purpose of the baseboard heaters and radiators is to transfer the heat from the hot water to the air in the room. Therefore, the devices must be made of materials that are good heat conductors. They are always made of metal. As well, baseboard heaters and radiators need to have large surface areas to provide a lot of contact between the hot metal and the air in the room. The baseboard heaters have fins and radiators have many sections to provide these large areas of contact with the air.

The purpose of car radiators is the opposite of home radiators. A car engine creates a lot of heat. If the engine gets too hot, it will be damaged. Therefore, a coolant circulates from the engine to the radiator and back through the engine. While in the radiator, heat is transferred to the outside air. The coolant then returns to the engine to absorb more heat.

Figure 6.19 shows a diagram of a car radiator. The coolant flows through a very large number of metal tubes. The tubes are all connected to a stack of veins made of a metal alloy. This alloy is chosen because it is a very good heat conductor. When the car is moving, air passes through the veins in the radiator and removes the heat. There is also a fan behind the radiator to blow air through when the car is not moving fast enough and the engine temperature increases.

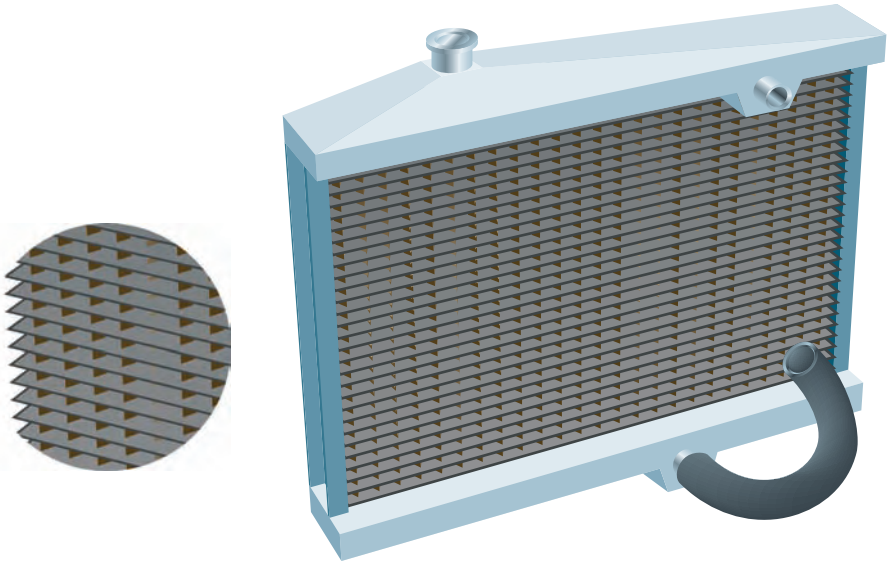


Figure 6.19 The honeycomb shape of the car radiator provides a very large metal surface area so that it can efficiently transfer heat from the engine to the outside air.

Reading Check

1. Why might you choose to purchase cookware with copper bottoms?
2. What class of substances are usually the best conductors of heat?
3. State two important features of radiators that are used in home heating.
4. List some similarities and differences between car radiators and household radiators.

Did You Know?

Materials that are good conductors of heat are usually also good conductors of electric current.

Did You Know?

An alloy is a mixture of two or more metals. Some alloys have properties that work better for many applications than the pure metals. For example, stainless steel is an alloy of iron with chromium and some carbon. It is much more resistant to rust than pure iron. Bronze is an alloy of copper and tin. Bronze is harder and more durable than pure copper or pure tin.

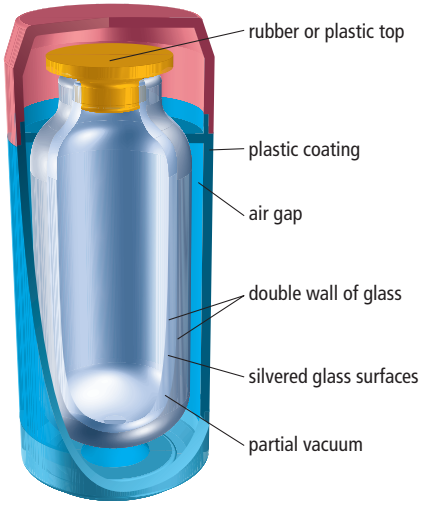


Figure 6.20 You can keep a cold drink cold or some hot soup hot for many hours in a Thermos® bottle.

Insulators

Materials that are very poor conductors of heat are called insulators. You have already seen one important use of an insulator—the handles of cookware. One of the very best insulators is "nothing." In this case, "nothing" means a vacuum. When no particles are present, neither conduction nor convection can occur. It is not possible to create a perfect vacuum in which all particles are removed. However, you can create a partial vacuum in which most particles of gas are removed. A Thermos® bottle as shown in Figure 6.20, is a good example of an insulator that uses a vacuum to prevent heat transfer. The inside of a Thermos® bottle is made of a double glass wall from which most air was removed and then the glass was sealed. The surfaces of the glass walls usually are silvered like a mirror to reduce radiation.

Insulating Your Home

Humans have lived in the far North for thousands of years. They used clever methods for keeping the heat in and the cold out of their homes during the long, cold winters. The first European settlers in North America were the Vikings who sailed from Greenland and settled on the island of Newfoundland in about 1000 C.E. In 1960, a Norwegian explorer discovered the remains of one of these settlements. Some of the structures in this settlement were restored. A sod hut from the settlement called L'Anse aux Meadows is shown in Figure 6.21. The aboriginal peoples also built sod huts and supported the structures with whale bones. The thick layers of sod kept the heat inside and the cold outside in the winter.

Suggested Activity

Investigation 6-2C on page 200.

Figure 6.21 For several years, the Norse settlers lived in these sod huts that are located on the northern tip of the island of Newfoundland. When these huts were discovered in 1960, they were restored, as nearly as possible, to their original condition.

Although sod was a very effective insulator for homes and was used for hundreds of years, great progress had been made in the technology of insulating buildings over the past thousand years. The cost of fuel makes heating modern homes very expensive. All houses leak some heat and it must be replaced. Keeping heat loss as small as possible will save fuel and save money. Home builders and contractors need to understand how and where heat leaks from buildings and the best ways to reduce the heat loss.

The largest surfaces of any house are the walls. There is always a space between the outer wall and the inner wall. If that space contained only air, the air would form convection currents as shown in Figure 6.22. Warm air would rise and cool air would fall. If the outside temperature is cool, the warm air that is in contact with the outer wall would lose heat to the outdoors by conduction through the wall. The air would begin to cool and drop and continue to lose heat to the outside. The cool air near the bottom of the space would receive heat by conduction through the inner wall. As the air warmed, it would begin to rise and continue to receive heat from the inner wall. As the warm air rises, the process would begin again.

As you know, when air can move, the convection currents it forms transfer heat from the inside to the outside of a house when the outside temperature is cool. However, if air is not allowed to move, it becomes a good insulator. The insulation that is built into walls of houses and other buildings, traps air and prevents it from moving. The material from which insulation is made is also a good insulator. Several types of materials, such as fibreglass and polystyrene, are used to make insulation. Figure 6.23 shows a variety of forms of insulation that are available. Builders and contractors must decide which type is best for each situation.

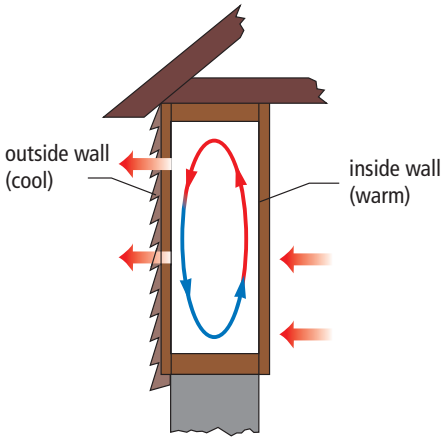


Figure 6.22 In the winter, if there was nothing but air between the inner and outer sections of a wall, convection of air would cause rapid heat loss from the house.

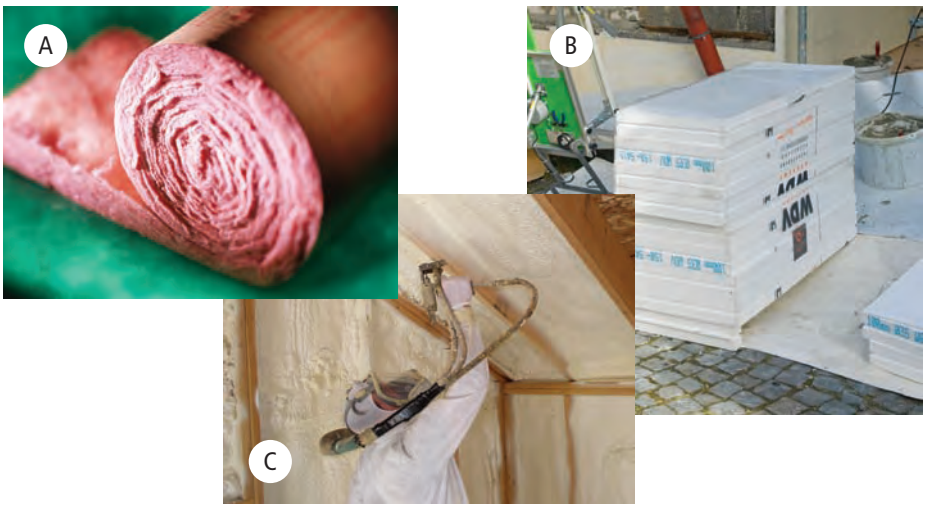


Figure 6.23 (A) Insulation often comes in rolls of a soft material called batt that is placed between the wooden beams in a wall. (B) Solid foam sheets of insulation are used for some situations. (C) Some builders prefer a spray foam that is applied directly to the structure of the building.

All types of insulation are rated according to their "resistance to heat transfer" or R-value. Table 6.1 lists the R-value of some common types of insulation. Materials with higher R-values are better insulators. In a wall, there will be several layers of different types of material. The total R-value is the sum of the R-values of each layer. For example, if you had plywood, fibreglass batt, and drywall, the total R-value would be 1.26 + 0.90 + 3.14 = 5.30.

Suggested Activities

Investigation 6-2D on page 202.

Table 6.1 R-Values of Building Materials

Type and Thickness of Material	Approximate R-Value
25 mm concrete	0.19
25 mm drywall	0.90
25 mm plywood	1.26
25 mm vermiculite	2.13
25 mm fibreglass batt	3.14
25 mm expanded polystyrene	3.86
25mm polyurethane (foamed-in-place)	6.25
25mm polyisocyanurate (foil-faced)	7.20

Windows are the places where the greatest heat loss occurs in a house. A single thickness of glass has an R-value of 0.91. Some new windows have two pieces of glass with an air space sealed between the layers of glass as shown in Figure 6.24. Sometimes a gas called argon is added to the air between the layers of glass. The total R-value of these windows can be as high as 2.04.

You can probably think of many more places that insulation is used. For example, the sides of a refrigerator or a freezer need to be insulated. Although you may not think of them as insulators, your own sweaters, jackets, mittens, and coats are forms of insulation for your body.

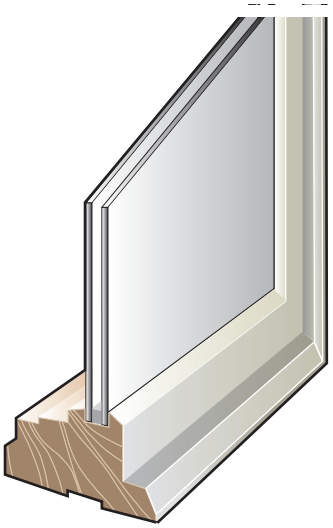


Figure 6.24 Air is sealed between the two pieces of glass to form some insulation in the window. If the seal is broken, however, moisture can get between the panes and condense creating water droplets between the pieces of glass.

Reading Check

1. Why is a vacuum a good insulator?
2. Air is a poor conductor of heat. Why would heat leak out through the double wall of a house if there was only air between the inner and outer walls?
3. Polyurethane foam, which is sprayed directly onto walls, is very expensive. Why might a builder or contractor choose to use an insulator that is more expensive than others that are available?
4. A single pane of glass has an R-value similar to that of one layer of drywall. Why, then, does so much heat escape through windows?

6-2B Heat Conductivity Rate

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Predicting
- Measuring
- Classifying
- Evaluating information

Although all solids conduct heat, some conduct it much more rapidly than others. Some materials conduct heat extremely slowly. These materials are called insulators. In this investigation, you are going to test the rate of heat conduction in several materials.

Question

What is the rate of conduction of heat in various substances?

Prediction

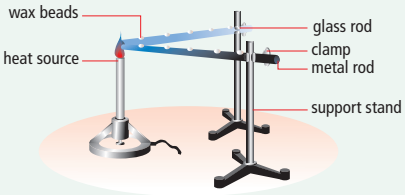
Predict the order of the materials, copper, glass, iron, and aluminum, in the order of their ability to conduct heat from fastest to slowest rate of heat transfer.

Safety

- Clean the equipment and wash your hands thoroughly at the end of the investigation.

Materials

- matches
- candle
- Bunsen burner
- 2 clamps
- glass rod and metal rods of equal diameter and length
- heat conductivity apparatus
- 2 support stands
- timing device
- ruler



Procedure

1. Light the candle. Let it burn until there is some melted wax at the top. Tilt the candle carefully and place drops of wax along the metal and the glass rods, one drop every 4 cm.
2. Use clamps to attach one end of each rod to a support stand.
3. Arrange the rods so that the free ends come together over the Bunsen burner flame.
4. As the rods heat, observe the melting of the wax beads. Record your observations.
5. To compare the thermal conductivity of different metals, use a conductivity apparatus (not shown). Place a drop of wax on the *end* of each metal rod of the apparatus.
6. Secure the conductivity apparatus hub over the flame.
7. Measure the length of time that it takes for each wax bead to melt. Record your observations.

Analyze

1. What do your results tell you about the transfer of heat through metals and non-metals?
2. List the tested materials according to their ability to transfer heat, from fastest to slowest.

Conclude and Apply

3. Compare your results with your predictions. Explain any differences.
4. Describe three places in your home in which you want a fast transfer of heat. List three situations in which you want a slow transfer of heat.

6-2C Keep it Cool

Skill Check

- Predicting
- Measuring
- Controlling variables
- Evaluating information

Safety

- Use care when handling the coffee cans because they can have sharp edges.

Materials

- scale or balance
- 6 identical, empty, metal coffee cans with plastic lids
- large basin
- thermometer
- ice cubes
- paper towels
- foam pellets about the size of peanuts
- poured insulation
- sheets of plastic bubble wrap
- wood shavings
- aluminum foil
- sealable plastic bags

Imagine that your assignment for a party was to bring a frozen dessert. You have to make it at home and take it to the party. How will you prevent it from melting while you transport it to the party and keep it until after the dinner? In this investigation, you will test the ability of several possible materials to prevent ice cubes from melting.

Question

Which type of insulating material will prevent ice cubes from melting?

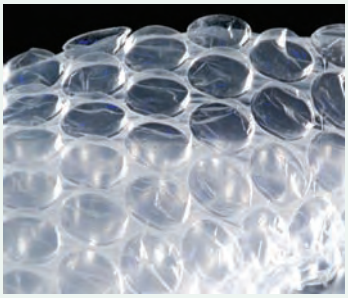
Prediction

Predict the order of the following types of materials, as well as poured insulation, as insulators from best insulator to poorest.

(a) foam pellets

(b) aluminum foil

(c) sheets of plastic bubble wrap



(d) wood shavings

Procedure

1. In the large basin, prepare a warm water bath of about 60°C.
2. Prepare the coffee cans as follows:
   - Half fill one can with wood shavings.
   - Half fill one can with foam pellets.
   - Place the bubble wrap so that it will fit, rolled, in another can.
   - Cover the inside of another can with poured insulation.
   - Line the fifth can with aluminum foil.
   - Leave the sixth can empty.

3. Choose six ice cubes that are approximately the same size.
4. Place each ice cube into a sealed plastic bag. Measure the mass of each one and record this data on a table similar to the one on the next page.
5. Put the ice cubes and bags into the cans as follows:
   - One onto the wood shavings. Add enough shavings to fill the can.
   - One onto the foam pellets. Add enough foam pellets to fill the can.
   - One onto the bubble wrap. Place more bubble wrap on top to fill the can.
   - One onto the poured insulation. Cover it with insulation.
   - One into the can lined with aluminum foil. Wrap aluminum foil around it.
   - One onto the bottom of the empty can.
6. Put the lids on the cans.
7. Place the six coffee cans into a warm water bath for 30 min.
8. While you are waiting, consider and revise your predictions.
9. After 30 min, quickly remove all of the ice cubes from their cans. Take each ice cube out of its bag. Pour out the water.
10. Place the cubes back into the plastic bags. Record the mass of each ice cube.
11. Clean up all materials and wash your hands thoroughly.

Insulation Material	Ice Cube Initial Mass (g)	Ice Cube Final Mass (g)	Ice Cube Lost Mass (g)
Wood shavings			
Foam pellets			
Bubble wrap			
Poured insulation			
Aluminum foil			
Empty can			

Analyze

1. In which container did the ice melt most? least?
2. Which container had the best insulation?
3. Which container had the poorest insulation?

Conclude and Apply

4. Which would be the best material(s) to use to get the frozen dessert to the party?
5. Are there any other factors that you would have to consider when you are planning a way to carry your dessert to the party? Explain.

6-2D When You're Hot....

Problem-Solving Focus

Skill Check

- Predicting
- Controlling variables
- Evaluating information
- Working co-operatively

Safety

- Be careful when working with hot liquids.

Materials

- 2 glass jars with metal lids
- wood chips
- thermometer
- plastic bags
- wool blankets or scarves
- aluminum foil
- newspapers
- foam pellets
- duct or electrician's tape
- string

A Thermos® bottle is just what you need if you want to keep your soup hot or your drink cold. The Thermos® bottle does have one big fault. If you drop it once, the vacuum bottle inside will break and you will have to buy another one. Perhaps you can improve on that design.

Problem

How can you construct a container that will keep water hot?

Design Criteria

A. You may choose from the materials in the list on the left.

B. Insulate one jar. Use another as a control. Compare the results of the two jars to see how well your insulation works.

C. Even with the insulation in place, the top of the insulated jar must be easy to reach and easy to unscrew.

Design and Construct

1. With a group, consider and record the advantages and disadvantages of each available insulating material. Record your conclusions in a table similar to the unfinished table below.

Insulation Material	Advantages	Disadvantages

2. Decide which insulator would be best for this job. Sketch and label the design using these materials. Get your teacher's approval.
3. Build your insulated jar.
4. Fill both jars with hot water from the tap. Measure and record the temperature of the water in each container. Put tops on the jars. Set them aside for four hours.
5. Arrange for someone in your group or your teacher to open both jars after four hours. The assigned person will measure and record the temperature of the water in each jar.

Evaluate

1. Would you be able to keep hot chocolate warm with your insulated jar?
2. How might you improve your plan? Make a list of things to consider including the following:

   (a) ability to insulate

   (b) ease of carrying

   Write a paragraph describing your improved plan.

Career Connect

Ask an Expert

Mario Patry is a salesman at a camping equipment store. He knows a lot about outdoor equipment. He can help campers decide which of the store's 30 different sleeping bags they will need for their camping trips. Mario knows a lot about insulation and energy transfer—the same topics that you have been studying. Here is what Mario tells his customers.

When a customer is choosing a sleeping bag, the first question I ask is where and when do they intend to use the bag. If you are backpacking in southern Canada in July, you will want a very different bag than if you are backpacking on Baffin Island in April. The right kind of sleeping bag can keep you warm on Baffin Island. Our warmest bag has a temperature rating of –40°C. It can keep you warm on a very cold night, if you use it in a tent that acts as protection from the wind. Also, you should put a pad under it for insulation from the cold ground.

Many factors affect how well a sleeping bag can keep the camper warm. Probably the biggest factor is the kind of insulation it uses. By that I mean what the filling in the bag is made of. There are two main types of sleeping bags: those filled with down (the fluffy layer under the feathers of water birds) and those that have synthetic fills (fibres made by machine). If you compare a down sleeping bag with a synthetic sleeping bag of the same thickness, the down bag is warmer.

Down puffs up very high—we call this effect "loft"—because of the many, many tiny air pockets between the bits of down. These air pockets are excellent insulators. They warm up with heat from the body and hold on to this warmth instead of letting it seep out of the sleeping bag. If you unroll your sleeping bag when you first set up camp, it has a chance to puff up with as many air pockets as possible before you sleep in it. Synthetic fill doesn't have as much puffiness, or loft, as down has. Fewer air pockets mean less trapped heat.

Down is very expensive. It is sometimes twice the price of a comparable synthetic bag, so some customers would not buy a down bag. Also, synthetic is a better choice if there is a chance your sleeping bag will get wet. A down bag takes much longer to dry out than a synthetic bag. While it is wet, the feathers stick together and, as a result, it will not insulate as well.

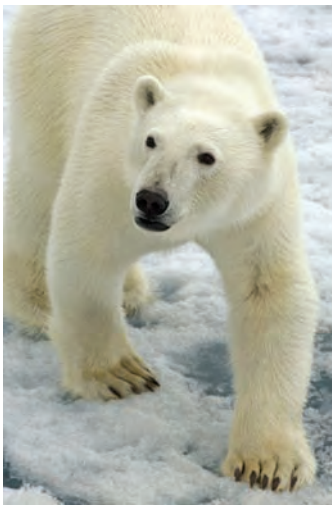
A lot of what I know about equipment I've learned from reading backpacking books and magazines and from trying out the equipment myself. I have been cycling, skiing, and winter camping for years. When I began working here, I completed two weeks of training to learn about the specific products the store offers.

Wild, Weird, Wonderful

www Science

Animal Insulation

Animals that live in the Arctic have many different ways to insulate their bodies from the extreme cold.



The polar bear has a very thick fur that traps air making it a good insulation. Also, the individual hairs are hollow. They act like light pipes collecting sunlight and guiding it to the skin. Although their coat is white, polar bear skin is black, and therefore, absorbs radiant energy very well. In addition, polar bears have a layer of fat just below the skin. Fat is a good insulator. If a polar bear runs across the ice for a while, it gets too warm. It then lies flat on the ice to cool off.

Arctic seals swim in icy water. Water is a much better heat conductor than air so water can remove heat from a body very rapidly. Seals are insulated with a thick layer of blubber under the skin. The blubber can be as much as 7 cm thick. If a seal moves across land for too long, even at freezing temperatures, they become extremely hot because the blubber is such a good insulator.

The coat of the arctic fox is so thick that it needs no other insulation. In addition, the pads of the fox's feet have fur to prevent them from freezing. The fur also helps prevent them from slipping on ice. When the fox sleeps, it curls its long fluffy tail around its nose and face to protect them from the cold.

The musk ox has a very thick coat with a very soft, thick fur under the longer, stiffer hairs. A herd of musk ox huddle together, not only to protect each other from predators but also to keep warm. You might say that musk ox use each other as insulators.

Check Your Understanding

Checking Concepts

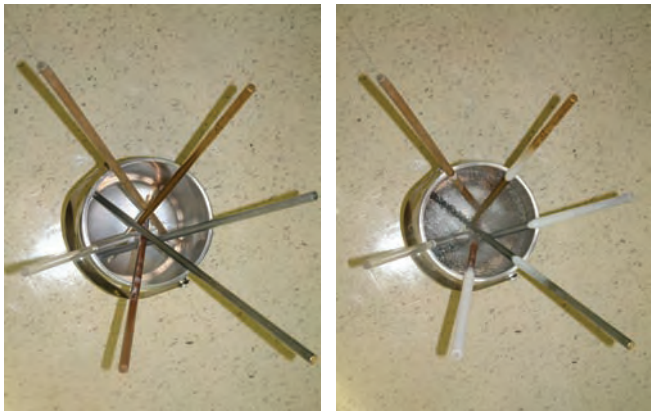
1. Why are handles on cookware often made of plastic?
2. Copper and aluminum are good thermal conductors. Why is stainless steel often used for the lining of cookware?
3. Why are household radiators made of metal?
4. What is the purpose of a car radiator?
5. Describe the parts of a Thermos® jug. How can they keep cold drinks cold and hot foods hot for such a long time?
6. There are many types of insulation used in homes and other buildings. What is one feature that they all have?
7. Glass is a poor insulator but all homes have many windows. What is one way to reduce the loss of heat through windows?
8. What does the R-value of a type of insulation tell you?

Pause and Reflect

Imagine that you are going on a picnic and taking a lunch for four people. You do not have a cooler so you are going to construct one from materials that you can find around your home. List items that you would use that are likely to be available in your home. Make a sketch of the cooler and explain why you chose the different parts.

Understanding Key Ideas

9. In the picture below, on the left, the rods made of different types of metals had just been placed in a thermos containing liquid nitrogen, which is extremely cold. The picture on the right shows the rods after they sat in the liquid nitrogen for several minutes. Explain how you can determine the order of the abilities of the metals to conduct heat. Which one is the best conductor and which is the poorest?



10. Use Table 6.1 on page 198. What would be the R-value of a wall that had 50 mm of concrete, 50 mm of expanded polystyrene, and 25 mm of plywood?
11. While baking a cake, you want to avoid burning the bottom of the cake. Should you use a glass or a metal baking pan? Explain why.

6.3 Temperature versus Heat

Heat and temperature are related but different quantities. Heat is related to the total kinetic energy of all of the particles in a substance. Temperature is related to the average kinetic energy of the particles in a substance.

Key Terms

thermal energy
specific heat capacity

St. John's sits on the east coast of Newfoundland and Labrador, looking out on the Atlantic Ocean. The average temperature in January is –3°C and in July it is 15°C. As you read in Table 4.1 in Chapter 4, the average temperature in January in Winnipeg, Manitoba is –17°C and in July it is 20°C. Winnipeg is located in the central plains of Canada. Notice that St. John's is not as cold as Winnipeg in the winter and not as hot as Winnipeg in the summer. The main difference between St. John's and Winnipeg is that Winnipeg is surrounded by land and St. John's is nearly surrounded by water. Could water prevent St. John's from having the temperature extremes that Winnipeg has?

Figure 6.25 The Atlantic Ocean prevents the temperature from being extremely high or extremely low in St. John's.

Did You Know?

The Gulf Stream is part of a group of currents in the Atlantic Ocean. It starts in the Gulf of Mexico and flows north along the east coast of the United States. Just before it reaches Newfoundland and Labrador, it goes east across the Atlantic Ocean. When it reaches Europe, it is called the North Atlantic Drift. The current carries enough heat from near the equator to northern Europe to significantly affect the climate.

If you made many more comparisons of temperatures in cities that are surrounded by land and cities located near large bodies of water, you would find patterns that are similar to those found in St. John's and Winnipeg. The presence of large bodies of water has a major effect on the climate. In this section, you will learn how the temperature of substances responds when heat is added or removed. This information will help you to understand the effect of large bodies of water on the local climate.

6-3A Mix It Up

Find Out ACTIVITY

When you combine liquids that are at different temperatures, what determines the final temperature of the mixture? In this activity, you will combine 10 mL of room-temperature water, alcohol, and vegetable oil to separate 20 mL samples of ice water. Predict whether the final temperatures will be the same.

Safety

- Use care when handling the alcohol.

Materials

- 3 50 mL beakers
- 25 mL graduated cylinder
- laboratory thermometer
- stirring rod
- ice water
- room-temperature water
- room-temperature alcohol
- room-temperature vegetable oil

What to Do

1. Measure and pour 20 mL of ice water into each of the three 50 mL beakers. Do not allow any ice to get into the water in the beakers.
2. Measure and record the temperature of the water in each beaker.
3. Measure 10 mL of room-temperature water and pour it into one of the 50 mL beakers. Stir with a stirring rod and measure the temperature of the water.
4. Measure 10 mL of room-temperature alcohol and pour it into the second 50 mL beaker. Stir with a stirring rod to thoroughly mix the water and alcohol. Measure and record the temperature of the mixture.
5. Measure 10 mL of room-temperature vegetable oil and pour it into the third 50 mL beaker. The oil and water will not mix but by stirring thoroughly, you can create enough contact for the oil and water to exchange heat. Measure the temperature of the water after mixing.

What Did You Find Out?

1. To separate samples of 20 mL of ice water, you added equal amounts of water, alcohol, and oil that were all at the same temperature. List the mixtures in order of final temperature from highest to lowest.
2. Provide a possible explanation for any temperature differences that you observed.

Average and Sum of Kinetic Energies

To understand the difference between heat and temperature, you need to analyze the meaning of the average kinetic energy of the particles and the sum of the kinetic energies of the particles in a substance. You have learned that the average kinetic energy of the particles in a substance is directly related to the temperature of the substance. You will now find out how heat is related to the sum of the kinetic energies of the particles of a substance. Consider the following example.

Suppose that you had a beaker with 100 mL of water in it. You measured the temperature as shown in Figure 6.26A and found that it was 40°C. Then, imagine that you poured half of the water into another identical beaker and measured the temperature in both beakers as shown in Figure 6.26B. What would be the temperatures of the water in each of the two beakers? You are probably thinking, "Of course, the temperatures would both be 40°C." This is correct. The temperature does not depend on the amount of water. In Chapter 4, you read that temperature is a measure of the average kinetic energy of the particles in a substance. There might be 1000 particles, 1 000 000 000 particles or 1 with a hundred zeros following it. The temperature of a substance does not depend on the number of particles present.

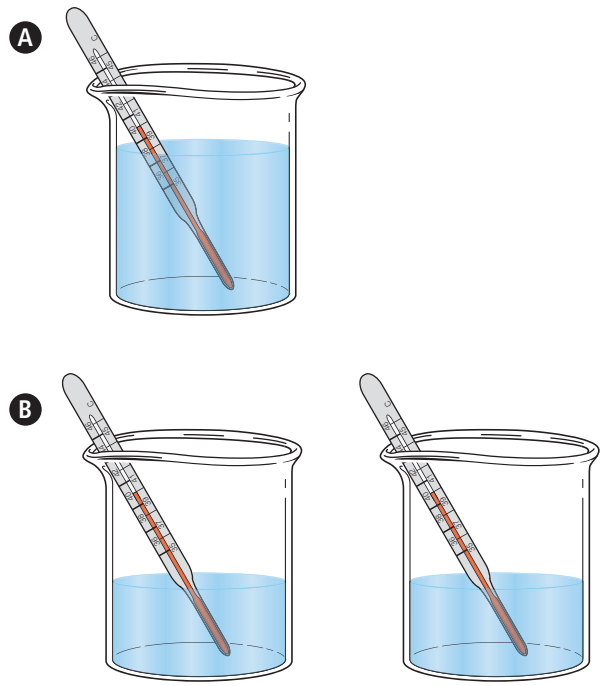


Figure 6.26 When you divide water into several different parts, the temperature is not affected. What is affected?

Now analyze the total amount of kinetic energy of the particles in the beakers in Figure 6.28. The total kinetic energy of all of the particles in a substance is the *sum* of the kinetic energies of each of the particles. Therefore, when you pour half of the water in one beaker into another beaker, the total kinetic energy in each beaker is half of the original. The *average* kinetic energy of the particles is still the same even though there are only half as many particles in each beaker. Since the average kinetic energy is the same, the temperature is still the same. Although, the *total* kinetic energy in each beaker is only half of the original, the temperature in each beaker is the same as the original.

Scientists usually call this total kinetic energy of the particles the **thermal energy** of the substance. People who are not scientists usually think of thermal energy as heat. So, the amount of thermal energy, or heat, is reduced when you pour some of the water out of the beaker but the temperature does not change. Heat and temperature are *not* the same. They are related but clearly different quantities.

Did You Know?

Scientists reserve the word *heat* to mean thermal energy that is transferred from one object to another or from one place to another. Technically, heat is the transfer of thermal energy.

Absorbing and Losing Heat

You know that adding heat to a substance will increase its temperature. However, do you know how much the temperature will increase when you add, for example, 1000 J of heat to 100 mL of a substance? Examine Figure 6.27 to find an answer to that question.

When you add 1000 J of heat to 100 g of water and to 100 g of alcohol, the increase in the temperature is not the same. When you add the same amount of heat to the same mass of two different substances, the size of the temperature increase depends on the type of substance. Scientists call this property of substances the specific heat capacity of the substance.

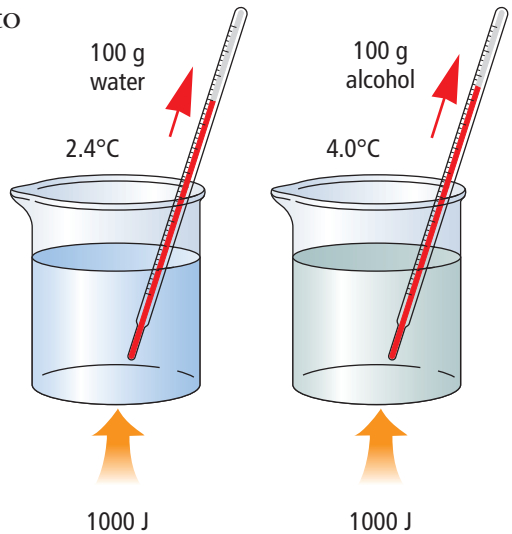


Figure 6.27 When you add 1000 J of heat to 100 g of water, the temperature of the water increases by 2.4°C. When you add 1000 J of heat to 100 g of alcohol, the temperature of the alcohol increases by 4.0°C.

The **specific heat capacity** of a substance is the amount of heat needed to raise the temperature of 1.00 g of the substance by 1.00°C.

For example, it takes 4.18 J of heat to increase the temperature of 1.00 g of water by 1.00°C. You would say that the specific heat capacity of water is 4.18 J/g ·°C (4.18 joules per gram per degree). It takes 2.43 J of heat to increase the temperature of 1.00 g of alcohol by 1.00°C. You would say that the specific heat capacity of alcohol is 2.43 J/g ·°C. (2.43 joules per gram per degree).

Suggested Activity

Investigation 6-3B on page 212.

Sun, Water, and Solid Ground

As you can see in the example of the water and the alcohol, it takes much more heat (4.18 J) to raise the temperature of 1.00 g of water by 1.00°C than it does to raise the temperature of 1.00 g of alcohol by 1.00°C (2.43 J). In fact, the specific heat capacity of water is higher than the specific heat capacity of most other substances. This difference in specific heat capacity is one reason why the temperature of water does not increase as much as the temperature of the ground when the Sun shines on them. Figure 6.28 shows you more reasons why the temperature of water does not change as readily as the temperature of the ground.

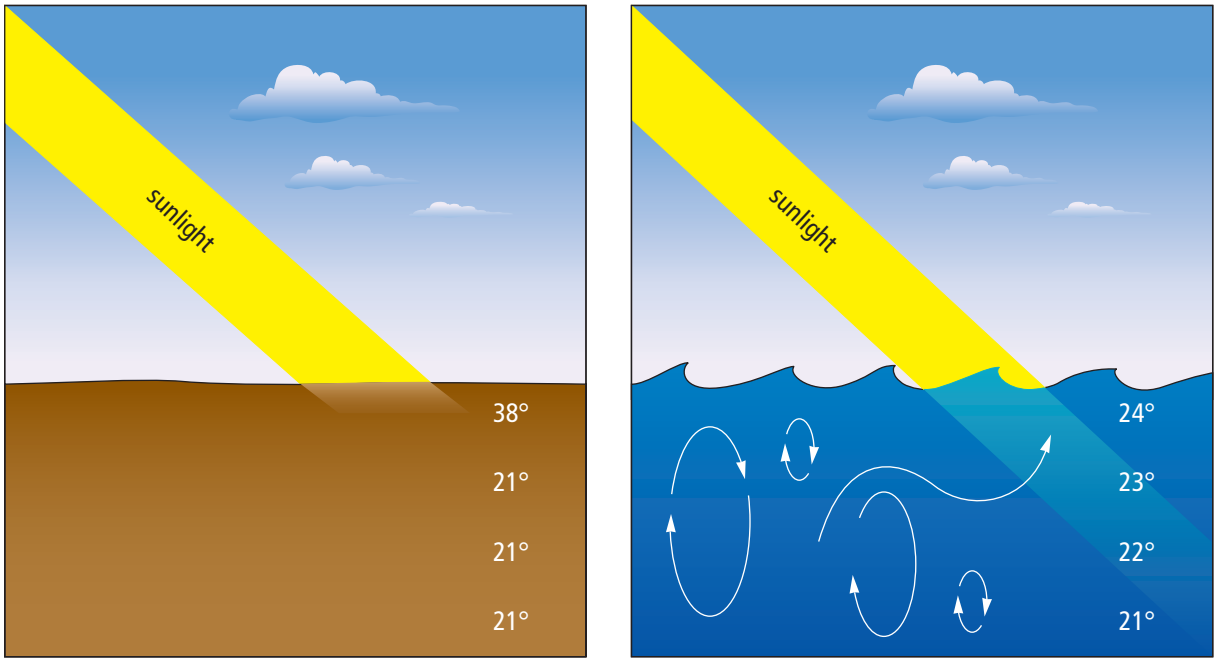


Figure 6.28 When the same amount of sunlight hits ground and water, the temperature of the ground increases more than the temperature of the water.

As you can see in Figure 6.28, the sunlight is absorbed by the top few centimetres of ground, or soil, so it increases in temperature a lot. The only way that heat can be carried deeper into the ground is by conduction, which is quite slow. Sunlight penetrates much deeper into the water so the energy is spread through a larger amount of water. As well, any motion of the water mixes the warmer and cooler water and spreads the heat around more. For these reasons and because water has a much higher specific heat capacity, the water temperature does not rise nearly as much as the temperature of the top layer of ground. If you have ever gone to the beach on a sunny day in the summer,

you might have experienced these temperature differences. If you walk on a sandy beach in bare feet, the sand can feel extremely hot. As soon as you step into the water, the water feels cool. Now you can understand why.

Figure 6.29 The sand at the beach can be so hot that you want to run to get to the water. Once in the water, your feet feel cool.

Reading Check

1. Define "specific heat capacity".
2. If you combined four samples of water that each had a temperature of 4°C, would the final temperature be 16°C? Why or why not?
3. What property of a substance influences both heat and temperature?
4. How are heat and temperature different?

6-3B Keeping it Cool

Skill Check

- Observing
- Measuring
- Controlling variables
- Evaluating information

Safety

- Handle containers of hot materials with care.
- If hot oil or water touches your skin, hold the burned skin under a stream of cold water for several minutes. Have a classmate inform your teacher at once.
- Wash your hands thoroughly at the end of the investigation.

Materials

- hot plate
- 500 mL beaker
- graduated cylinder
- thermometer
- retort stand with thermometer clamp
- oven mitts
- stopwatch
- stirring stick
- balance and masses
- water
- oil such as paraffin oil, mineral oil, or motor oil
- vegetable oil
- glass marbles
- sand
- steel shot

In the summer, people often want to go to the beach, to a swimming pool, or just run through the sprinkler. You know that water will make you feel cooler but do you know why? This investigation will help you understand more about why water helps you stay cool.

Question

Part 1: Do all liquids absorb heat at the same rate?

Part 2: Do all solids absorb heat at the same rate?

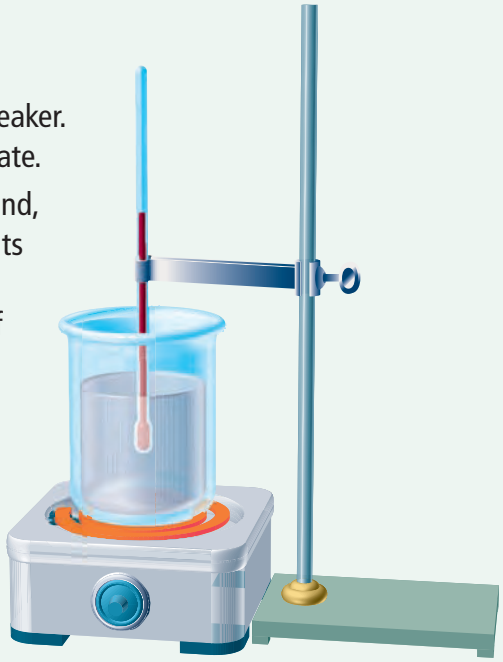
To get an accurate reading, the thermometer should be held away from the side of the beaker.

Procedure

Part 1 Liquids

1. Pour 200 mL of water into a beaker. Place the beaker on the hot plate.
2. Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water but not touching the side or bottom of the beaker.
3. (a) Record the initial water temperature.

   (b) You want to raise the water temperature by 30°C. Calculate what the temperature will be then.



4. Turn the hot plate to medium high. Time how long it takes to reach the temperature that you calculated in 3(b). Record the time.

5. Turn off the hot plate. Use oven mitts to remove the beaker from the hot plate. Allow time for the hot plate to cool.
6. Repeat steps 1 through 5 using vegetable oil and the other oil. **CAUTION:** If droplets of oil fall on the hot plate, they can ignite.

Part 2 Solids

7. Pour 100 mL of water into a beaker.
8. Add about 100 g of glass marbles to the water in the beaker. Place the beaker on the hot plate.
9. Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water.
10. (a) Record the initial water temperature.

    (b) You want to raise the temperature by 30°C. Calculate what the temperature will be then.
11. Turn on the hot plate to medium high. Time how long it takes to reach the temperature that you calculated in 10(b). Record the time.
12. Use oven mitts to remove the beaker from the hot plate. Turn off the hot plate and allow it to cool.
13. Repeat steps 7 through 12 using approximately 100 g of sand and then using 100 g of steel shot. (**Hint:** To be sure that the sand is heated evenly, you need to stir it with the stirring stick.)
14. Clean up and put away the equipment you have used.

Analyze

Part 1

1. Which liquid(s) took the longest time to increase in temperature by 30°C?
2. Which liquids took about the same amount of time to warm by 30°C? Can you suggest a reason for this result?

Part 2

3. Which solid(s) took the longest time to raise its temperature by 30°C?
4. Which solids took about the same amount of time to warm by 30°C? Can you suggest a reason for this result?

Conclude and Apply

5. Compare the time it takes to heat the materials in Part 1 and Part 2.

   (a) Does the kind of material being heated affect the amount of heat needed to change its temperature?

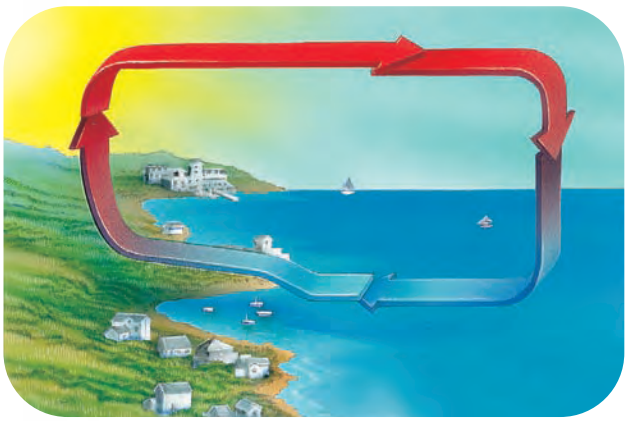
   (b) What piece of information shows you the answer to 5(a)?

Wild, Weird, Wonderful

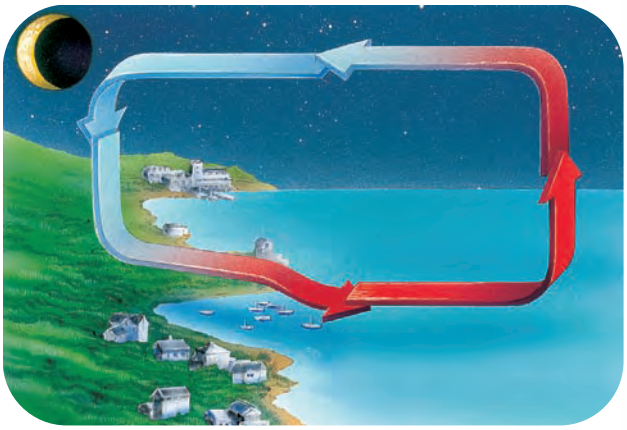
www Science

Sea and Land Breezes

Have you ever spent a few days by a large lake or by the sea? If you have, you might have experienced a sea breeze. On a hot summer day, you can depend on a gentle breeze blowing onto land from the water to help you feel cool. Why is a sea breeze so dependable on a hot day? What happens when the air cools down at night? An understanding of specific heat capacities and of convection currents will help you understand sea and land breezes.



On a hot summer day, the Sun beats down on the land and on the water. The low specific heat capacity of soil causes the ground to heat up quickly. Conduction in the soil does not carry the heat away very quickly so the top few centimetres of the soil get very hot. At the same time, the high specific heat capacity of water prevents the water from heating rapidly. The mixing of the water spreads any heat throughout the water. As a result, the water temperature is much cooler than the temperature of the ground. Heat is transferred from the ground to the air and the air begins to rise over the land. The air over the water is about the same temperature as the water so it is cooler than the air above the land. As the air above the land rises, it creates convection currents that draw the cool air in from above the water. The cycle continues as long as the day is hot.



When the Sun goes down, the low specific heat capacity of the soil allows the temperature to drop quickly when the heat leaves the ground by conduction with the air above. The high specific heat capacity of water prevents a rapid change in temperature because a large amount of heat would have to leave the water. Soon after the Sun goes down, the water is warmer than the land. The air above the water is, therefore, warmer than the air over the land. The air above the water begins to rise and the cooler air over the land flows out over the water forming another convection current. This time, however, the breeze is blowing out toward the sea. It is called a land breeze. The sea and land breezes make sitting on the shore comfortable on a summer day or evening.

Notice that wind direction is described as the direction *from* which the wind is blowing. A sea breeze is a wind blowing from the sea to the land. This method of reporting is always used in weather reports. For example, a westerly wind is a wind blowing *from* the west and not toward the west. A land breeze is a wind blowing from land to the sea.

Checking Concepts

1. Vancouver, British Columbia is on the Pacific Ocean while Regina, Saskatchewan is in the prairie. Which city would you expect to be colder in the winter? Which city would you expect to be warmer in the summer? Explain why.
2. The average kinetic energy of the particles in a substance is related to what quantity?
3. The sum of the kinetic energies of the particles in a substance is related to what quantity?
4. Does heat or temperature depend on the amount of substance?
5. The specific heat capacity of aluminum is 0.900 J/g ·°C and the specific heat capacity of iron is 0.444 J/g ·°C. If you added 1000 J of heat to 100 g of each metal, which one would have the greatest temperature increase? Explain why.
6. List two reasons why water stays cooler than soil if the same amount of sunlight falls on both of them.

Pause and Reflect

Fire-walkers are people who walk on hot coals with their bare feet. One of their secrets is a knowledge of specific heat capacity. Before they walk on hot coals, fire-walkers wear a thick pair of socks. The socks make their feet sweat. How might having a layer of water (sweat) on the soles of their feet protect the fire-walker from burns?

CAUTION: This is a very dangerous stunt. Even if you have wet feet, *do not* try this yourself.

Understanding Key Ideas

7. Which beaker, in each of the following pairs, requires more heat to achieve the stated results? Explain each answer.
   (a) Beaker A with 250 mL of water and Beaker B with 500 mL of water are warmed from 10°C to 20°C.
   (b) Beaker A with 250 mL of water is heated from 10°C to 20°C. Beaker B with 250 mL of water is heated from 10°C to 30°C.
   (c) Beaker A with 250 mL of water and Beaker B with 250 mL of vegetable oil are heated from 10°C to 20°C.
8. Use your knowledge of specific heat capacity to explain why water is a better coolant than vegetable oil.
9. Why does water at a beach feel cooler than the beach sand during the day and warmer at night?
10. (a) Write a sentence using the word "capacity" in its everyday sense.
    (b) Write a sentence using the term "specific heat capacity." Your sentence must show that you understand its meaning.
    (c) How is the word "capacity" in its everyday sense different from the word "capacity" when used in the term, "specific heat capacity"?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the methods of heat transfer, insulators, and specific heat capacity. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Conduction, Convection, and Radiation
2. Wind and Convection
3. Waves and Radiation
4. Thermal Conductivity
5. Insulators
6. Specific Heat Capacity

Checking Concepts

1. Each of the situations described below can be used to model a type of heat transfer. Indicate which type of heat transfer can be modeled by each of the following and explain why.
   (a) At a sports event, the spectators do "the wave." Starting at one end of the stadium, they stand up and then sit down as the next person stands. A rippling motion appears to travel through the crowd.
   (b) Several dominoes are standing close together on edge. You give the end domino a small push, increasing its kinetic energy. It falls onto the next one, which falls onto its neighbour, and so on. Soon all of the dominoes have fallen.
   (c) On a ski hill, people line up at the bottom of the hill, take the lift to the top, and then ski down again to join the crowd waiting for the lift.
2. What type of heat transfer is most important to a lizard that is basking in the Sun? Explain why?
3. Suppose you are given two cups of hot chocolate. One cup is made of shiny metal, and the other cup is made of a metal that has been painted black. Which cup will keep your hot chocolate warm longer? Explain.
4. Why are the handles of pots and pans usually made of non-metals?
5. (a) Why does so much heat escape from windows and doors?
   (b) How can heat transfer from windows and doors be slowed?
6. When boiling fruit and sugar to make jam, the mixture can easily reach a temperature of 105°C.
   (a) Which type of spoon could be used to stir the mixture without becoming soft or burning your fingers: wooden, metal, or plastic?
   (b) Which method of heat transfer must be prevented from happening in the spoon?
7. What is the difference between heat and temperature?
8. The R-value of 25 mm of solid wood is 1.25. The R-value of 25 mm of wood shavings is 2.42. Explain why there is such a large difference.
9. You heat a copper pot and an iron pot using the same method. Which pot heats more quickly? Explain your answer.

Understanding Key Ideas

10. When discussing conduction, you usually think of the process occurring in solids.

(a) Could convection occur in solids? Explain.

(b) Could conduction occur in liquids? Explain.

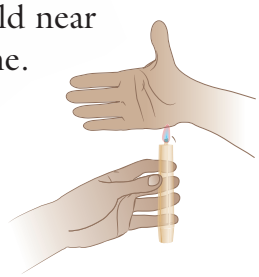
11. You have been asked to explain to a third grade class why the wind blows. Design an exhibit that you could use to demonstrate and explain wind to third graders. Make a sketch of your exhibit and explain how it works.

12. You hold a burning candle in one hand. Which of the processes of heat transfer causes your other hand to feel the heat in each of the following situations?

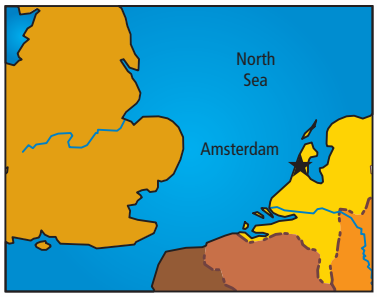
(a) Your other hand is held high above the burning candle and feels the heat.

(b) Your other hand is held near to the side of the flame. The palm of your hand feels the heat.

(c) A drop of wax falls on your hand and you feel the heat.



13. Edmonton, Alberta and Amsterdam, the Netherlands (Holland) are about the same distance north of the equator. Their climates are very different. What might account for this difference?

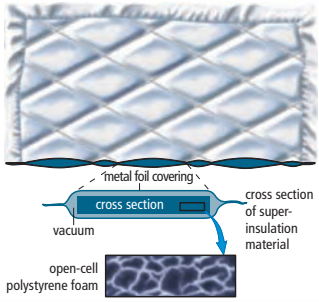


14. Why do builders put more insulation in an attic than in the walls?

15. A new "super insulation" is made from plastic foam with a shiny, metal foil covering (see diagram below). All the air is pumped out of the holes in the plastic foam. The foil prevents air from entering the foam again. Experts estimate that widespread use of this new material could save as much as one billion dollars' worth of fuel for heating buildings each year.

(a) Explain how the super insulation prevents heat transfer by conduction, convection, and radiation

(b) Suggest one problem that might occur with the new insulation?



16. In an experiment, a student observed that when 1000 J of heat was added to 50 g of granite, the temperature increased by 25.3°C. When 1000 J of heat was added to 50 g of limestone, the temperature increased by 21.7°C. Which type of rock, limestone or granite, has the largest specific heat capacity? Explain your reasoning.

Pause and Reflect

Coffee drinkers are sometimes told that if their coffee is too hot, they should let a metal spoon sit in the cup and the coffee will cool faster. Based on what you know about heat transfer, do you think this will work? Explain your reasoning.

4 Temperature describes how hot or cold an object is.

- Normal body temperature of humans is 37°C. (4.1)
- Body temperature is an indicator of health. (4.1)
- Hypothermia and hyperthermia can be life threatening. (4.1)
- Average air temperatures in Newfoundland and Labrador vary from –25°C to 20°C. (4.1)
- The first temperature sensing devices were developed in the 1500s. (4.2)
- The commonly used temperature scales are the Fahrenheit scale, the Celsius scale, and the Kelvin scale. (4.2)
- Thermometers must be calibrated by exposing them to substances at known temperatures. (4.2)
- Thermometers must contain a substance that changes as the temperature changes so that the change can be observed. (4.2)

5 Scientists use the particle theory of matter to describe temperature.

- All matter consists of tiny particles that are always moving, have spaces among them, are attracted to each other, and particles of different substances are different. (5.1)
- The average kinetic energy of the particles in a substance is directly related to its temperature. (5.1)
- All pure substances can exist in any of the three states—solid, liquid, or gas—depending on the temperature. (5.2)
- The particle model of matter can explain why particles exist in different states. (5.2)
- Matter in any state expands when the temperature increases and contracts when the temperature decreases. (5.2)
- The changes of state are called melting, freezing, evaporation, condensation, sublimation, and deposition. (5.3)
- Every pure substance has its own melting point and boiling point under conditions of standard pressure. (5.3)
- The particle theory can explain changes of state. (5.3)

6 Heat is transferred from one place to another by three different processes.

- The three mechanisms of heat transfer are conduction, convection, and radiation. (6.1)
- Conduction and convection depend on the motion of particles. Radiation is energy carried by electromagnetic waves. (6.1)
- Absorption of radiant energy by an object depends on its lustre and colour. (6.1)
- Conductors are substances that conduct heat rapidly. (6.2)
- Insulators conduct heat very slowly. (6.2)
- The R-value of building materials describes their effectiveness as insulators. (6.2)
- Heat and temperature are related but are not the same quantity. (6.3)
- The amount of heat required to change the temperature of 1.00 g of a substance by 1.00°C is called its specific heat capacity. (6.3)

Key Terms

- bimetallic strip
- body temperature
- calibrate
- Celsius scale
- Fahrenheit scale
- hypothermia
- Kelvin scale
- room temperature
- thermocouple
- thermogram
- thermometer
- thermoscope
- wind chill

Key Terms

- boiling point
- change of state
- condensation
- deposition
- evaporation
- freezing
- gas
- heating curve
- kinetic energy
- liquid
- matter
- melting
- melting point
- particle theory of matter
- solid
- sublimation
- temperature
- thermal contraction
- thermal expansion

Key Terms

- conduction
- convection
- convection currents
- insulators
- radiation
- specific heat capacity
- thermal conductivity
- thermal energy

Water Heater

In this unit, you have learned a lot about heat, temperature, energy transfers, insulation, and many more concepts involving heat. Can you apply much of this new knowledge in a practical way?

Problem

Design and build a simple but efficient device to harness and transform energy: a candle powered water heater.

Criteria

- Your goal is to raise the temperature of the water as much as possible.
- The water may be heated directly with the candle or indirectly using the candle to heat something else, which will then heat the water.
- Use as many types of heat transfer as possible.
- Your energy transfer device must be non-flammable and movable so that it can be safely placed over the candle after the candle has been lit.
- The candle will be allowed to burn for only 3 min during your demonstration.

Procedure

1. Carefully follow the list of safety precautions below.
   - All non-flammable materials must be approved by your teacher.
   - During and after heating, handle the apparatus with care.
   - Candle flame soot is hard to wash off clothing. Wear a lab coat and wash your hands immediately with soap and hot water if you get soot on them.
   - Have water or a fire extinguisher nearby.
2. You may use any or all of the following materials.
   - thermometer
   - birthday candle
   - 100 mL room-temperature water
   - non-flammable containers, fasteners, reflectors, and insulation
   - matches
3. Brainstorm ideas about how to build the most efficient heater. Think about:
   - energy transfer by convection, conduction, and radiation.
   - prevention of heat loss to the surroundings
   - specific heat capacity (you will need to make sure that the heater itself does not absorb too much energy)
   - possible materials to use (remember that paints, plastics, glues, and tape are flammable, so they do not meet the design criteria)
4. Choose the most practical ideas and write a design proposal that includes:
   - a list of materials
   - a labelled sketch of your device
   - a task list and a time line to show how each group member will contribute
5. Assemble the materials and build your device. You may test and modify it but the candle can be burned for only 3 min during a test. Keep a written record of any design changes you make.
6. For the demonstration, be ready to give a brief explanation of the design features of your device. Then, show how it works!

Report Out

1. Perform a demonstration to the class or present a report that describes your device and your data and results.
2. What was the highest water temperature that you obtained?
3. What was the temperature increase that you achieved during the three-minute burn?

Building Codes and Insulation

Contractors, architects, and builders have to understand heat transfer and insulation. All buildings, residential and commercial, need many different types of insulation to keep the heat inside in the winter and to keep the heat outside in the summer.

Background

Governments make regulations about the amount and type of insulation that buildings must have. The codes are different in different climates. Some types of materials, such as asbestos, were used in the past but have been found to be toxic. They are no longer permitted.

Asbestos insulation can be a hazard for people living or working in a building where it is present. It should be identified and removed.

When is spray foam the appropriate type of insulation to be used?

When must insulation be applied to the outside of a building?

Are all inside walls insulated?

Find Out More

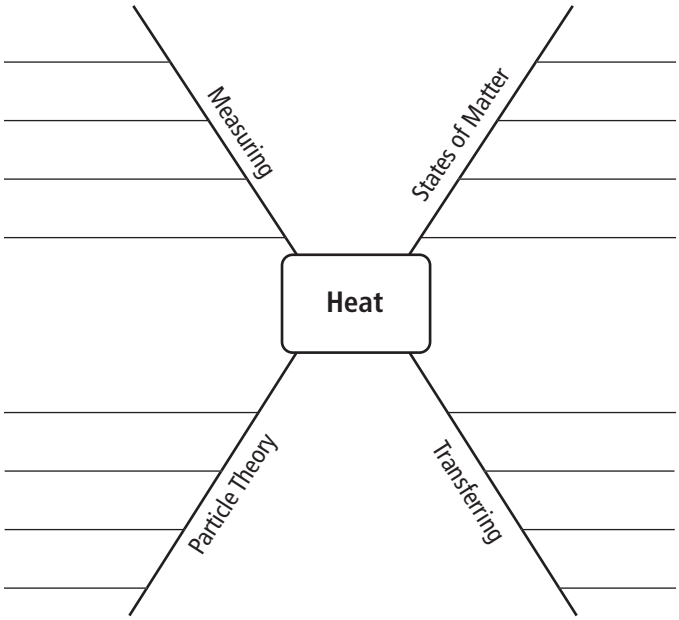
What does the homeowner need to know about insulation? Whose responsibility is it to ensure that the correct amount and type of insulation is used? What types of insulation are appropriate for walls, attics, crawl spaces, pipes, metal buildings, ceilings, and other places? Use the Internet, encyclopedias, books, or interview contractors to learn more about insulation and the codes. Record and organize your findings.

Report Out

1. Prepare a pamphlet to present the information you have learned about insulation and building codes. Include information about R-values and types of insulation and about who is responsible for following building codes.
2. Prepare a poster and an oral presentation to present with the pamphlet about your findings. Include the items that are listed in the first suggestion.

Visualizing Key Ideas

1. Copy the spider map on the right into your notebook. Do not look at your textbook. Beside each topic, fill in as many words as you can that are related to that topic. When you have completed the map, go back through this unit and look for other words you could include. Add these words to the map using a different colour pen.



Using Key Terms

2. Decide whether each of the following statements is true or false. If it is false, rewrite it to make it true.
   (a) The Celsius scale is defined to make absolute zero equal to 0°C.
   (b) Comfortable room temperature is 37°C.
   (c) Zero degrees on the Fahrenheit scale is the freezing point of water.
   (d) The boiling point of water is 212°F.
   (e) Condensation is the reverse process to sublimation.
   (f) Thermal contraction occurs when the temperature of an object increases.
   (g) Matter is anything that has mass and takes up space.
   (h) Wind is a form of conduction.
   (i) Liquids are incompressible at a constant temperature.
   (j) The specific heat capacity of a substance tells you how much heat is required to melt 1.00 g of a substance from its solid state to its liquid state.

Checking Concepts

4

3. Which of the following temperatures would you *not* expect to find on a recipe for cooking or baking food in a normal oven?
   (a) 160°C
   (b) 200°C
   (c) 240°C
   (d) 450°C
4. State a reasonable temperature for each of the following.
   (a) summer day in Bonavista
   (b) a person with a severe infection
   (c) comfortable room temperature
   (d) body temperature of a bird

5. How is a thermoscope different from a thermometer?
6. If the temperature of a substance is 273.15 K, what is the temperature on the Celsius scale?
7. What does it mean to calibrate a thermometer?
8. Describe how a bimetallic strip responds to a change in temperature. State one common use for a bimetallic strip.

5

9. What two factors determine the kinetic energy of an object?
10. If the temperature of an object increases, what can you say about the kinetic energy of the particles that make up the object?
11. Compare the shapes of solids, liquids, and gases.
12. How does the particle theory of matter explain the differences between solids and liquids?
13. Use the particle theory to explain why gases expand when they are heated.
14. The amount of thermal expansion of solids is very small. Explain why it is still very important for design engineers to know the exact amount that a solid might expand.
15. Why can pure water *not* be used in a car radiator in the winter?
16. Sublimation is the change from what state of matter to what other state?
17. What does the particle theory tell you about the forces between the particles of a substance that has very high melting and boiling points?

6

18. How does the particle theory explain conduction of heat?
19. Explain why gases and liquids rise when they are heated.
20. Why can convection *not* occur in solids?
21. What carries energy through empty space?
22. What happens to the particles in an object when it absorbs radiant energy?
23. State two applications in which you would want to use a material that is a good heat conductor.
24. What are two important features of radiators that are used in hot-water heating systems in homes?
25. Why does a vacuum make a good insulator?
26. Heat and temperature of an object are both related to the kinetic energy of the particles in a substance. How are the two quantities different relative to the kinetic energy of the particles?
27. State two reasons why the temperature of the ground increases much more than the temperature of water when they absorb the same amount of radiant energy from the Sun.

Understanding Key Ideas

28. Many household appliances, such as irons, are heated electrically. They usually contain a thermostat that switches electric power on and off to keep the appliance at a constant temperature. Think of at least three examples of other appliances that might use thermostats to switch electric power on and off.
29. With a group, create a short skit to show the behaviour of particles of matter in each of the following situations.
    (a) low temperature
    (b) warming up
    (c) high temperature

30. Imagine that you can see the moving particles in a drop of liquid on your skin. Describe:
(a) the speed of the particles that are able to escape from the surface of the drop
(b) the speed of the particles that are left behind in the drop
(c) the temperature change of the drop as particles continue to escape
(d) the change of state that is occurring

31. Carbon dioxide gas sublimes at –78.5°C.
(a) If you cool carbon dioxide below –78.5°C, in what state will it be?
(b) Could you produce liquid carbon dioxide by warming the solid?

32. Explain why hot water can float on top of cold water.

Thinking Critically

33. One of the characteristics of a liquid is that it takes the shape of the container. However, the illustration below shows sand, a solid, taking the shape of its container.
(a) Does this mean that sand is a liquid?
(b) Explain why or why not in terms of the particle theory of matter.

34. Choose the most appropriate temperature-measuring instrument to use in each situation below. In each case, explain your choice.
(a) controlling an electric frying pan
(b) making long-term temperature records at a weather station
(c) detecting small forest fires before they spread
(d) monitoring temperatures inside a furnace
(e) checking trains for overheating wheel bearings as they pass by a station
(f) studying temperature changes inside a building over a 24 h period

35. The photograph shown here was taken in the summer. Describe how the position of the transmission lines would change as the temperature dropped in winter. Why would it be a bad idea to stretch the transmission lines more tightly when they were hung between the towers in the summer to save on the amount of line that would be needed?

36. Aerosol spray cans often have a warning on their label to avoid heating them. Explain what would happen if an aerosol can was heated.

37. On a very cold day, a car enters a carwash. As soon as the hot water strikes the windshield, it cracks. Based on what you know about the effect of temperature on solids, explain this event.

38. Reinforced concrete is concrete that has had metal bars added to increase its

strength. Without the steel, concrete can tend to be brittle and crack. Engineers are careful to use steel when reinforcing concrete because it has almost the same rate of thermal expansion as concrete.

(a) Why is it so important that the concrete and steel have similar expansion rates?

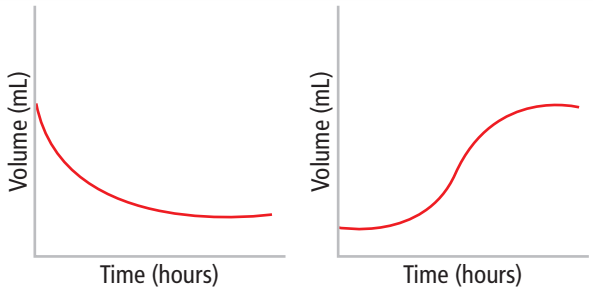
(b) What would happen if metal bars with a different thermal expansion rate were used to reinforce concrete?

Developing Skills

39. The two graphs below show the volume of a liquid in a laboratory thermometer during a temperature measurement.

(a) Which graph shows what happens when the thermometer is placed in water in a pot on the stove and the burner is turned on?

(b) Which graph shows what happens when the thermometer is placed in a jug of water that was just placed in a refrigerator?



Graph A **Graph B**

40. Copy the following graph. Add the labels listed below to your graph. Explain the meaning of the graph and the labels.

(a) boiling point

(b) melting point

(c) solid

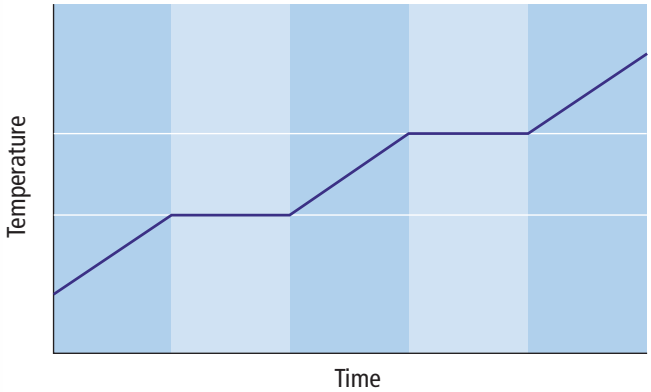
(d) liquid

(e) gas

(f) melting

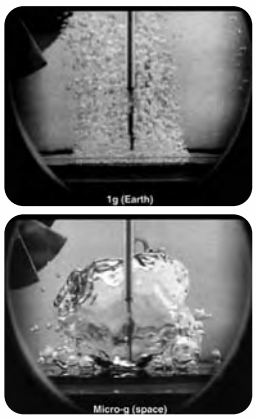
(g) evaporating

Heating Curve



Pause and Reflect

Astronauts in the Space Shuttle and the International Space Station do experiments and make observations in the weightlessness, or microgravity, of the orbiting spacecraft. They have made observations while heating water with an electrical probe that is inserted into water. When the water near the hot probe becomes warmer, it does not make convection currents. The hot water just stays beside the probe. When it begins to boil, a bubble of water vapour just stays in contact with the hot probe and grows larger. Provide an explanation for these observations made under conditions of weightlessness.



UNIT

3 Mixtures and Solutions

A mixture of rocks on the beach at Green Point in Gros Morne National Park

Key Ideas

7 **Matter can be classified as mixtures or pure substances.**

7.1 How Mixtures Are Different from Pure Substances
7.2 Classifying Mixtures

8 **Some substances dissolve to form solutions faster and more easily than others.**

8.1 Solutes, Solvents, and Solubility
8.2 Solubility and Concentration

9 **Many useful products depend on technology for separating mixtures and solutions.**

9.1 Processing Solutions and Other Mixtures
9.2 Separating Earth's Mixtures

Getting Started

Gold has been prized for thousands of years by people in nearly every culture.

According to history, King Hiero II was the ruler of Syracuse on the island of Sicily about 2300 years ago. According to legend, one day Hiero had the royal goldsmith make a new crown of gold. Hiero provided pure gold for the task. When the crown was presented to him, however, Hiero became suspicious. The crown looked like gold. It felt like gold to the touch, and it seemed to have the mass of pure gold. Despite these appearances, Hiero believed that the goldsmith had cheated him by mixing silver in with the gold. But how could the deception be found without damaging the crown?

One of the great problem solvers of the time was a distant relative of Hiero named Archimedes. The king asked him to find out if the crown was made of pure gold. Legend has it that Archimedes solved the problem while taking a bath. As he settled into the tub, water spilled out over its sides. Archimedes realized that the volume of water that spilled out was equal to the volume of his body that was under the water. He reasoned that he could find the volume of the crown by measuring the volume of water that the crown displaced. Then, all he had to do was find the mass of the crown and calculate its density. (Density, you may recall, is the amount of mass in a given volume. It is

calculated by dividing mass by volume: $D = m/v$.) So thrilled was Archimedes by his discovery that he leaped from the tub and ran through the streets of Syracuse yelling, "Eureka!"

What had he found? Density is a property of matter. Archimedes knew that he could find out if the density of the crown matched the density of pure gold. If it did, the crown was pure gold. If it did not, the king had been cheated. Archimedes found that the crown had a density that was less than that of pure gold. The crown was, in fact, a mixture of gold and silver.

Your study of mixtures in this unit may not be as dramatic as the story of Hiero's crown. However, like Archimedes, you will discover how attention to the properties of matter can help you make, identify, and separate mixtures.

Word Connect

Sometimes people use the word *eureka* when they are excited about something. It comes from a Greek word that means, "I have found it!"

internet connect

Archimedes had much to say "eureka" about in his lifetime. Find out about his inventions and accomplishments. Start your search at **www.discoveringscience.ca.**

Mixed or Pure?

Find Out ACTIVITY

Suppose that you pick up a rock on the beach, in a garden, or on a lawn. You see that some parts of it are grey, some parts are white, and some parts are blue. You conclude that the different-coloured parts of the rock must be different types of matter. Is this a reasonable conclusion?

There are many properties that can help us tell one type of matter from another. In this activity, you will compare the properties of pairs of items.

What to Do

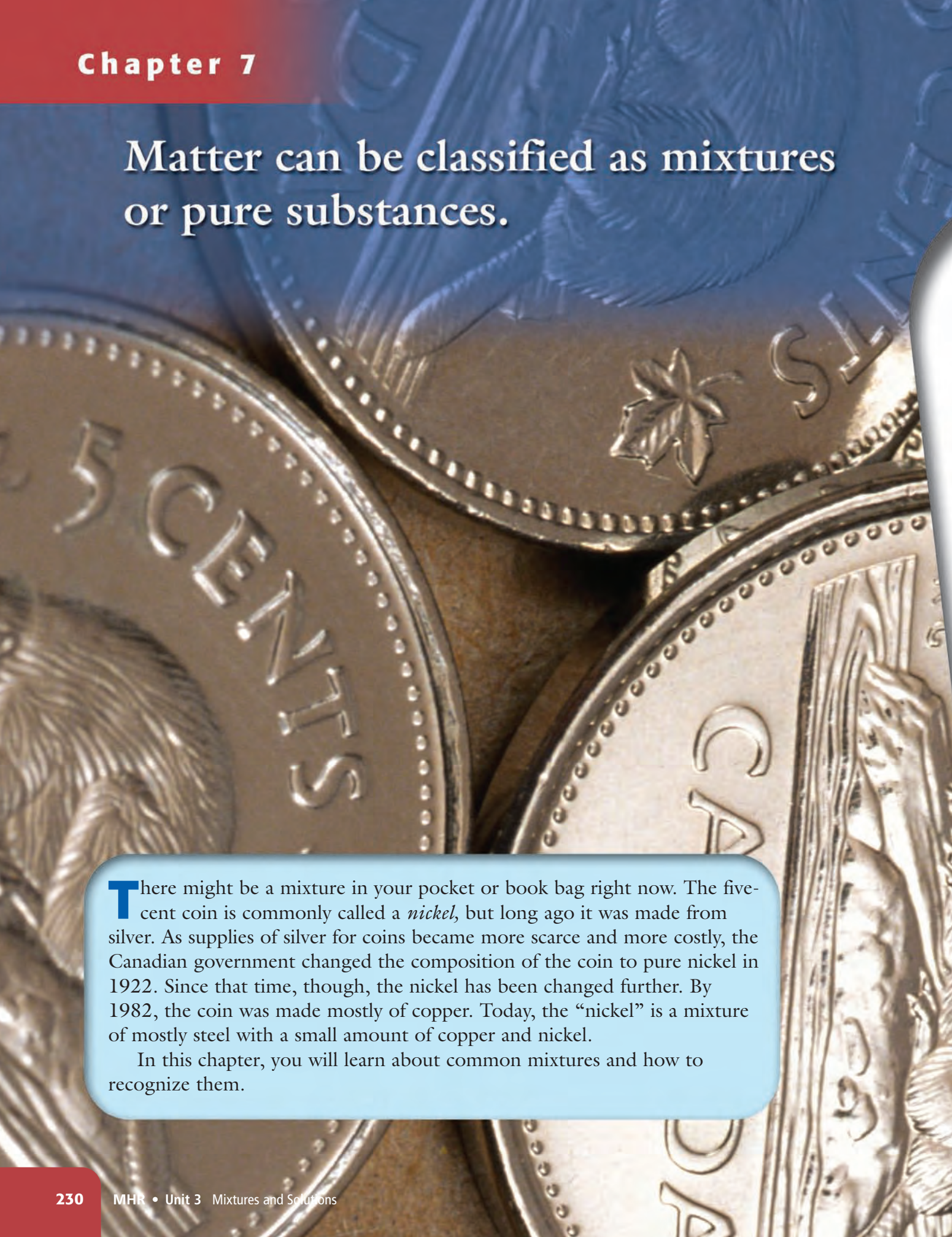
1. With a partner, select one of these pairs of items:
   vinegar and water
   aluminium foil and plastic wrap
   stainless steel and glass
   molasses and cooking oil
   metal paper clips and sawdust
   Make a list with as many differences as you can. **Hint:** Some properties that you could include are colour, transparency, hardness, strength, and mass.
2. Repeat step 1 for the other pairs of items.

What Did You Find Out?

1. Compare your list of differences with the rest of the class. How many differences between each item did your class discover?
2. Suppose that you have a bowl filled with a mixture of the paper clips, bits of aluminium foil, and water.
   (a) Describe one way that you could separate the items from each other.
   (b) Describe how your separation technique would change if you added water to the original mixture.

Chapter 7

Matter can be classified as mixtures or pure substances.



There might be a mixture in your pocket or book bag right now. The five-cent coin is commonly called a *nickel*, but long ago it was made from silver. As supplies of silver for coins became more scarce and more costly, the Canadian government changed the composition of the coin to pure nickel in 1922. Since that time, though, the nickel has been changed further. By 1982, the coin was made mostly of copper. Today, the "nickel" is a mixture of mostly steel with a small amount of copper and nickel.

In this chapter, you will learn about common mixtures and how to recognize them.

What You Will Learn

In this chapter, you will

- **identify** different mixtures in your home and in the world around you
- **distinguish** between heterogeneous and homogeneous mixtures
- **distinguish** between mixtures and pure substances
- **distinguish** between mixtures and pure substances using the particle theory of matter

Why It Is Important

You eat, drink, breathe, wear, and use mixtures each day. So knowing about mixtures can help you appreciate and understand more about the world around you.

Skills You Will Use

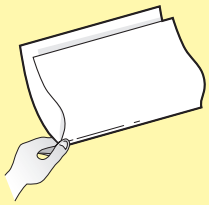
In this chapter, you will

- **observe** properties of mixtures
- **classify** mixtures
- **model** the particles in mixtures
- **communicate** your observations and your understanding of mixtures

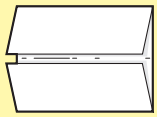
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 7.

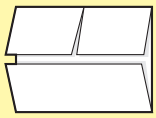
STEP 1 **Using** an 11″ × 17″ sheet of paper with the short side along the top, begin as if you were going to fold the paper in half along the long axis, but instead of creasing the paper, **pinch** it in to show the midpoint.



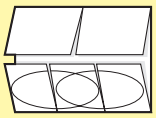
STEP 2 **Fold** the outer edges of the paper in to meet at the midpoint, forming a shutter fold.



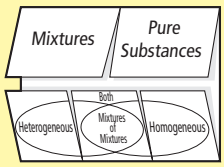
STEP 3 **Cut** the top tab in half to form two equal tabs.



STEP 4 **Draw** two overlapping ovals on the bottom tab and cut the tab into thirds, forming a Venn diagram with three tabs.



STEP 5 **Label** the Foldable as shown.



Organize As you read the chapter, record notes, observations, definitions, and examples of mixtures and pure substances. Distinguish between heterogeneous and homogeneous mixtures.

7.1 How Mixtures Are Different from Pure Substances

Matter can be either mixtures or pure substances. Mixtures may be either homogeneous or heterogeneous. Homogeneous mixtures have the same properties throughout. Heterogeneous mixtures have different visible parts with different properties. All matter is made up of particles. We can classify something as a mixture or as a pure substance based on the types of particles that it is made of.

Key Terms

heterogeneous mixture
homogeneous mixture
mixture
pure substance

Many of the objects that you have at home come with labels that tell you what they contain. You can see these labels on foods, clothes, and cleaning products. Figure 7.1 shows some examples you may have seen.

The labels list all the ingredients in these products. If the label shows more than one ingredient, the product is a mixture. Most of the types of matter that you use each day are mixtures. A **mixture** contains two or more different types of matter.

Most objects that you see or use have an ingredient list. Is a beach a mixture? Is an ocean a mixture? What about air, or even a simple glass of water? How can you tell that something is a mixture if it does not have an ingredient list?

Figure 7.1 What evidence do you see that each of these products is a mixture?

7-1A Now You See It...

Find Out ACTIVITY

Is it possible to make a mixture in which you cannot detect the different parts? Use sugar and water to find out.

Safety

Do not taste, eat, or drink the sugar and water.

Materials

- beaker or plastic cup
- tap water
- white sugar
- measuring spoon
- magnifying lens

What to Do

1. Prepare a table of observations like the one below. Give your table a title.

Observable Properties	Sugar	Water	Sugar-Water Mixture (Initial Appearance)	Sugar-Water Mixture (After 24 h)
Colour				
State (solid, liquid, or gas)				
Transparency (clear, cloudy, or opaque)				

2. Observe the three properties of sugar and water that are listed in the table. Record your observations.
3. Add water to the cup until it is about three-quarters full. Let it sit for a few seconds until the water is still.
4. Gently pour 5 mL (one teaspoon) of sugar into the water. Observe the appearance of the water and the sugar. Record your observations in your table.
5. Place the cup where it can stay untouched for about 24 h.
6. Observe the contents of the cup after 24 h. Record your observations in your table.

What Did You Find Out?

1. The three statements below compare the properties of the sugar-and-water mixture with the properties of the sugar and the properties of the water. Choose the statement that you think is the most accurate. Record it, and give reasons for your choice.
   - The mixture has all the properties of water and only these properties of the water.
   - The mixture has all the properties of sugar and only these properties of the sugar.
   - The mixture has a some of the properties of sugar and some of the properties of water.
2. You know that the mixture you made has two parts: sugar and water. However, the mixture *looks* like it has only one part. Think about what you have learned about the particle model. (Review Section 5.1.) Make a sketch to show what you think the particles in the sugar-water mixture look like. Add labels and a caption to explain your sketch.

Heterogeneous and Homogeneous Mixtures

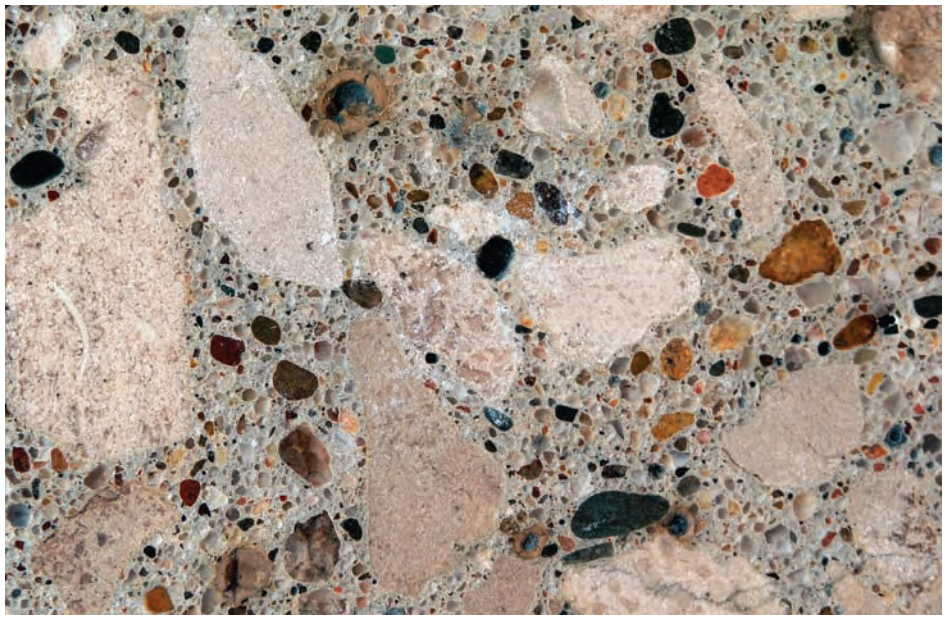


Figure 7.2 Concrete is an example of a heterogeneous mixture. You can easily see the different types of matter. Each type of matter in the mixture has its own distinct set of properties such as colour, size, and shape.

When you see a sample of matter that has more than one set of properties, you know for sure that it is a mixture. For instance, the concrete shown in Figure 7.2 is a mixture. You can see that it contains different types of rock with different shapes, sizes, and colours. If you have watched someone make concrete, you may know that it also contains sand, cement powder, and water.

Concrete is an example of a heterogeneous mixture. So is a beach, salad dressing, a computer, and smog-filled air. A **heterogeneous mixture** is a mixture that is made up of two or more parts. Usually, the parts are visible to the eye. Often, you can see the different parts just by looking at the mixture. Sometimes you need a microscope to see them. (You will see an example of a mixture with microscopic parts on page 245.) In a heterogeneous mixture, the different parts of the mixture are combined in a way that each part keeps its own properties.

When you mix sugar with water, the solid grains of sugar seem to disappear. You cannot see them with a hand lens or even with a microscope. A sugar-water mixture is an example of a homogeneous mixture. A **homogeneous mixture** is a mixture in which the parts appear to be the same throughout. The stainless steel frying pan shown in Figure 7.3 is a homogeneous mixture. Other examples include salt water, vegetable oil, and clean air. In a homogeneous mixture, the different parts are combined in a way that their properties are the same throughout the mixture.

Word Connect

Heterogeneous comes from two Greek words that mean "different" (*heteros*) and "kind" (*genos*). So, heterogeneous means "different kind." Homogeneous comes from two Greek words that mean "same" (*homos*) and "kind" (*genos*). So, homogeneous means "same kind."

Figure 7.3 Stainless steel is a homogeneous mixture. Metals such as iron and chromium are used to make this mixture. Non-metals such as carbon and silicon may be added as well.

Reading Check

1. What is a mixture?
2. Write a definition for the term *heterogeneous mixture*. Include two examples in your definition.
3. Write a definition for the term *homogeneous mixture*. Include two examples in your definition.

Suggested Activity

Conduct an Investigation 7-1C on page 238.

7-1B Mixture Match-Up

Find Out ACTIVITY

Your task is to examine five items from a kitchen and five items from a bathroom or laundry room. From the kitchen, you could select ketchup, prepared mustard, spices, soft drinks, dishwashing liquid, cereal, jam, molasses, or bread. From the bathroom or laundry room, you could select shampoo, conditioner, soap, toothpaste, shaving cream, a pumice stone, an emery board, hand lotion, hair gel, or detergent.

Safety

- In this activity, you will be choosing a variety of household products to examine. The suggested products have been chosen as safe for you to examine. Do not use any products other than those listed here. Wash your hands after handling each product.

What to Do

1. Prepare a table of observations like the one below. Give your table a title.

Product	Classification (Heterogeneous, Homogeneous, or Other)	Reasons

2. In the first column, list each product you examine. In the second column, say whether the product is a heterogeneous mixture or a homogeneous mixture. If you can't decide, or if you think the product is some other kind of mixture, record your choice as "Other." In the third column, give reasons for your choice.

What Did You Find Out?

1. What properties did you think were most useful for helping you decide what type of mixture each product is?
2. Compare your choices with choices made by your classmates.
   (a) Which products did the class agree about?
   (b) Which products did the class disagree about?
   (c) Explain why the class disagreed.

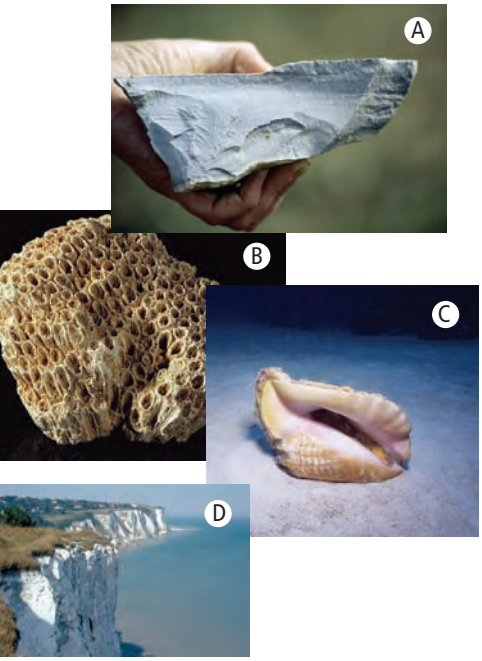


Figure 7.4 Limestone is a common name for a chemical called calcium carbonate. In nature, calcium carbonate (A) is found in many forms. For example, you may find it as coral (B), seashells (C), and the chalky white cliffs of Dover in England (D).

Pure Substances

Is there any kind of matter that is *not* a mixture? Figure 7.4 shows one example: calcium carbonate (limestone). Pure calcium carbonate contains only calcium carbonate. Every sample of calcium carbonate has the same properties as every other sample of calcium carbonate. So, a piece of calcium carbonate from the Northern Peninsula of the island of Newfoundland has the same properties as a piece of calcium carbonate from the Bruce Peninsula in Ontario or the Burren in County Clare, Ireland.

Calcium carbonate is a pure substance. A **pure substance** is matter that is the same throughout. Sucrose (white sugar) is another pure substance. So are copper, pure water, iron, carbon dioxide, and table salt. In a pure substance, each part of the substance has the same properties. So, for instance, the outside of a piece of calcium carbonate has the same colour and other properties as the inside.

Every sample of a pure substance always has the same properties. Why is this the case? In Chapter 5, you learned about the particle theory of matter. One part of the theory explains what pure substances are: *Each pure substance has its own kind of particle. This kind of particle is different from the kinds of particles that make up all other pure substances.* Use Figure 7.5 to help you understand this idea. A pure substance always has the same properties, because it is made up of exactly the same kind of particles.

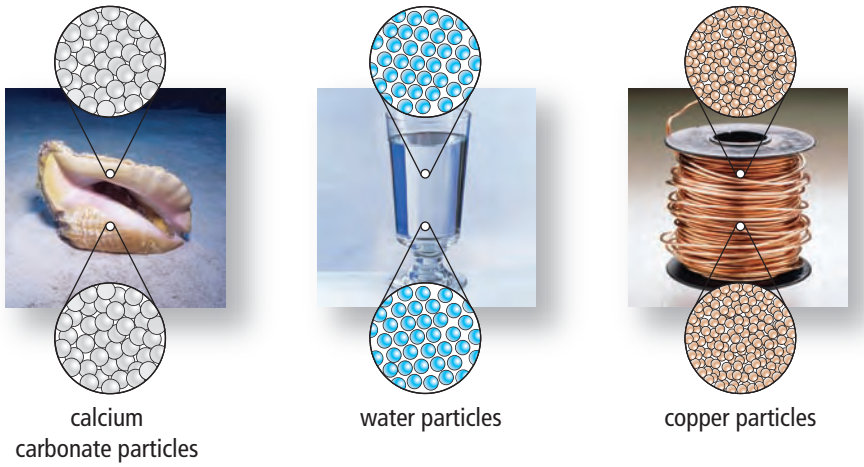


Figure 7.5 Calcium carbonate, pure (distilled) water, and copper are pure substances. See how any part of pure calcium carbonate is made up of only calcium carbonate particles. Any part of pure water is made up of only water particles. Any part of pure copper is made up of only copper particles.

How Pure Substances Are Different from Mixtures

Figure 7.6 shows two clear, colourless, and odourless liquids. Suppose that someone told you that one of the liquids is a salt-water mixture and the other is the pure substance, water. Could you tell which is which just by looking at them? It is very unlikely that you can. To tell the two liquids apart, you would

have to observe more of their properties. For example, you could measure their boiling points—the temperature at which each liquid changes state from a liquid to a gas. Pure water has a boiling point of 100°C. If you knew that either one of the liquids in Figure 7.6 boils at this temperature, you could be fairly sure that it is water.

Figure 7.6 Which pure substances and mixtures could these two liquids be? How could you tell whether one, both, or neither is a pure substance or a mixture?

Pure substances are different from mixtures, because their compositions are different. As you know, a pure substance is composed of only one type of particle. A mixture, on the other hand, is composed of two or more types of particles. Figure 7.7 models how the particles in a pure substance are different from the particles in a mixture.

The different particles in a mixture keep their own properties. So, for example, a mixture of salt and water may have a boiling point of 103°C. The mixture has a different boiling point from pure water because salt has a very high boiling point: 1465°C. When salt is mixed with water, the properties of the salt affect the temperature at which the mixture can boil.

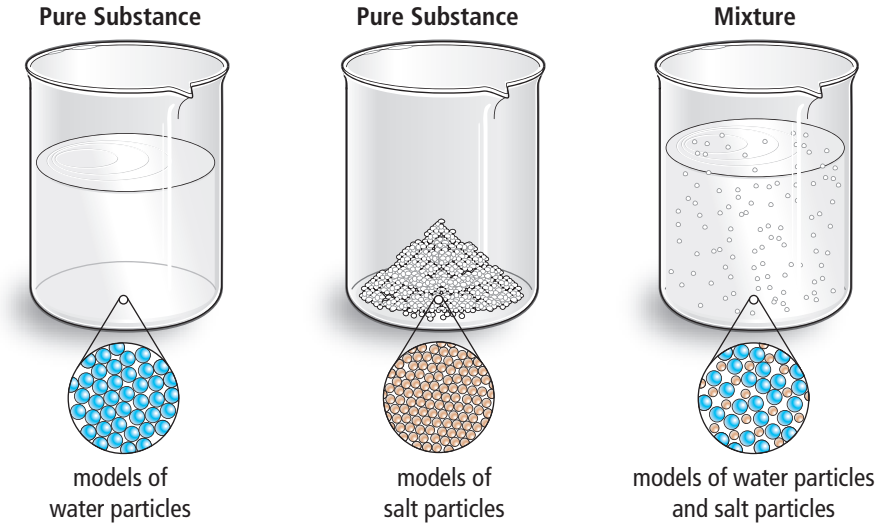


Figure 7.7 Pure substances have only one type of particle, while mixtures have two or more types of particles.

Explore More

Use sketches, drawing software, or solid objects such as marbles or bolts to model the particles that make up two mixtures and two pure substances of your choice. Add labels to explain your models.

Reading Check

1. What are two examples of pure substances?
2. Use the particle theory of matter to explain what a pure substance is.
3. Use the particle theory of matter to explain how a pure substance is different from a mixture.

Connection

You can review the particle theory of matter in Section 5.1.

7-1C Examining Three Common Beverages

Skill Check

- Observing
- Measuring
- Classifying
- Evaluating information

Is your favourite beverage heterogeneous or homogeneous? In this investigation, you will inspect three common beverages—milk, orange juice, and soda water—and classify them based on your observations.

Question

On what basis can you classify milk, orange juice, and soda water?

Safety

- It is not safe to taste these common beverages in the science classroom. Laboratory containers that look clean may still contain invisible traces of harmful chemicals left over from a previous activity.

Materials

- 3 clean test tubes
- marking pen and masking tape (for labels)
- test tube rack
- magnifying glass
- eye dropper
- watch glass or Petri dish
- homogenized milk
- orange juice (fresh or from concentrate)
- soda water

Science Skills

Go to Science Skill 8 for information about how to use a microscope.

Procedure

Beverage	Method of Observation	Observations	Inference	Reasons
Milk	Unaided eye			
	Hand lens			
	Microscope			
Orange Juice	Unaided eye			
	Hand lens			
	Microscope			
Soda Water	Unaided eye			
	Hand lens			
	Microscope			

1. Your teacher will give you a copy of the table of observations. Give your table a title.
2. Label the three test tubes M (for milk), O (for orange juice), and S (for soda water). Fill half of each test tube with the correct beverage, and place it in the test tube rack.
3. Using only your unaided eye, examine the beverage in each test tube. Can you see any bits that are different from the rest of the beverage? Record your observations for each beverage in your table.
4. Based only on what you see for yourself, infer whether each beverage is heterogeneous or homogeneous. Record your inference in the correct row of your table. Include the reasons for your inference in the last column.
5. Place a small amount of one of the beverages on a watch glass or Petri dish. Using the magnifying glass, examine the beverage again. Record your observations in your table. Repeat for the other two beverages.
6. Infer whether each beverage is heterogeneous or homogeneous. Remember to include your reasons.

7. Your teacher will set up three compound light microscopes for inspecting each of the beverages. Observe the beverages using the low power objective lens of the microscope.
8. What new observations might lead you to reconsider some of your previous inferences? Record your new observations in your table.
9. Next, observe what each beverage looks like under the microscope at high power. Note the sizes and shapes of any different materials that you see. Also note whether or not they are evenly spaced throughout the liquid.
10. Make your final inferences, based on the microscopic evidence. Record them in your table.
11. Clean up and put away the equipment you have used.

Analyze

1. When you examined the beverages with your unaided eye, you looked for different types of matter with different properties within each liquid.
   (a) Which types of matter were big, small, or microscopic?
   (b) Were the types of matter all the same shape?
   (c) Explain which types of matter were solids, liquids, or gases.
2. Describe what, if anything, you were able to see with the magnifying glass that you could not see with your unaided eye:
   (a) in the milk
   (b) in the orange juice
   (c) in the soda water
3. **(a)** Which beverage appeared to be homogeneous until you saw what it looked like under the microscope?
   (b) Describe the new evidence that you observed.
   (c) Under high power, you could see bits of different matter with different properties, but the bits were not all exactly the same size and shape. What reasons can you give to explain the differences?
4. Summarize your findings. Write one or two sentences about each beverage. Be sure to state whether it is heterogeneous or homogeneous. Give reasons for your answers.

Conclude and Apply

1. What would you have to observe before you would be willing to identify a mixture as homogeneous? Explain your answer.

Wild, Weird, Wonderful

www Science

What's the Metal in the Ice Man's Axe?

In September 1991, hikers in the Alps, near the border between Austria and Italy, discovered the body of a man. But this was no ordinary discovery. The man had been trapped in a glacier for thousands of years. He was almost perfectly preserved. With him was an assortment of tools, including an axe with a metal blade.

Scientists were especially interested in the axe. At first, they thought that the metal axe blade was bronze, which is a mixture of copper and tin. This was not possible, though. The Iceman and his clothing had been dated to be about 5200 years old. Scientists believe that bronze was invented only about 4000 years ago. So, the axe blade could not be bronze.

Scientists then hypothesized that the blade could be copper. People have been using copper for at least the past 6000 years. To test their hypothesis, scientists exposed the axe blade to X-ray radiation. When metals are exposed to high-energy radiation, their particles vibrate very energetically. As the vibration of the particles slows down, the particles give off energy that can be examined with specialized equipment. Scientists use this "energy signature" to identify the type of particle that is giving off the energy.

Analysis using this technique confirmed the scientists' hypothesis. The metal of the axe blade was almost pure copper.

Check Your Understanding

Checking Concepts

1. Identify each of the following as a mixture or a pure substance, and give a reason to explain your choice. If you are not sure, write "unsure," and give a reason to explain why.
   (a) oxygen gas
   (b) air
   (c) whipped cream
   (d) slush
   (e) garden soil
   (f) iron
   (g) sandwich
   (h) chocolate chip cookie
   (i) pencil
   (j) freshly squeezed orange juice
2. Classify each of the mixtures you identified in question 1 as homogeneous or heterogeneous. Explain your decisions.
3. Make a sketch to show the particles that make up a pure substance. Add any labels that you think are needed to make your ideas clear.
4. Make a sketch to show the particles that make up a mixture. Add any labels that you think are needed to make your ideas clear.

Understanding Key Ideas

5. When you first open a bottle of pop, the liquid is filled with tiny bubbles.
   (a) Is the pop homogeneous or heterogeneous? Explain your answer.
   (b) If you let the pop sit for a day, what happens? Is the liquid homogeneous or heterogeneous now? Explain your reasoning.
6. The photo below shows polluted air—smog. Smog is air that contains solid and gaseous pollutants. Is smog a heterogeneous or homogeneous mixture? Explain your answer.

Pause and Reflect

Think about your experiences so far in this chapter. At this time, do you think that most materials on Earth are homogeneous or heterogeneous? Explain why you think so.

7.2 Classifying Mixtures

Mixtures may be classified as heterogeneous and homogeneous. The different types of matter in a heterogeneous mixture usually are easy to see. Solutions are homogeneous mixtures in which two or more substances combine to form a mixture that looks the same throughout. Some mixtures are neither clearly heterogeneous nor clearly homogeneous. They are, instead, mixtures of mixtures.

Key Terms

alloy
solution

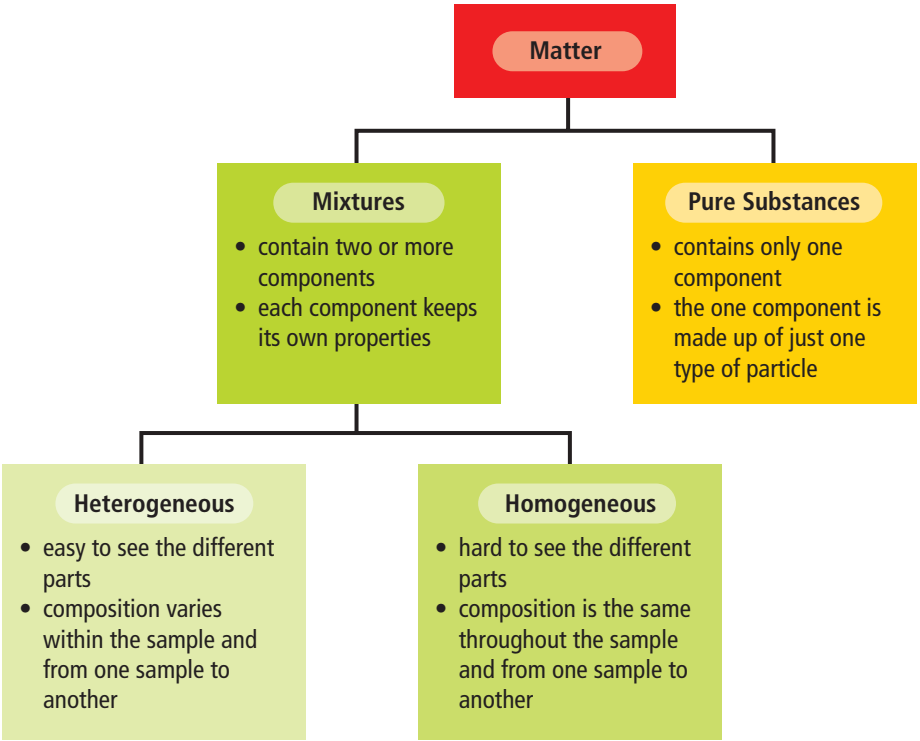


Figure 7.8 A classification of matter

In the previous section, you classified matter as either a mixture or a pure substance. The flowchart in Figure 7.8 summarizes this sorting of matter into two broad categories. You also learned that mixtures may be heterogeneous or homogeneous. The flowchart includes this information, too.

Mechanical Mixtures

Mixtures that are obviously heterogeneous (you can easily see the different types of matter) are sometimes called mechanical mixtures. These mixtures are easy to separate by hand or by mechanical means such as filtering. Many foods are mechanical mixtures. Think of sandwiches, salads, salsa, and stir-fried vegetables, for instance. Figure 7.9 shows another great example: pizza.

Figure 7.9 A pizza is a mechanical mixture because you can easily see the different parts: the crust, sauce, cheese, and toppings.

Figure 7.10 Window cleaners are solutions of ammonia (or vinegar, in some cases) and other substances in water.

Solutions

If a mixture is homogeneous, it is a **solution.** Household vinegar, tap water, and household hydrogen peroxide (for disinfecting cuts) are all solutions. So is the window cleaner shown in Figure 7.10. A solution is made when two or more substances combine to form a mixture that looks the same throughout, even under a microscope.

You encounter solutions everywhere. Seawater is a solution of salts and water. Clean air is a solution of nitrogen gas, oxygen gas, and tiny amounts of other gases, including carbon dioxide and water vapour. There are even solutions of solids, such as the objects shown in Figure 7.11. Solutions that are made from two or more metals are called **alloys.** You will learn more about solutions in Chapter 8.

Figure 7.11 The pie graphs show the percentages of gold and other metals in different "gold" objects. Which of the objects shown here are pure substances? Which are homogeneous mixtures (solutions)?

Solution or Heterogeneous Mixture?

How can you tell if a mixture is a solution or a heterogeneous mixture? Often you can tell just by looking. But what if you can't? There are a few techniques that can help you decide.

Figure 7.12 Which of the two mixtures in this photo is homogeneous? (Re-read the third bulleted point in the text area of the page for help if you are not sure.)

- Use a microscope. If the mixture is a solution, you will be able to see only one type of matter, even with a microscope.
- If the mixture is a liquid, pour it through a filter. If anything is caught in the filter, then the mixture is definitely heterogeneous (a mechanical mixture).
- Shine a light through the mixture. Figure 7.12 shows an example of this technique. Solutions do not scatter light. So you will not see a beam of light as it passes through a solution. A heterogeneous mixture such as muddy water or dusty air, however, *does* scatter light.

Figure 7.13 Many juices are solutions of concentrated juice, water, flavourings, and vitamins.

Suggested Activity

Conduct an Investigation 7-2A on page 246

Combinations of Mixtures

Some mixtures are clearly heterogeneous (mechanical mixtures). You can easily see the separate parts that make up a tossed salad, for instance. What about solutions? As you can see in Figure 7.13, you can use a food product label to help you tell that this juice is a solution.

Sometimes, though, you cannot tell whether something is homogeneous or heterogeneous just by looking at it. For example, is milk homogeneous or heterogeneous? Milk looks as if it is homogeneous. But under a microscope, you can see that milk contains "blobs." These "blobs" are globules of fat. Figure 7.14A shows a sample of milk under a microscope. One single drop of milk contains about 100 000 000 (one hundred million) fat globules. The globules are so tiny that milk seems to be homogeneous when you look at it with the unaided eye.

Does this mean that milk is really a heterogeneous mixture? No. There are other substances in milk, too. You can see this in Figure 7.14B. The Figure shows that some parts of milk are homogeneous (solutions). Other parts of milk are heterogeneous. So, milk is really a mixture of mixtures!

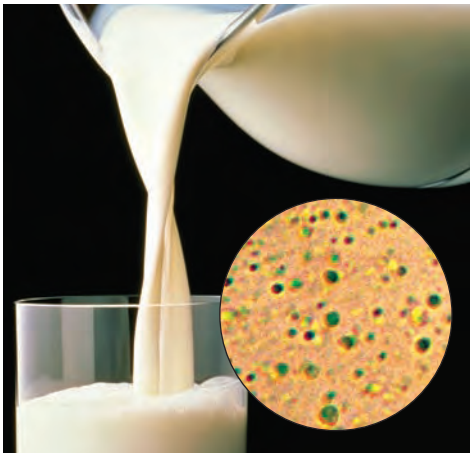


Figure 7.14A The round photograph shows how milk looks under a microscope. The milk is magnified about 400 times. How can you tell, from this image, that milk is not homogeneous?

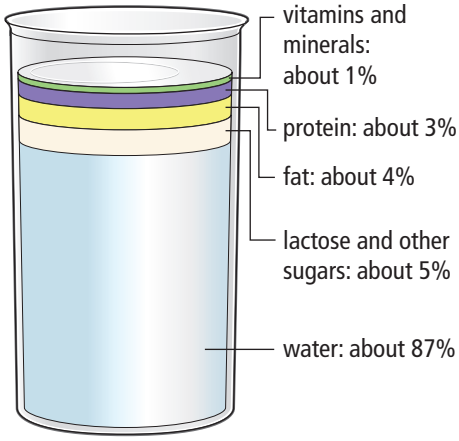


Figure 7.14B Milk is a mixture of different mixtures. The liquid part of milk is mostly water. The solid parts of milk are either dissolved in the liquid (homogeneous), or they are suspended in it (heterogeneous).

There are other mixtures that are hard to classify. For instance, is freshly squeezed orange juice heterogeneous or homogeneous? Orange juice tastes sweet, so you know there are sugars in it. You cannot see them, so you can infer that they are dissolved. This would lead you to say that freshly squeezed orange juice is a solution. But what about the pulp or other solid bits that might get into the juice? You can see them, so that would make the juice a heterogeneous mixture. Which type of mixture is it, then? Both. Freshly squeezed orange juice is a mixture of mixtures.

Explore More

There are other kinds of heterogeneous mixtures besides mechanical mixtures. Find out about these mixtures—called colloids and suspensions—by going to **www.discoveringscience.ca.**

internet connect

Many years ago, when you poured yourself a glass of milk, the fat globules floated to the top. There, they clumped together to form a layer of cream. Today, milk is homogenized. What does that mean? Is homogenized milk really homogeneous? Begin your research at **www.discoveringscience.ca.**

Reading Check

1. Give two examples of a solution.
2. A mechanical mixture is heterogeneous, while a solution is homogeneous. Explain why.
3. Describe what you will see if you shine a beam of light through a solution.
4. Give two examples of mixtures that are mixtures of mixtures.

Suggested Activity

Conduct an Investigation 7-2B on page 247

7-2A Shine On

Conduct an INVESTIGATION

Skill Check

- Observing
- Predicting
- Classifying
- Explaining systems

Safety

Materials

- 3 clean 250 mL beakers or jars
- 5 mL (one teaspoon) fine-grained starch
- 5 mL (one teaspoon) table salt
- water
- 2 stirring rods
- masking tape (for labels)
- marker
- flashlight
- additional mixtures for testing

In this activity, you will shine a light through a selection of mixtures to decide which ones are homogeneous and which ones are not. Mixtures that are heterogeneous will scatter the light as it passes through, so you will see a beam of light through the mixture. Mixtures that are homogeneous will not scatter the light, so no beam will be visible through the mixture.

What to Do

1. Prepare a table of observations like the one below. Give your table a title.

Beaker	Appearance After Stirring	Appearance With Beam of Light
1 (starch and water		
2 (salt and water)		
3 (water)		

2. Add the starch to one of the beakers. Add the salt to a second beaker.
3. Pour water into each beaker until it is about three-quarters full. Stir the mixtures well. Record their appearance in the second column of your table.
4. Use the masking tape and marker to label each beaker.
5. Fill a third beaker about three-quarters full of water, and label it. Stir the water. Record its appearance in your table.
6. The lights in the classroom will be turned out. Shine the flashlight through the beakers, one at a time. Observe the contents of each beaker. Record your observations.
7. Your teacher may supply you with additional mixtures to test. Predict which ones are heterogeneous and which ones are homogeneous. Then test your predictions. Make a table to record your predictions and observations of these mixtures.

What Did You Find Out?

1. Is the starch-water mixture homogeneous or heterogeneous? Give evidence to support your answer.
2. Is the salt-water mixture homogeneous or heterogeneous? Give evidence to support your answer.
3. For any additional mixtures your teacher gave you, how did your predictions compare with your observations?

7-2B What Kind of Mixture?

Conduct an INVESTIGATION

Inquiry Focus

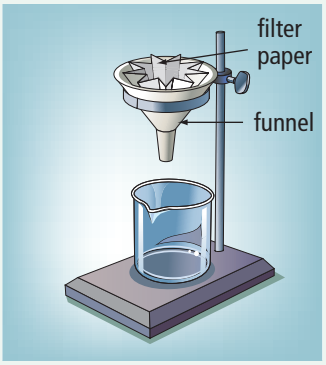
SkillCheck

- Observing
- Predicting
- Communicating
- Explaining systems

Safety

Materials

- 4 mixtures
- 4 beakers or jars
- 4 pieces of filter paper
- ring stand and ring clamp
- funnel



One way to tell whether a mixture is a solution or a heterogeneous mixture is to pour it through a filter. In this investigation, you will practise using a filter.

Question

How can you tell if a mixture is a solution or a heterogeneous mixture?

Procedure

1. Prepare a table of observations like the one below.

Mixture	Prediction: Heterogeneous Mixture or Solution	Observations Before Filtering	Observations After Filtering	
			On Filter Paper	In Beaker
1				
2				
3				
4				

2. Your teacher will give you four mixtures of common substances.
3. Observe each mixture. Predict whether it is heterogeneous or a solution. Write your prediction in your table. If you cannot decide, record your prediction as "unsure."
4. Set up the materials as shown in the diagram.
5. Pour each mixture through a clean filter.
6. For each mixture, observe the substance that went through the filter. Was anything left on the filter? Record your observations in your table.
7. Wipe up any spills. Clean up and put away the equipment you have used. Wash your hands thoroughly.

Analyze

1. Which of your observations matched your predictions? Did any observations surprise you? Explain why or why not.

Conclude and Apply

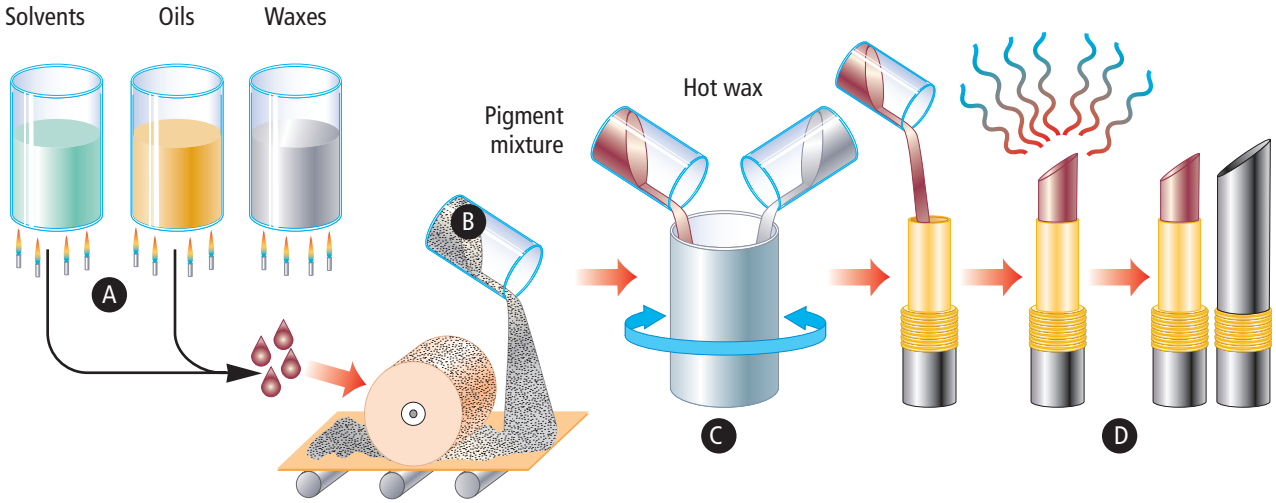
1. If you observe matter on the filter, can you state that the mixture is definitely heterogeneous? Explain your answer.
2. If you do not observe any matter on the filter, can you state that the mixture is definitely a solution? Explain your answer.

Science Watch

A Mix for Lips

Lipstick is a mixture of heterogeneous and homogeneous mixtures. Unlike nail polish and mascara, which are sold in liquid form, lipstick is solid when it is sold. Therefore, it is necessary to modify the ingredients during the manufacturing process so that they can be combined. Then, the final mixture can be poured into a mould to get a distinctive shape.

Lipstick is an elaborate mixture of ingredients, including a wide range of pigments (colouring agents).



The manufacture of lipstick involves heating, dissolving, melting, mixing, grinding, pouring, and cooling.

- **A** Two mixtures are prepared. One contains oils and other oily ingredients such as sunblock chemicals and fragrances. The second mixture contains dissolving ingredients. Both of these mixtures are heated separately, and then they are blended together with pigments and passed through a large roller mill to grind the grainy pigment to ensure a smooth product.
- **B** A wax mixture is heated and melted in a separate container. Waxes, such as beeswax and carnauba wax, enable the final product to hold its distinctive "stick" shape.
- **C** The warm pigment mixture (from A) is added to the hot wax (from B) and stirred until a smooth mixture results. The molten lipstick is strained and poured into a tube.
- **D** After cooling, the lipsticks are inspected for undesirable characteristics such as air holes. If they are acceptably smooth and clean, they are inserted into their containers, capped, and packaged. If not, they are removed, remelted, and remoulded.

Questions

1. Why is lipstick best described as a mixture of mixtures?
2. How likely is it that the mixture created in step C in the diagram is a solution (homogeneous)? Give reasons to justify your opinion.
3. The two mixtures in step A and step B are heated separately. What do you think the purpose of this is? (Hint: Think about any cooking you have done.)

Check Your Understanding

Checking Concepts

1. Classify each of the following mixtures as a heterogeneous mixture or a solution.
   (a) bran cereal with raisins and nuts
   (b) soil mixed with water
   (c) oil mixed with vinegar
   (d) clean air
   (e) an aluminium frying pan
   (f) a brass doorknob
2. Give an example of a heterogeneous mixture that is made up of
   (a) a solid mixed with a liquid
   (b) a solid mixed with another solid
   (c) a solid mixed with a gas
3. Read the properties below for Mixture A and Mixture B. Then state which mixture is a heterogeneous mixture and which is a solution.
   - Mixture A is transparent and its parts are not visible to the unaided eye.
   - Mixture B is not transparent and has parts that are visible to the unaided eye.
4. What evidence would you need to collect to be able to classify something as a solution?

Understanding Key Ideas

5. Suppose that your teacher gives you a liquid mixture. You cannot see any small pieces of different matter in the mixture. When you pass the mixture through a filter, nothing is left on the filter paper.
   (a) Is the mixture a solution or a heterogeneous mixture? Justify your answer.
   (b) How could you be more certain about your inference?
6. The photo below shows the air in a room where a projector is being used. Based on what you see in the photo, is the air in the room a solution? Give reasons to justify your answer.

Pause and Reflect

A few coloured, solid crystals of iodine are dissolved in colourless liquid alcohol. The liquid that results is purple. Each sample taken from the liquid has the same colour. No solid pieces are visible.

(a) In your notebook, draw a simple labelled sketch to represent the mixture.

(b) Use your sketch to explain why the mixture has properties of the solid iodine crystals and the liquid alcohol.

(c) Use the particle theory of matter to explain the properties of the mixture. (Don't worry if your answer is right or not. You will learn the "right answer" in a later chapter. For now, use the science that you know to help you imagine what happens when one substance dissolves in another.)

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated mixtures and their classification, and you were introduced to pure substances. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. How Mixtures Are Different from Pure Substances
2. Heterogeneous and Homogeneous Mixtures
3. Classifying Mixtures
4. Combinations of Mixtures

Checking Concepts

1. Identify the following mixtures items as heterogeneous mixture, homogeneous mixture, or a pure substance.
   (a) percolated coffee
   (b) instant coffee
   (c) Ranch salad dressing
   (d) milkshake
   (e) clean air
   (f) oatmeal-raisin cookie
   (g) shortbread cookie
   (h) oxygen
2. What is the relationship between the following pairs of terms?
   (a) mixture, solution
   (b) solution, homogeneous
   (c) pure substance, mixture
   (d) mixture, heterogeneous
   (e) particle, pure substance
3. Properties of matter often can help you to classify it as homogeneous or heterogeneous.
   (a) Give one example of a mixture that is definitely homogeneous.
   (b) Give one example of a mixture that is definitely heterogeneous.
   (c) Easily observed properties can be misleading. What is an example of a mixture that looks homogeneous but is actually heterogeneous?
4. Examine the diagrams below. Identify which diagram represents
   (a) a homogeneous mixture
   (b) a mechanical mixture
   (c) a pure substance
   (d) a different pure substance

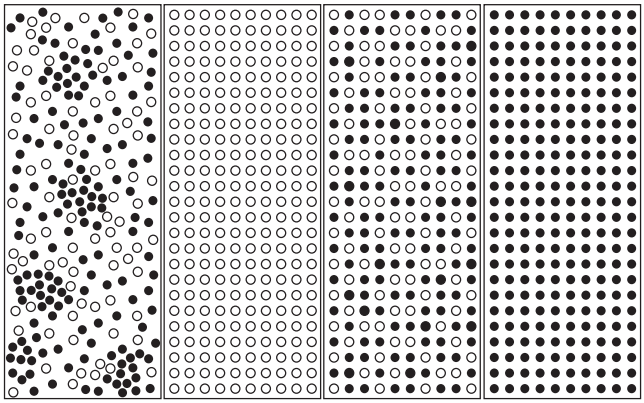


Diagram A Diagram B Diagram C Diagram D

5. Explain how you arrived at your answers for question 4.

Understanding Key Ideas

6. Katie says that sugar and water make a heterogeneous mixture. Mike says that they cannot. Decide who is right, explain why, and give evidence to support your answer.
7. In this chapter, you read that pure water is a pure substance. The water that comes out of a tap is clean and safe to drink, but it is not pure water.
   (a) If tap water is not a pure substance, then what is it?
   (b) Use your answer in part (a) to explain how it is possible for the water from one source to taste different from the water from another source.
8. How would you classify a soft drink when the sealed bottle is on the store shelf? Use the particle theory of matter to support your answer.
9. How would you classify a soft drink when it is poured into a glass? Use the particle theory to support your answer.
10. Classify and describe the mixture that each beaker in the photo will contain after the water is poured and mixed.

Pause and Reflect

Very few of the metals that you use or come in contact with are pure substances. Most are alloys—homogeneous mixtures of two or more different metals. This is certainly true of coins such as the nickel you read about at the start of this chapter. Give three reasons why you think that alloys of metals are used more often than pure-substance metals.

Chapter 8

Some substances dissolve to form solutions faster and more easily than others.

Did you notice in Chapter 5 that water was called "pure water" when it was identified as a pure substance? Why was it necessary to call it "pure water?" In what way is "pure water" different from "ordinary water?" The water that flows out of a tap or that falls from the sky as rain or that empties into the ocean from a river is not a pure substance. It's actually a solution. There are very small amounts of dissolved solids such as sodium chloride and dissolved gases such as carbon dioxide and oxygen. In fact, you would be hard-pressed to find totally pure water anywhere in nature. Water is so good at dissolving things that it cannot stay pure for very long at all.

You will find out how pure water, called distilled water, is made when you explore how to separate solutions and other mixtures in the next chapter. In this chapter, you will first learn more about how solutions are made and the factors that affect making them.

What You Will Learn

In this chapter, you will

- **identify** the solute and the solvent in a variety of solutions
- **distinguish** between soluble and insoluble substances
- **describe** the concentration and solubility of substances qualitatively and quantitatively

Why It Is Important

You make or make use of solutions each day. Learning how to describe the solutions that you make and use lets you communicate with others more effectively. This is especially important for solutions that require safe handling, such as pesticides.

Skills You Will Use

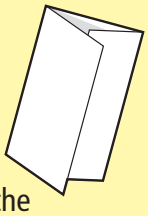
In this chapter, you will

- **express** the concentration of a solution and the solubility of a solute
- **predict** and graph the effect of temperature on solubility
- **investigate** factors that affect the rate of dissolving

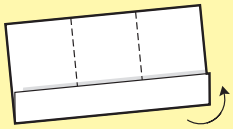
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 8.

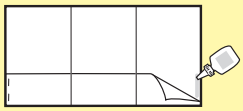
STEP 1 **Fold** a horizontal sheet of 11 × 17″ paper into thirds by folding first the right, then the left sides inward.



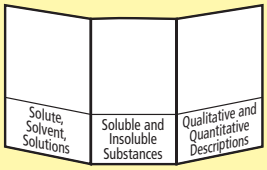
STEP 2 Unfold the paper and fold the bottom quarter of the page upward to create a pocket.



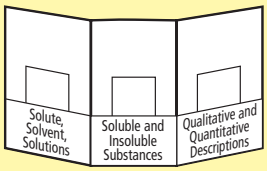
STEP 3 **Glue** or **staple** the outer edges of the pocket closed.



STEP 4 **Label** the pockets with the following titles: *Solute, Solvent, Solutions; Soluble and Insoluble Substances;* and *Qualitative and Quantitative Descriptions.*



STEP 5 **Cut** small pieces of paper to fit in each pocket. These will be used as note cards.



Organize Use the note cards to record main ideas, supporting facts, new terms, and definitions from the chapter. Use half-sheets of grid paper to predict and graph the effect of temperature on solubility. Store these sheets in the appropriate pockets of the Foldable.

8.1 Making Solutions: Solutes and Solvents

When one substance dissolves in another, the substance that dissolves is the solute and the substance in which it dissolves is the solvent. A substance is soluble in a solvent when it dissolves in the solvent. A substance is insoluble in a solvent when it does not dissolve in this solvent. The particle theory of matter can explain why soluble substances dissolve in a solvent.

Key Terms

dissolves
insoluble
soluble
solute
solvent

Figure 8.1 shows the only type of hummingbird that is found in eastern Canada. Many people like to put out special feeders to attract the quick, colourful bird to their homes. Hummingbird feeders hold a solution that is made by mixing sugar with water. You may recall from Chapter 7 that a solution is a homogeneous mixture. When you mix two substances and they form a solution, you say that one substance **dissolves** in the other substance. As you can see in Figure 8.2:

- The **solute** is the substance that dissolves.
- The **solvent** is the substance in which the solute dissolves.

When you mix sugar and water, the sugar is the solute and the water is the solvent. The sugar dissolves in the water.

Figure 8.1 The ruby-throated hummingbird feeds on insects as well as the nectar (sugary sap) of plants. The birds willingly dine on the sugar-water solution that people make for them, too.

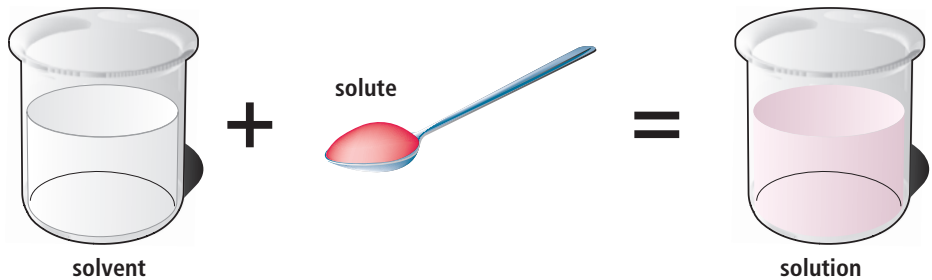


Figure 8.2 To make a solution, a solute dissolves in a solvent.

Different States of Solutes and Solvents

If you read the labels on liquid products around your home, you will notice that water is the solvent for many different solutes. But water is not the only type of solvent. In fact, solvents can be solids and gases, too! The same is true of solutes. Table 8.1 gives some examples of solutions with their solutes and solvents. In most solutions, there is usually less solute than solvent.

Table 8.1 States of Solvents and Solutes for Various Solutions

Solution	Solute	Solvent	State of Solute	State of Solvent
air	oxygen, carbon dioxide, and other gases	nitrogen	gas	gas
soda water	carbon dioxide	water	gas	liquid
vinegar	acetic acid	water	liquid	liquid
filtered ocean water	sodium chloride (salt) and other minerals	water	solid	liquid
brass	zinc	copper	solid	solid

Did You Know?

The ruby-throated hummingbird grows no larger than 9 cm long. But don't judge it by its size alone. Each fall, fueled by their nectar-feeding, these small birds leave Canada and migrate to their winter destination: Mexico!

8-1A Name That Solute and Solvent

Think About It

In this activity, you will identify the solute and the solvent in a variety of solutions.

What to Do

1. Read the four statements about solutions carefully. The way that each statement is written gives you clues to help you tell which part of the solution is the solute and which part is the solvent.
2. For each statement, do the following:
   (a) Identify the state of the solution that is described. Refer to Table 8.1 if you need help.
   (b) Identify the solute.
   (c) Identify the solvent.

What Did You Find Out?

1. Explain how you decided which part of the solutions was the solute and which part was the solvent.

Statement 1

Brass is a metal that is used to make musical instruments and doorknobs. Brass is a solution of zinc metal in copper metal.

Statement 2

Hydrogen peroxide is used to disinfect cuts and wounds. Hydrogen peroxide is a solution made of 3% hydrogen peroxide and 97% water.

Statement 3

Dental amalgam is a metal that is used to fill cavities. Dental amalgam is a solution of mercury in tin. (Mercury is a metal that is liquid at room temperature.)

Statement 4

Deicing fluid is a powerful liquid that is used to clean car and truck windshields. One kind of less-toxic deicing fluid is a solution of propylene glycol in water.

Soluble and Insoluble

As you know, when you mix a solute like sugar with a solvent like water, the sugar dissolves in the water. Another way of saying "the sugar dissolves in the water" is to say "the sugar is soluble in the water." A substance that is **soluble** is able to dissolve in a certain solvent.

What about things that do not dissolve? For instance, sand does not dissolve in water. Another way of saying "sand does not dissolve in water" is to say "sand is insoluble in water." A substance that is **insoluble** is not able to dissolve in a certain solvent.

8-1B Eggshell Shocked

Find Out ACTIVITY

Eggshells are mostly calcium carbonate. In this activity, you will see what happens when an egg is left floating in water and another egg is left floating in vinegar.

Safety

- Raw eggshells can sometimes be a source of food poisoning. Wash your hands after you handle the eggs.

Materials

- 2 large beakers (400 mL or 500 mL) or large jam jars
- 2 raw eggs
- water
- white vinegar

Connection

Remind yourself of what calcium carbonate is in section 7.1.

What to Do

1. Add water to one beaker or jar until it is about half-full. Add vinegar to the other beaker or jar until it is about half-full.
2. Gently place a raw egg in each jar.
3. In your science notebook, write the date and describe the appearance of the egg in each jar. Also, describe the appearance of the water and the vinegar.
4. Observe the two jars each day for a few days. Describe the eggs, the water, and the vinegar each day. Remember to write the date each day.
5. When the activity is over, clean up and put away the equipment you have used.

What Did You Find Out?

1. What, if any, changes to the egg did you observe in the water?
2. What, if any, changes to the egg did you observe in the vinegar?
3. Is eggshell (calcium carbonate) soluble or insoluble in water? Is it soluble or insoluble in vinegar? Give evidence to support your answers.

Insoluble in Some Solvents, Soluble in Others

As you can see in Figure 8.3, motor oil does not dissolve in water. In other words, motor oil is insoluble in water. As you can see in Figure 8.4, though, motor oil is soluble in other substances. For instance, motor oil dissolves in gasoline.

Figure 8.3 Motor oil is one type of petroleum product. Petroleum products do not dissolve in water.

Figure 8.4 Small engines, like those in some lawnmowers and chainsaws, run on a solution of motor oil and gasoline. A certain volume of the oil is dissolved in a larger volume of gasoline. So, the oil is the solute and the gasoline is the solvent.

Figure 8.5 shows another example of a substance that is insoluble in one solvent but is soluble in another. Grass stains are caused by a green-coloured chemical called chlorophyll. Grass stains are hard to wash out of clothing because chlorophyll is insoluble in water. It is also insoluble in laundry detergent. A different solvent, such as rubbing alcohol, is needed to dissolve grass stains. Chlorophyll is soluble in rubbing alcohol.

Figure 8.5 Chlorophyll is a green-coloured chemical that is found in the leaves of green plants. Water cannot dissolve chlorophyll, but rubbing alcohol can.

Reading Check

1. What does the term *soluble* mean?
2. What does the term *insoluble* mean?
3. Vinegar is insoluble in vegetable oil. Does this mean that vinegar is a totally insoluble substance? Explain why or why not.

Explore More

If a Styrofoam cup comes in contact with nail polish remover, the cup material will dissolve. And yet nail polish remover does not harm fingernails. How can this be? Why are people cautioned to use nail polish remover carefully? Begin your research at **www.discoveringscience.ca**

Suggested Activity

Conduct an Investigation 8-1C on page 259.

Connection

Section 5.1 has information to help you review the particle theory of matter.

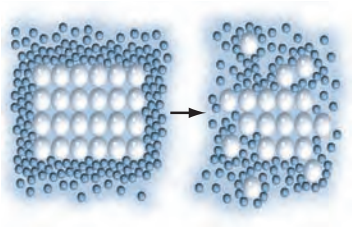


Figure 8.6 The water particles pull one sugar particle away from the other sugar particles in the crystal. Then the motion of the water particles carries the sugar particle away. This makes room for more water particles to move in and pull other sugar particles away.

internet connect

Find out how nanotechnology and other methods are helping people dissolve dirt and other impurities that have invaded great works of art. Start your search at **www.discoveringscience.ca.**

Why Some Substances Dissolve

The particles of a substance stay together because they are attracted to each other. What happens to the attraction among sugar particles when you put sugar in water? Why does each sugar crystal break up and dissolve? There must be other attractions. The sugar particles are also attracted to the water particles, so they mix with the water particles.

A group of water particles can attract a sugar particle more strongly than the other sugar particles around it. Figure 8.6 shows what happens to sugar particles on the edge of a sugar crystal. The process in Figure 8.6 continues until all of the sugar is dissolved. Particles of sugar gradually move around and mix evenly amongst the particles of the water. A solution is formed.

A solution can also form when oil is mixed with gasoline. In this case, the attractions between the oil particles and the attractions between the gasoline particles are alike. They are both very weak. Do not forget, the particles in each are always moving. When these two substances mix, the weak attractions are broken by the motion of the particles and a solution is formed.

Why Some Substances Do Not Dissolve

Just mixing two substances together does not always make a solution. Why are some substances insoluble? Think about the attraction of fat particles and the attraction of water particles in a glass of milk. For the particles of fat to dissolve in the water, they would have to be more attracted to the water particles than to the other particles of milk fat. But fat particles are not more attracted to the water particles. So the fat particles stay together and form insoluble globules in the liquid.

This idea of particle attraction applies to many other combinations of substances. For instance, it can help to explain why grass stains are tough to get out of clothing. The particles of chlorophyll in the grass stains are more attracted to each other than they are to water particles. To get out the grass stains, you need to use a different solvent—one whose particles attract the particles of chlorophyll. As you learned on the previous page, rubbing alcohol is such a solvent.

Reading Check

1. Why are some substances insoluble in a certain solvent?
2. When sugar is added to water, which is stronger: the attraction of water particles for sugar particles or the attraction of sugar particles for sugar particles?

8-1C Does It Dissolve?

Find Out ACTIVITY

In this activity, you will test two solutes to see how well they dissolve in different solvents.

Safety

- Do not taste, eat, or drink any of the substances in this activity.

Materials

- 4 small transparent containers (such as small beakers or plastic cups)
- 4 labels
- 4 stir sticks
- water
- vegetable oil
- salt
- flour
- measuring spoons

What to Do

1. Copy the table of observations below into your science notebook. Give your table a title.
2. Label the four cups 1, 2, 3, and 4.
3. Use a measuring spoon to pour about 2 mL of water (about half a teaspoon) into cups 1 and 2. Pour about 2 ml of vegetable oil into cups 3 and 4.
4. Record the solvent in your table.
5. Predict whether each of the two solutes (salt and flour) will dissolve in one, both, or neither of the solvents. Record your predictions.
6. Using the stir sticks, add a little salt to cups 1 and 3 and a little flour to cups 2 and 4. Record the names of the solutes in your table.
7. Stir each mixture. Observe the contents of each container to see if the solutes have dissolved. Record your observations in your table.
8. Clean up and put away the equipment you have used.

Container	Name of Solvent	Name of Solute	Observations
1			
2			
3			
4			

What Did You Find Out?

1. Write a summary of your results.
2. Were your predictions accurate? Explain why you think they were or were not.
3. Predict what would happen if you did this activity again using ethanol (a type of alcohol) as a third solute. Give reasons to explain your prediction. If there is time, test it. (Make sure you observe all safety rules when handling the ethanol.)

Wild, Weird, Wonderful

www Science

The Strange Case of the Water That Wasn't

In 1966, a Russian scientist who was giving a talk in England told the scientists of a new discovery. He said that Russian scientists had discovered a new form of liquid water. The particles of this new form of water were held together in a way that made the water thicker and denser than ordinary water. This new water, called polywater, could stay a liquid at temperatures as low as –55°C and at temperatures as high as 260°C. It was made in the lab by heating and condensing water in very narrow glass tubes. But the process was so painstaking that only a few drops could be made at a time.

The difficulty of making polywater didn't stop other scientists from studying it. During the late 1960s and the early 1970s, hundreds of scientists from around the world published their thoughts and experiments with polywater. Some proclaimed dire consequences if polywater ever got out of the lab and into nature. It would, the scientists predicted, change all normal water into polywater.

It took about seven years for the truth about polywater to emerge. And the truth was: There was no such thing!

"Polywater", it turned out, was just a solution. Small amounts of silicon and a few other impurities had dissolved from the thin glass tubing into water. Polywater, it turned out, was water that was polluted with impurities.

The polywater event happened for a simple reason. Scientists forgot, for a period of time, about water's abilities as a solvent.

Check Your Understanding

Checking Concepts

1. Give two examples of substances that are soluble in water.
2. Give two examples of substances that are insoluble in water.
3. Give one example of a substance that is insoluble in water but is soluble in a different solvent.
4. Identify the solute and the solvent in these examples.
   (a) Your friend makes lemonade by mixing lemon-flavoured drink crystals with water.
   (b) Vinegar is a solution that is made up of 5% acetic acid and 95% water.
   (c) Humid air is a solution of water vapour in air.
   (d) Home-made window cleaner can be made by dissolving vinegar in water.
   (e) One way to make apple juice is by mixing water with frozen concentrated apple juice.
   (f) A small outboard motor on a boat is fuelled with a mixture of motor oil and gasoline.
   (g) Some people prefer to drink tea with lemon juice.
   (h) Therapeutic massage oil is a solution that contains the oil of a medicinal plant such as sage mixed with almond oil.
5. In Chapter 7, you learned that a stainless steel frying pan is a solution called an alloy.
   (a) Name the solvent in stainless steel.
   (b) Name one solute in stainless steel.

Understanding Key Ideas

6. Use the particle theory of matter to explain why glass is insoluble in water. Use diagrams as well as words to answer this question.
7. Some people suggest using hairspray to remove ink stains. Use the terms "soluble," "solvent," and "insoluble" to explain this suggestion.
8. (a) List six substances (two solids, two liquids, and two gases) that dissolve in water.
   (b) List six substances that do not dissolve in water.
   (c) Water is often called "the universal solvent." How do you know that this statement is incorrect?
   (d) Even though it is incorrect to call water a universal solvent, the statement is still useful and accurate. Explain why.

Pause and Reflect

What is the difference between a substance that is soluble and a substance is insoluble? Imagine that you have to explain this difference to a class of grade 5 students. Devise an analogy that will make this difference simple and understandable to the students. (An analogy is a type of comparison in which you use something that is familiar to explain something that is or might be unfamiliar.)

8.2 Concentration and Solubility

A concentrated solution has a larger mass of solute for a certain volume of solvent. A dilute solution has a smaller mass of solute for a certain volume of solvent. The concentration of a solution may be expressed quantitatively in units of grams of solute per litre of solvent (g/L). When a solution is unsaturated, more solute can dissolve in the solvent at the same temperature. When a solution is saturated, no more solute can dissolve at the same temperature. Different solutes have different solubilities. The solubility of most solids in a liquid can be increased by increasing the temperature. Stirring a solution increases the rate of dissolving, but not the solubility of a solute. The solubility of gases in a liquid can be increased by decreasing the temperature.

Key Terms

concentrated solution
concentration
dilute solution
saturated solution
solubility
unsaturated solution

Figure 8.7 The darker-coloured tea on the left is a concentrated solution. The lighter-coloured tea on the right is a dilute solution.

Figure 8.7 shows two cups of tea. Both cups have the same volume of tea. And both tea bags are the same size. You can see, though, that the tea on the right is lighter in colour than the tea on the left. How can you explain this difference?

Look at the light-coloured tea on the right. Because of its light colour, you might guess that the tea bag has not been sitting in the water for very long. Only small quantities of the substances in the tea bag have dissolved in the water.

Now look at the dark-coloured tea on the left. The tea bag likely has been sitting in the water for several minutes or longer. The substances in the tea bag have had more time to dissolve in the water. The dark-coloured tea contains more dissolved substances than the light-coloured tea.

The darker tea is a concentrated solution of tea and water. A **concentrated solution** has a large mass of dissolved solute for a certain quantity of solvent.

In comparison, the lighter tea is a dilute solution of tea and water. A **dilute solution** has a small mass of dissolved solute for a certain quantity of solvent.

Suppose that you make a fruit drink with drink crystals. If you find that the taste is too sweet, you can add water to make the solution more dilute. If you find that the taste is not sweet enough, you can add more drink crystals to make the solution more concentrated.

Concentration

The quantity of solute that is dissolved in a certain quantity of solvent is the **concentration** of the solution. You can describe concentration *qualitatively* (with words) if you use the terms "concentrated" and "dilute." You can also express concentration *quantitatively* (with numbers). This is especially important when safety is an issue. For instance, manufacturers include the concentration of the solution on the label of many products. That way, people know how to use the product safely.

One of the most common ways to show concentration is in units of grams per litres (g/L). This tells you the mass of solute that is dissolved in 1 L of solution. For example, the product shown in Figure 8.8 is a herbicide (a plant-killing chemical) commonly used to kill weeds before a crop is planted. Roundup™ is a solution of a chemical called glyphosate and water. The label shows that this product contains 7 g/L of glyphosate. This means that there are 7 g of glyphosate in 1 L of the product.

Figure 8.8 The active ingredient in this herbicide is glyphosate. According to the label, what is the concentration of glyphosate? What other information does the label show? Why?

Reading Check

1. You put three teaspoons of sugar in jug with half a litre of water. You put two teaspoons of sugar in a second jug with half a litre of water. Which jug is more concentrated?
2. How is the qualitative definition of concentration different from the quantitative definition?
3. Explain what g/L means.

Suggested Activity

Find Out Activity 8-2B on page 270
Find Out Activity 8-2C on page 271

Figure 8.9 When 316 g of bluestone are dissolved in 1 L of water at 0°C, the bluestone solution is saturated. No more bluestone will dissolve in the solution at this temperature.

A Limit to Concentration

If you put a spoonful of salt in a glass of water, the salt will dissolve. You can add a second spoonful and a third and a fourth. With each spoonful, the solution becomes more and more concentrated. Can you continue to add salt to the same volume of water forever? No. Eventually, you reach a point at which the salt will not dissolve in this volume of water any more. At this point, the solution is said to be saturated.

A **saturated solution** forms when no more solute will dissolve in a specific amount of solvent at a certain temperature. For example, a saturated solution of salt and water is formed when 357 g of salt are dissolved in 1 L of water at 0°C. If more salt is added to this solution at this temperature, the salt will not dissolve. Figure 8.9 shows a saturated solution of water and a substance called bluestone. Notice the lump of undissolved solid that is left on the spoon.

An **unsaturated solution** is a solution that is not yet saturated. Thus, more solute can dissolve in it.

Solubility

Solubility refers to the mass of a solute that can dissolve in a certain amount of solvent at a certain temperature. For example, you read earlier that 357 g of salt will dissolve in 1 L of water at 0°C. In other words, the solubility of salt in water at 0°C is 357 g/L.

Table 8.2 lists the solubility of several common substances in water. Notice that the solubilities are given as mass of solute (in grams) that will dissolve in 1 L of water at 0°C to form a saturated solution.

Did You Know?

A supersaturated solution is one that has more solute than would normally dissolve at a given temperature. Only some solutes can be used, and the solute can come out of solution very easily. You start with a saturated solution and then cool it without disturbing it. If you disturb the solution by adding a small crystal of solute (as in photo A), the extra solute quickly becomes solid (photo B).

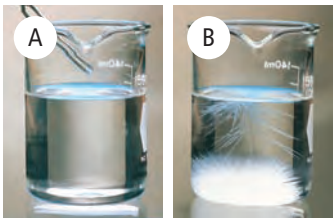


Table 8.2 Solubilities of Some Common Substances at 0°C

Substance	State (of Solute)	Solubility in Water (g/L)
baking soda	solid	69
bluestone	solid	316
calcium hydroxide	solid	1.9
carbon dioxide	gas	3.4
Epsom salts	solid	700
ethanol	liquid	unlimited
limestone	solid	0.007
nitrogen	gas	0.03
oxygen	gas	0.07
salt	solid	357
sugar	solid	1792

Rate of Dissolving

You know from your daily life that it takes a while to dissolve sugar in water. But you may also know from your daily life that you can make sugar dissolve faster. For instance, sugar will dissolve faster if the water is at a higher temperature. What factors do you think affect *how fast* something will dissolve?

When you investigate a question like this, you are talking about the *rate of dissolving*. The rate of dissolving refers to how quickly a solute dissolves in a solvent.

You probably already know another way of making a solute dissolve more quickly: stirring. For example, if you make a fruit drink with drink crystals, you likely do what the student in Figure 8.10 is doing. You stir the mixture to increase the rate of dissolving. Figure 8.11 explains why.

Word Connect

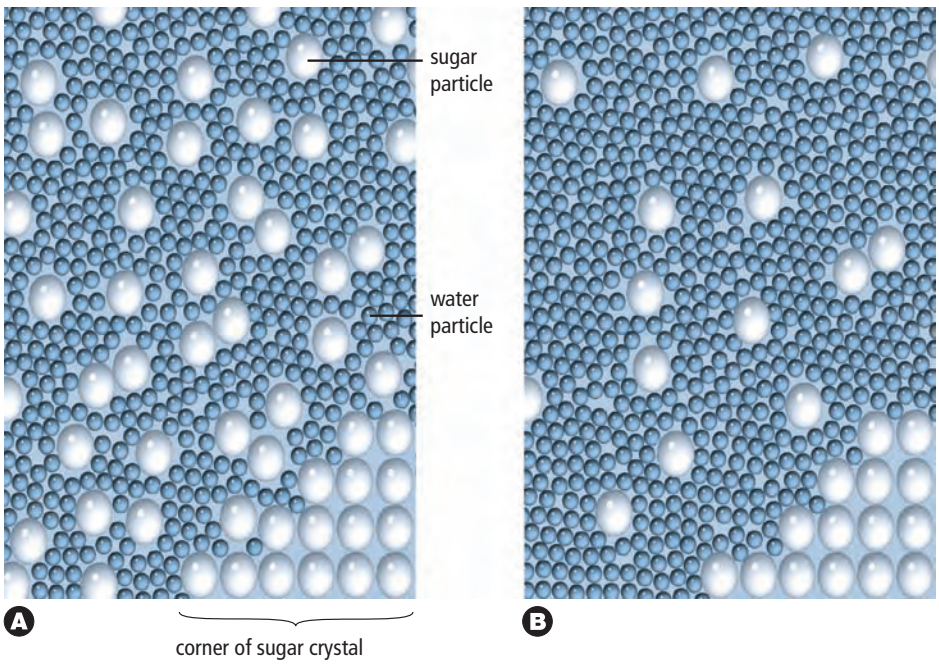
In Table 8.2, the solubility of ethanol in water is listed as unlimited. This means that any amount of ethanol will dissolve in *any* amount of water. Liquids such as these, which can dissolve in any amount in each other, are said to be *miscible*. Miscible comes from a Latin word that means "to mix."

Figure 8.10 Why might stirring or shaking a mixture make a solute dissolve faster?

Suggested Activity

Conduct an Investigation 8-2A on page 268

Figure 8.11 The particle theory of matter can be used to explain how stirring increases the rate of dissolving.



(A) Before the mixture is stirred, the sugar particles move into the solution at a rate that depends only on the natural movement of the nearby water particles. The solution close to the crystal is more concentrated, and the solution farther from the crystal is more dilute.
(B) When you stir the mixture, you cause the solute and the solvent to interact more quickly. Stirring pushes some of the concentrated solution away from the crystal. At the same time, stirring also pushes dilute solution closer to the crystal. Because there is more interaction between the solute and the solvent when you stir, the rate of dissolving increases.

Did You Know?

Some candies are made with confectioner's sugar. It is the same as table sugar, but it has smaller grains. If you put a grain of each type of sugar on your tongue, the confectioner's sugar will taste sweeter. That's because more of it can dissolve in the same time. (You can only taste sugar when it is dissolved on your tongue.)

Size of Solute and Rate of Dissolving

You probably know from experience that smaller pieces of solute will dissolve more quickly than larger pieces. For instance, smaller grains of sugar dissolve faster than larger grains of sugar. (You can try this yourself to verify it.) Why does the size of sugar or any other solid solute affect the rate of dissolving? Dissolving a solid in a liquid takes place at the surface of the solid. By breaking a large solid into smaller pieces, you expose more surfaces. Now there are more surfaces for the solvent to interact with. Because there is more interaction between the solute and the solvent, the solute dissolves faster—the rate of dissolving increases.

You can see how this idea works in Figure 8.12. The photo shows a whole sugar cube and a sugar cube that has been broken into smaller pieces. Both sugar cubes have the same mass. The surfaces of both cubes were coloured red with a felt pen before one cube was broken.

Breaking the cube has made more surfaces, which are white in the photo. So, now the total surface area of the pieces of sugar is greater than the surface area of the whole cube. Now there can be more interaction between the cube pieces and a solvent. So, the broken cube will dissolve faster than the whole cube.

Figure 8.12 These two sugar cubes are identical in size and in mass. But the broken sugar cube has more surfaces (many red and white surfaces) that can interact with a solvent than the whole sugar cube (just six red surfaces).

Pressure and the Solubility of Gases in Liquids

A sealed bottle of pop like the one in Figure 8.13 has a lot in common with a deep-sea diver like the one in Figure 8.14. Both are under pressure, and both contain concentrated solutions of gases in liquids.

Figure 8.13 When the pressure of the carbon dioxide gas in a pop bottle decreases, the solubility of the gas in the liquid pop decreases. Bubbles of gas quickly come out of solution.

In a bottle of pop, carbon dioxide gas is pumped under pressure into the water in the bottle. Gases are more soluble in liquids when the pressure is higher. The higher pressure forces extra gas particles into the spaces between the water particles. But the extra gas particles dissolve only because they are forced into the solution under pressure. When the cap is removed, the pressure inside the bottle lowers very quickly. This causes the gas to be less soluble. As a result, the gas comes out of solution. That's why you see lots of small bubbles when you open a bottle of pop such as the one in Figure 8.13.

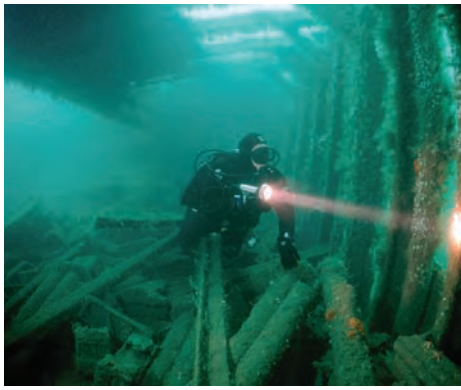


Figure 8.14 The blood of all deep-sea divers develops a life-threatening solution of a gas dissolved in a liquid. That's why it's important for all divers to learn how to descend into the water and ascend from the water properly.

This is similar to what happens inside a diver's blood. The diver's body is under pressure caused by the deep water, so the blood contains more gas particles than normal. These gases stay dissolved only as long as the pressure remains. As the diver rises to the surface, the pressure on the diver's body (and blood) becomes less. If the diver rises too quickly, the gases in the blood come out of solution very quickly. They form bubbles in the diver's blood, just like the bubbles in a bottle of pop. These gas bubbles are released from the blood into body tissues with painful, and possibly fatal, results.

This condition is often called "the bends." To avoid it, a diver must ascend gradually from any depth greater than 9 m. This helps the nitrogen gas to come out of solution slowly and into the lungs so that it can be exhaled safely.

Explore More

Soda water and pop are used for enjoyment today, but they began as medicines! Find out about the history of pop—and why it's called pop in the first place. Begin your research at **www.discoveringscience.ca.**

Reading Check

1. What is the difference between a saturated solution and an unsaturated solution?
2. The solubility of salt is 357 g/L at 0°C. Explain what this statement means.
3. How does the size of the solute affect the rate of dissolving?
4. What happens to carbon dioxide gas when the pressure on a solution of pop is reduced?

Suggested Activity

Find Out Activity 8-2D on page 271

8-2A How Does Temperature Affect Solubility?

SkillCheck

- Predicting
- Measuring
- Controlling variables
- Graphing

Safety

- It is not safe to taste any substances in the science classroom, even if you think they are safe. Containers or substances that look clean may still contain invisible traces of harmful chemicals left over from a previous activity

Materials

- balance
- graduated cylinder
- thermometer
- small beakers or test tubes with stoppers
- stirring rod
- measuring spoon
- solute of your choice (for instance: table salt, Epsom salts, flavoured drink powder, baking soda)
- clock or stopwatch

Do you think heating a solvent will affect the amount of solute that will dissolve in it? The data table below shows the solubility of three different solutes in water at various temperatures. In this activity, you will examine these data to develop a hypothesis about how temperature affects solubility. Then, you will design an experiment to test your hypothesis.

Question

How does temperature affect the solubility of a solid solute in a liquid solvent?

Procedure

Part 1—Analyzing Solubility

1. Draw the axes for a graph. Label the *y*-axis Solubility (g/L). Label the *x*-axis Temperature (°C). Mark the scale for the *x*-axis to go from 0 to 100.
2. Plot the data in the table below. Use a different colour for each solute. Include a legend to show the solute that each colour represents.

Temperature versus Solubility for Three Solutes

Temperature (°C)	Solubility in Water (g/L)*		
	Sugar (Sucrose)	Potassium Chlorate	Ammonium Chloride
10	1910	50	320
20	2040	70	370
30	2200	110	410
40	2390	150	460
50	2610	210	500
60	2870	270	550
70	3200	340	600

* Values have been rounded to the nearest 10.

3. Connect the points for each solute by drawing a line of best fit.
4. Use dashes to extend (extrapolate) the line for each solute so that it crosses 100°C.
5. Give your graph a title.
6. Answer Analyze questions 1, 2, and 3, and answer Conclude and Apply question 1.

Inquiry Focus

Part 2—Design Your Own Solubility Study

1. Based on the evidence from Part 1, how does temperature affect solubility for a solid solute that is mixed with a liquid solvent? Write a hypothesis.
2. Design an investigation to test your hypothesis. Here are some other tips and reminders that you might find useful.
   - There is more than one safe way to increase the temperature of a liquid.
   - Heating a liquid is not the only way to investigate the effect of temperature on solubility.
   - Which variables will you control? Which variable will you change (independent variable), and which variable do you expect will change in response (dependent variable)?
   - How will you guarantee safety for yourself and everyone else in the class?
   - How will you record your data?
3. Write the procedure for your investigation. Get your teacher's approval. Then, carry it out.
4. Clean up and put away the equipment you have used.
5. Answer Analyze question 4, and answer Conclude and Apply question 2.

Analyze

1. Describe the shape of the lines on your graph.
2. What happens to the lines as temperature increases?
3. Predict the solubility of each solute at 90°C. (Use your dashed line to help you make your prediction.)
4. How did the solubility in warmer water of the substance you tested compare with its solubility in colder water?

Science Skills

Go to Science Skill 1 for tips on drawing graphs.
Go to Science Skill 2 for tips on how to work with variables.

Conclude and Apply

1. What happened to the solubility of each solid solute as the temperature of the water increased?
2. How well did your results support your hypothesis?

8-2B How Much Is Too Much?

Find Out ACTIVITY

Is there a limit to the amount of solute that can dissolve? In other words, can a solution be made more and more concentrated, with no limit? Does it matter what the solute is? You will explore these questions in this activity.

Safety

Materials

- graduated cylinder
- 250 mL beaker
- measuring spoon
- about 40 g of salt
- Petri dish (or piece of paper)
- water
- stirring rod
- balance
- additional substance provided for testing (for example, sugar, bluestone, calcium hydroxide)

What To Do

1. Use the graduated cylinder to measure 100 mL of cold tap water. Pour the water into the beaker.
2. Pour the salt into the Petri dish. Place the Petri dish on the balance. Measure and record the mass of the salt and dish. Use a table like the one below to record your measurements. Remember to include the units of mass. Then remove the Petri dish from the balance.

Measurements for Determining the Amount of Salt that Dissolves in 100 mL of Water

A. Mass of salt and Petri dish before mixing with water	
B. Mass of salt and Petri dish when salt no longer dissolves in the water	
C. Mass of salt that dissolved in 100 mL of water (Hint: A – B = C)	

3. Use the measuring spoon to add a small amount (about 2.5 mL—half a teaspoon) of salt to the water. Stir the mixture until all the salt is dissolved.
4. Repeat step 3. After each stirring, check to see if there is any salt that does not dissolve. Keep repeating step 3 until you see that some of the salt will no longer dissolve.
5. When you reach the point at which no more will dissolve, place the Petri dish with its remaining salt on the balance. Measure and record the mass in your table.
6. Find the mass of salt that dissolved in the water. Record this mass in your table.
7. Your teacher will provide you with one more substance. Follow all safety guidelines for this substance provided by your teacher. Test this substance in the same way that you did with salt. Prepare a table like the one you used for salt to record your observations.

What Did You Find Out?

1. (a) What was the volume of water that you used to dissolve the salt?
   (b) What was the total mass of salt that you were able to dissolve in this volume of water?
2. (a) What was the volume of water that you used to dissolve the second substance?
   (b) What was the total mass of this substance that you were able to dissolve in this volume of water?
3. Did different students get different results? If so, suggest reasons for the different results.

8-2C Concentrations of Consumer Products

Find Out ACTIVITY

In this activity, you will look for concentrations on consumer products that are solutions.

Safety

Handle each product carefully as you observe its label. As a precaution, have an adult with you while you do this activity.

What to Do

1. In your home, look for five products that show their concentration on the label. The chart below shows some ways to recognize how concentration may be expressed on a label.
2. Use a table with the following headings to record information about each product.

Name of Product	Solute	Solvent	Concentration

What Did You Find Out?

1. In the products you listed, what is the most common solvent?
2. Why do you think the manufacturer provided concentration information on the label?

Unit of Concentration	What It Tells about the Solution
g/L	tells how many grams of solute per litre of solution
ppm (parts per million)	tells the ratio, 1:1 000 000, of the mass of solute in the mass of solution
%	tells the percentage of solute in the solution by volume (in other words, the volume of the solute divided by the total volume of the solution)
%	tells the percentage of solute in the solution by mass (in other words, the mass of solute divided by the total mass of the solution)

8-2D Dissolved Carbon Dioxide

Find Out ACTIVITY

Soda water is water with dissolved carbon dioxide gas. In this activity, you will make observations about solubility with your ears and eyes.

Safety

- Use sealed, plastic bottles of pop.
- Compare cold and warm (not hot) bottles.

What to Do

Design an experiment to compare the solubility of carbon dioxide gas in cold water with its solubility in warm water. You will not be able to measure the solubility in grams of solute per litre of solvent. You will need to find another way to compare the two solutions. (Hint: What do you hear when you open a can or bottle of pop? What causes the noise?)

What Did You Find Out?

1. If you wanted to have a very bubbly bottle of pop when you open it, would you store it in a cold fridge or in a cupboard? Explain answer.
2. The ocean waters around the North Pole and the South Pole have more sea life than the ocean waters near the equator. Infer a reason why. (Hint: All ocean life depends on oxygen that is dissolved in the water.)

Science

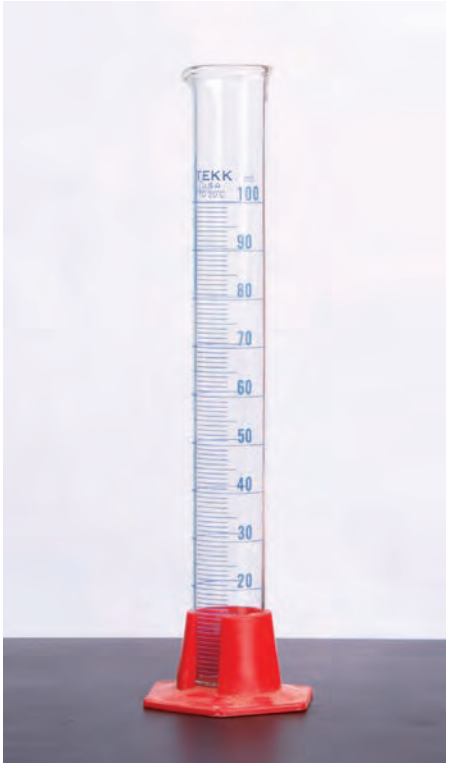
Math connect

Working with Concentration Units

Look again at Table 8.2 on page 264. Notice that the concentrations are expressed as grams of solute per litre of water (g/L). In the Find Out Activity on page 270, notice that the mass of solute being investigated is dissolved in 100 mL of water. How can you convert units of g/mL to g/L? How can you convert units of g/L to g/mL?

To answer these questions, start by thinking about how millilitres (mL) and litres (L) are related to each other. For instance, how many millilitres are there in one litre? If you are not sure, look at the scale on a graduated cylinder or on a beaker. You also might find it helpful to review Science Skill 4, Measurement.

Verify to yourself that there are one thousand millitres in one litre (1000 mL = 1 L). Use this information to help you solve the Practice Problems that follow.



Practice Problems

1. Devise a method to convert from mL to L. Test your method by converting the six units below. Check your answers with the class before going to step 3.
   (a) 1000 mL = ? L
   (b) 500 mL = ? L
   (c) 100 mL = ? L
   (d) 10 mL = ? L
   (e) 5 mL = ? L
   (f) 1 mL = ? L
2. Now devise a method to convert from g/mL to g/L. Check your answers with the class to make sure that everyone understands how to convert the units.
   (a) 10 g/100 mL = ? g/? L
   (b) 52 g/100 mL = ? g/? L
   (c) 65 g/100 mL = ? g/? L
   (d) 100 g/100 mL = ? g/? L
   (e) 137 g/100 mL = ? g/? L
   (f) 0.15 g/100 mL = ? g/? L
3. Review your methods closely. Then, convert all the solubilities in Table 8.2 from g/L to g/mL.

Check Your Understanding

Checking Concepts

1. Which is the most soluble substance listed in Table 8.2 on page 264?
2. (a) Which is the least soluble substance listed in Table 8.2?
   (b) How might the low solubility of this substance explain why it is a good choice for a building material?
3. Suppose that you add some solid detergent to the water in a washing machine. Then, you decide that your clothes are really dirty, so you add more detergent. Is the solution of detergent and water now more concentrated or more dilute? Explain how you know.
4. (a) The solution for a hummingbird feeder is made by dissolving 30 g of sugar in 100 mL of water at 0°C. Is the solution saturated or unsaturated? If it is unsaturated, how much more sugar could you dissolve in it before it becomes saturated?
   (b) You decide to boil the 100 mL of water for the hummingbird feeder in question (a) before adding the sugar. How much sugar, in total, can you add to the boiled water before it is saturated? (Hint: What is the temperature of boiling water?)
5. Refer to the Temperature versus Solubility table on page 268. Which solute has the highest solubility at each of the following temperatures?
   (a) 20°C
   (b) 60°C
   (c) 90°C

Understanding Key Ideas

6. Imagine that you are conducting a test for saturation. You add a small amount of solute to three different solutions, labelled A, B, and C. Based on the observations given, is each solution saturated or unsaturated?
   - Solution A: The added solute dissolves.
   - Solution B: The added solute does not dissolve.
   - Solution C: The added solute does not dissolve at first, but after some stirring the solute dissolves.
7. To keep roads safer in winter, road crews often spread salt on the roads to melt ice and snow. Which form of salt would you expect to stay on the road longer: rock salt (larger crystals) or table salt (smaller crystals)? Give reasons for your answer.
8. Suppose that you are dissolving a solute into 500 mL of water at 0°C. You find that no more than 495 g of solute will dissolve. Calculate the solubility of the solute.

Pause and Reflect

Your teacher asks you to help prepare some solutions for another class. Use the information in Table 8.2 to create a spreadsheet or a hand-drawn table that shows the number of grams of solute that are needed to make 10 mL, 50 mL, 100 mL, 500 mL, and 1000 mL of the following saturated solutions at 0°C: bluestone, Epsom salts, salt, sugar. Explain how you came up with the data for your table.

Chapter Review

Prepare Your Own Summary

Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Solutes and Solvents
2. Concentration
3. Solubility
4. Rate of Dissolving

Checking Concepts

1. Identify the solute and the solvent in each of the following statements about solutions. Explain your reasoning.
   (a) A dentist prescribes a sodium fluoride solution to a patient who has severe tooth decay. The solution is 1.1% sodium fluoride in water.
   (b) Bronze is an alloy (a solid solution) of copper in tin.
   (c) There are 30 g of sugars in 1 L of Gatorade™. (Hint: The solvent for Gatorade™ is water.)
   (d) Bubbly soda water comes from underground springs such as those found in the town of Spa, in Belgium. Soda water is a solution of carbon dioxide gas in water.
   (e) Stainless steel may be made by dissolving carbon in iron.
   (f) One brand of apple juice, made from concentrate, has 100 g/L of sodium.
2. Describe the difference between:
   (a) a saturated solution and an unsaturated solution
   (b) a dilute solution and a concentrated solution
   (c) a substance that is soluble in water and a substance that is insoluble in water
   (d) a substance that has a high solubility in water and a substance that has a low solubility in water
3. Why must you include information about temperature when you state the solubility of a substance?
4. Neatly sketch a line graph or a bar graph that shows what happens to the concentration of a solution (y-axis) as you add solute to it (x-axis).
5. Ringer's solution is a fluid that doctors use for people and animals when they have lost too much water (are dehydrated). The solution contains some key salts in the same concentrations as they are in blood. These salts are sodium chloride (table salt), potassium chloride, and calcium chloride. Each 100 mL of Ringer's solution contains the following masses of these salts:
   - sodium chloride: 0.86 g
   - calcium chloride: 0.033 g
   - potassium chloride: 0.03 g

   Convert these values to concentration in units of g/L.

6. You mix 65 g of Epsom salts with 100 mL of water at 0°C.
   (a) Is the solution saturated or unsaturated? Explain how you know.
   (b) If the solution is saturated, how much solute is undissolved? If the solution is unsaturated, how much more solute could you dissolve in it?
7. You put some sugar in a jar of water, put a lid on the jar, and shake it. Why does shaking the jar increase the rate of dissolving.
8. Neatly sketch a line graph that shows what happens to the solubility of a substance (*y*-axis) as the solvent in which it is dissolved increases in temperature (*x*-axis).
9. Describe how pressure affects the solubility of a gas that is dissolved in a liquid.

Understanding Key Ideas

10. The solubility of ammonium chloride (a solid) at 60°C is 550 g/L.
    (a) If the temperature of the solution is reduced to 40°C, would you expect more solute to dissolve or less? Explain why.
    (b) If you want to dissolve 580 g of solute, would you have to raise the temperature of the solution or lower it? Explain why.
    (c) If the solution of ammonium chloride is heated to 75°C, is the solution now saturated or unsaturated? Explain why.
11. Which is more dilute: a solution with a concentration of 25 g/100 mL or a solution with a concentration of 20 g/80 mL? (Hint: Look at the concentrations very carefully.)
12. Your friend tells you that she is able to dissolve 39 g of salt in 100 mL of water. She says that there is no undissolved solute at the bottom of the container. However, the solubility of salt in water is 35.7 g/100 mL. Could your friend be telling the truth? Explain why or why not.
13. Compare the terms solubility and rate of dissolving. In what ways are they similar? In what ways are they different?

Pause and Reflect

The top rock layer of Niagara Falls is made of limestone. The solubility of limestone is 0.007 g/L at 0°C. With 200 000 000 t of water going over the falls each day, 1400 t of limestone could be dissolved. Only a tiny fraction of this amount actually dissolves, though. Give a reason to explain why.

Chapter 9

Many useful products depend on technology for separating mixtures and solutions.

The smaller photo shows three forms of solid sugar: white, yellow, and brown. You or a member of your family has probably used sugar products like these directly or in baking. The dark liquid in the fourth spoon is another sugar product: molasses. Would you believe that all four of these sugar products come from the same source? The source may be either the roots of sugar beets or the stalks of sugar cane grass. During the sugar-making process, different methods are used to purify or remove the sugar products from the original mixture of sugar-containing materials. Filtering is one of these methods. Evaporation is another. You will learn about these and other methods of separating mixtures in this chapter.

What You Will Learn

In this chapter, you will

- **identify** separation techniques that are used in and around the home
- **describe** how to use different methods to separate a variety of mixtures
- **identify** examples of how science related to mixtures and solutions affects our lives

Why It Is Important

Most of the products that people use to eat, to clean themselves, to run machines, and to build homes and shelters are made by processing and separating mixtures and solutions. Learning about mixture-related technologies may lead to a future career. It also may help you appreciate the role of mixtures and solutions in your life.

Skills You Will Use

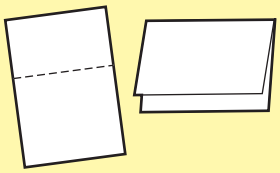
In this chapter, you will

- **separate** the components of a variety of mixtures
- **choose** and **use** an appropriate separation technique when given a known mixture
- **choose** and **use** an appropriate separation technique when given an unknown mixture

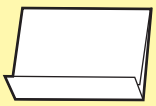
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 9.

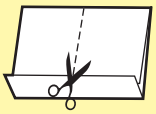
STEP 1 **Fold** an 8.5 × 11″ sheet of paper lengthwise, leaving a 2 cm tab along the bottom.



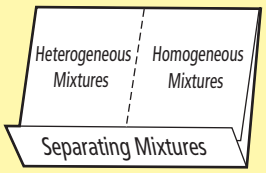
STEP 2 **Fold** the bottom tab up to cover the front flap.



STEP 3 **Cut** the front flap in half to create two flaps that open upwards.



STEP 4 **Label** the Foldable as shown.



Organize Describe methods for separating mixtures under each flap, and write down any questions that arise as you read the chapter.

9.1 Separating Mixtures and Solutions

You use a variety of techniques to separate mixtures in your daily life. Common methods that are used to separate heterogeneous mixtures into their parts include sorting by hand, mechanical sorting (such as using flotation and magnetism), and filtration. Common methods that are used to separate homogeneous mixtures (solutions) into their parts include evaporation, distillation, and paper chromatography.

Key Terms

evaporation
filtration
mechanical sorting
paper chromatography
simple distillation

You separate mixtures all the time—probably without even thinking about it. For instance, do you have a box or jar at home for pennies, nickels, and other loose change? You are separating a mixture when you sort the coins in order to spend them or to put them into coin rolls as in Figure 9.1. Figure 9.2 shows some other ways that people separate common mixtures.

Figure 9.1 Sorting coins is one example of separating a mixture.

Figure 9.2 Photos (A) to (E) show some familiar examples of mixtures being separated in and around the home.
(A) A colander is a handy device for separating pasta from a mixture of water and pasta.
(B) A screen window or door separates insects from the air that comes into a building.
(C) The spin cycle of a washing machine separates clothes from a mixture of clothes and water.
(D) A salad spinner lets you remove water from damp lettuce after it has been washed.
(E) Wearing a mask helps protect a carpenter from breathing in sawdust and other particles.

Word Connect

A colander is a type of filter that is used to strain water from washed and cooked foods. The device gets it name from a Latin word that means "to strain."

9-1A Strategies for Separation

Think About It

What methods could you use to separate different mixtures? Your teacher will give your group containers with at least three mixtures. Decide how you would recover all the substances from each mixture, in their original form.

Safety

- Do not open the containers unless requested by your teacher.

Materials

- containers of different mixtures such as: salt water, muddy water, nuts and bolts, iron filings and sand, vegetable oil and sand, vegetable oil and water, salt and pepper
- additional materials, if you are asked to test your ideas

Procedure

1. Copy the table below. Leave enough lines for all the mixtures your group is assigned. Give your table a title.
2. Observe each mixture. With your group, brainstorm possible methods that you could use to separate it.
3. In the table, record the two methods your group thinks would work best for each mixture. Give reasons why the methods would work. (You might find it helpful to refer to properties of matter.)

What Did You Find Out?

1. Which properties of matter did you refer to most often?
2. Which methods of separation did you refer to most often?
3. (a) Which mixtures would be easiest to separate? Why?
   (b) Which would be the most difficult to separate? Why?
4. Name the method or methods you would use to separate this mixture: marbles, sand, iron filings? Explain why each method would work.

Mixture	Separation Method	Reasons
		1.
		2.
		1.
		2.
		1.
		2.
		1.
		2.
		1.
		2.
		1.
		2.
		1.
		2.

Connection

Review section 7.1 to remind yourself about heterogeneous mixtures.

Separating Heterogeneous Mixtures

You can easily see the parts in a heterogeneous mixture such as raisin-flakes cereal. Figure 9.3 shows that separating the parts of this mixture is easy to do by hand or with tweezers. It will just take a long time this way!

With a heterogeneous mixture of sand and iron filings, the parts of the mixture are too small to see easily. Even if you could see them, imagine trying to pick out each grain of sand or each bit of iron one by one! Figure 9.4 shows a different property that you can use to separate the parts of the mixture. Since iron is magnetic, you can use a magnet to attract the iron filings away from the sand grains.

Figure 9.3 With a mixture such as raisin-flakes cereal, you can use properties of parts of the mixture, such as size and shape, to separate the mixture.

Figure 9.4 When you separate a mixture such as sand mixed with iron filings, you can use the property of magnetism to separate one substance (the iron filings) from another substance in the mixture. Why is the magnet inside a plastic bag?

Mechanical Sorting

The separation methods shown in Figures 9.3 and 9.4 are examples of mechanical sorting. **Mechanical sorting** is a way to separate the parts of a mixture based on properties such as particle size (Figure 9.3) and magnetism (Figure 9.4). Flotation is another type of mechanical sorting. It depends on the density of the parts. Some parts of a mixture will float while others may sink. For example, you use flotation to help you skim the fat off soup (Figure 9.5).

Figure 9.5 The density of fat is lower than the density of soup liquid, so the fat floats. When it cools and hardens, fat is easy to remove from the surface of the soup.

Filtration

Filtration is one of the most common ways to remove solid particles from a mixture. Filters like those shown in Figure 9.6 are devices that have holes in them. The holes can be large

enough that you can see them easily. For instance, you can see the filtering holes in a colander or a window screen. Or the holes may be so small that you need a magnifying glass to see them. For instance, you can just barely see the holes in a tea bag. But the holes in a coffee filter are too small to see.

Filtration works like mechanical sorting, because it depends on the size of the particles in a mixture. How well a filter works depends on the size of its holes. If the holes are smaller than the size of the particles, the particles will not pass through. So, they will be separated from the mixture. This is why filters do not separate the parts of a solution. The solute particles are smaller than the filtering holes, so they pass right through the filter along with the solvent.

Explore More

The mining industry uses a separation method called froth flotation to remove bits of desired substances from the rock in which they are found. But density is not the only property on which this method depends. What is the other property? Start your research at **www.discoveringscience.ca.**

Figure 9.6 Which of these types of filters have you seen or used? What other types of filters are there? How do the sizes of their holes match their function?

Reading Check

1. Describe mechanical sorting, using magnetism as an example.
2. Why is it easier to separate the parts of a heterogeneous mixture than the parts of a homogeneous mixture (a solution)?
3. Why is the size of the holes in a filter important for filtration?

Suggested Activity

Conduct an Investigation 9-1B on page 285.

Separating Homogeneous Mixtures

Recall that homogeneous mixtures are solutions. Two common methods that are used to separate solutions are evaporation and distillation. Another method, called chromatography, is a more specialized way to separate solutions. You will learn about these methods as you read on.

Separating a Solution by Evaporation

In Unit 2, you learned that adding heat to a liquid causes it to change state to become a gas. That is, the liquid evaporates. **Evaporation** is one common way to recover the solid solute from a solution. As the liquid (solvent) evaporates, the solute is left behind. Figure 9.7 shows how this happens naturally in some areas.

Figure 9.7 The plentiful heat from the Sun evaporates the water from this basin in California. Solid crystals of salt (the white parts of the shoreline) are left behind.

Figure 9.8 Buckets hanging on maple trees is a common springtime sight in North America. About 30 L to 40 L of sap are needed to make 1 L of maple syrup.

You may have eaten a product that is made by the evaporation method: maple syrup. The sap that flows under the bark of eastern maple trees is a dilute solution of sugar, water, and small amounts of other substances. Long ago, Aboriginal peoples learned how to make syrup from this sap. In the spring, the sap is collected by driving a small tube into the trunk of each maple tree. The sap flows out of the tube and into a bucket that is hung below it, as you can see in Figure 9.8. Buckets of collected sap are poured into large vessels and then boiled for several hours. Most of the water evaporates (boils away). What is left behind is a more concentrated solution of syrup.

Connection

You can review evaporation and other changes of state of matter in Chapter 5.

Separating a Solution by Distillation

Suppose that you are lost in a desert and the only liquid that you have is a salt solution. You need to separate the salt from the water so that you have something to drink. If you let the water evaporate, it will be lost to the air as water vapour. You will be left with only the salt. How can you recover the solvent from this solution? **Simple distillation** is a method that you can use to separate and recover a single solute *and* a single solvent from a solution.

During simple distillation, the solution is heated until the solvent changes state to become a gas. Then the gas changes back to a liquid by cooling it. The solute does not change state, so it is left behind. Figure 9.9 shows some equipment that is often used for distillation in a lab. Figure 9.10 shows a setup that you could use to collect drinkable water from salt water in a desert or other place with lots of sunlight.

Suggested Activity

Find Out Activity 9-1C on page 286.
Conduct an Investigation 9-1C on page 287.

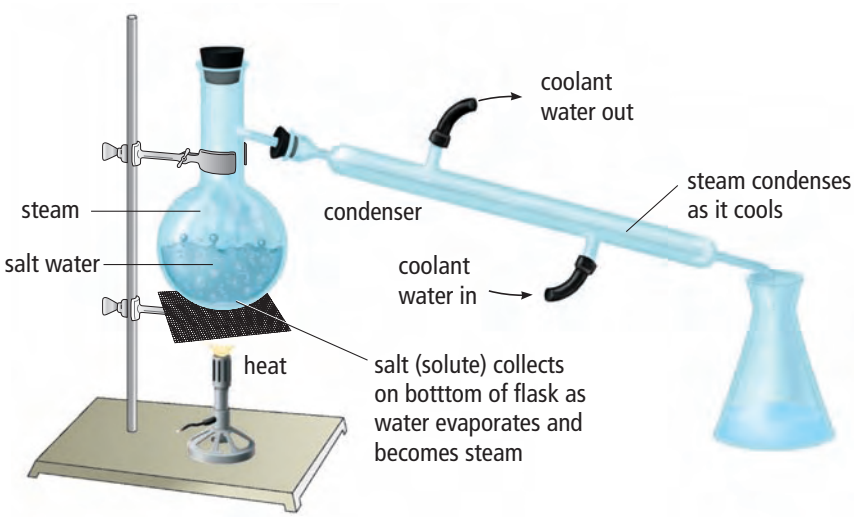


Figure 9.9 Simple distillation equipment. During what parts of this process is the solvent in the gas state? In what parts is it in the liquid state?

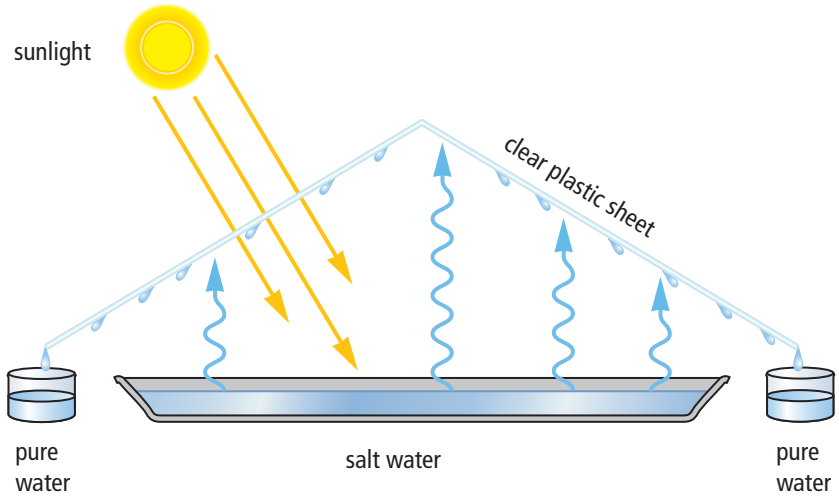


Figure 9.10 This method for distilling drinkable water from salt water requires simple materials and plentiful heat from the Sun.

internet connect

Earthquakes, floods, and other natural disasters often destroy the pipes that bring drinking water to a community. One of the risks to survivors is drinking contaminated water. How could you purify water in an emergency, using only energy from the Sun? Start your search at **www.discoveringscience.ca.**

Separating a Solution by Paper Chromatography

The patient was barely conscious when the paramedics wheeled him into the emergency room. As the attending doctor examined the patient, she suspected that he had been exposed to a toxic chemical. Among the tests she ordered was a "tox screen" of his blood. In the lab, chromatography would be used separate the components of the patient's blood. If a toxic chemical was present, it would show up in the test results.

Chromatography is a method that doctors, police detectives, and chemists use to separate and identify the solvents in a mixture. One type of chromatography that may be done with simple materials is called paper chromatography.

Paper chromatography is often used to separate the coloured substances in a mixture such as ink. It works by seeing how fast a dissolved substance is carried by a solvent through a material, such as filter paper, that absorbs the solutes. Figure 9.11 shows that different substances move with a particular speed to form a specific pattern. You can use the speed and pattern of the various substances in a test sample to identify them.

Did You Know?

Chromatography was invented in 1903 by a Russian scientist who was studying the pigments (coloured chemicals) in the leaves of green plants. He discovered that green leaves have not only green pigments, but also orange, yellow, and red pigments. You see these pigments in the fall when leaves change colour.

Suggested Activity

Conduct an Investigation 9-1C on page 289.

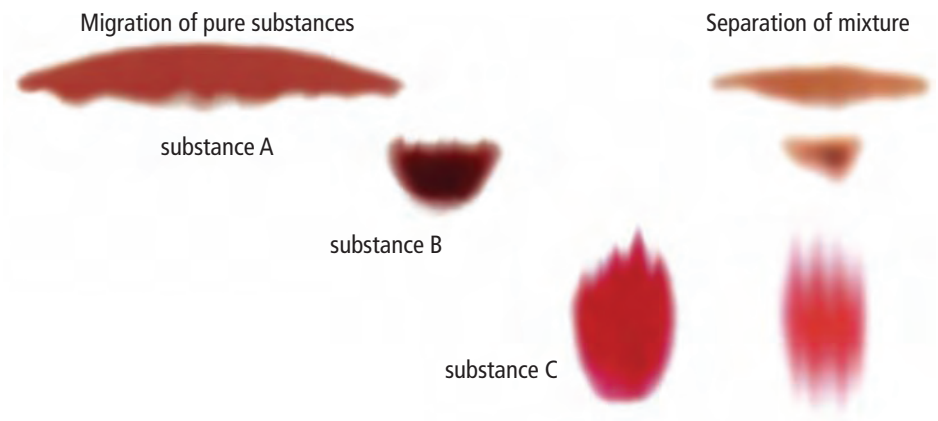


Figure 9.11 This picture shows how substance A, substance B, and substance C look after paper chromatography was done with each one separately. Then the three substances were mixed together in water, and paper chromatography was done with this solution. What do you notice?

Reading Check

1. Which part or parts of a solution does evaporation recover: the solute, the solvent, or both?
2. Which part or parts of a solution does distillation recover: the solute, the solvent, or both?
3. What is chromatography?
4. How does paper chromatography work?

9-1B Making Dirty Water Clear

Conduct an INVESTIGATION

Problem Solving Focus

SkillCheck

- Communicating
- Modelling
- Explaining systems
- Working co-operatively

Safety

- Do not taste, smell, or drink the water in this activity. It is not safe for these purposes.
- Handle the pop bottle carefully so that you do not accidentally cut yourself on the cut-off end.

Materials

- 2 L pop bottle with bottom cut off
- ring clamp
- ring stand
- stopwatch or other timer
- sand
- gravel
- cotton cloth
- 500 mL dirty water
- bucket or large beaker (to collect the filtered water)

Problem

Imagine that you run out of drinking water on a camping trip. There is a pond close by. You can see insects and leaves floating in the water. You can smell the mud and rotting leaves. How can you make 500 mL of this water clear as a first step in making the water safe to drink?

Criteria

- Design a filter that will clarify (make clear) 500 mL of dirty water.
- Use only the materials provided.
- This activity must be completed in one class period.

Design and Construct

1. With your partners, discuss which materials you will use and how you will use them.
2. Draw a diagram to show how you will set up your filtration method.
3. Get your teacher's approval before doing any tests.
4. Build your filter. Then test it with the dirty water. Use a stopwatch or other timer to time how long it takes to filter the water.
5. Clean up and put away the equipment you have used.

Evaluate

1. How did the water going into your filter compare with the water coming out of it? Describe any differences.
2. Compare the design of your filter to other designs in the class. Which design seems to work best? Explain why?
3. What could you do to make your filter produce clearer water?
4. How could you improve your design? For instance, how could you prevent the filter from clogging or make it work faster?

9-1C Separating Homogeneous Mixtures

Part 1: Evaporation

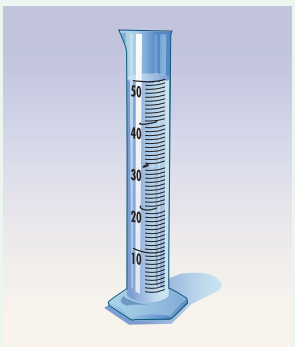
Solutions can be harder to separate than heterogeneous mixtures. You cannot use a filter or a magnet to get salt from salt water. In this activity, you will use a change of state to help you separate a solution.

Safety

- Use heat resistant gloves to handle hot glassware.
- Be sure you are wearing your safety goggles when you are near the evaporating dish as it is heating.
- Unplug the hot plate after you turn it off. Let it cool before putting it away.

Materials

- evaporating dish
- 50 mL graduated cylinder
- hot pad
- hot plate
- stirring rod
- tongs
- watch glass
- salt water



Procedure

1. Pour 50 mL of salt water into the empty evaporating dish. Cover the dish with the watch glass.
2. Put the evaporating dish on the hot plate. Very gently heat the solution. Observe the solution as it heats, and record your observations in your notebook.
3. When all the water has evaporated, remove the evaporating dish from the hot plate. Place the evaporating dish on the hot pad to cool.
4. When the evaporating dish has cooled, remove the watch glass. Observe the material that remains in the evaporating dish. Record your observations.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Describe the appearance of the solution in step 1.
2. Describe the material that remained in the evaporating dish in step 4.
3. What happened to the water in the solution? (Be sure to identify the change of state.)
4. (a) What substance likely remained in the evaporating dish?
   (b) Explain why it would be unsafe to use taste to be sure of what substance it is.
5. Suggest one way that you could collect the water that evaporated.

Part 2: Distillation

Safety

- You will be working with a hot plate, boiling water, and hot steam, all of which can cause painful burns. Work carefully around hot objects, especially steam.

Materials

- 2 mL to 3 mL distilled water
- salt
- microscope slide
- marker
- 2 beakers (250 mL)
- graduated cylinder
- medicine dropper
- hot plate
- 500 mL Erlenmeyer flask
- stopper with glass tubing already inserted
- 50 cm rubber or plastic tubing
- tongs to handle beaker or flask
- 5 mL measuring spoon

In this investigation, you will experiment with the distillation process as you separate the solvent (water) from a solution of salt water.

Question

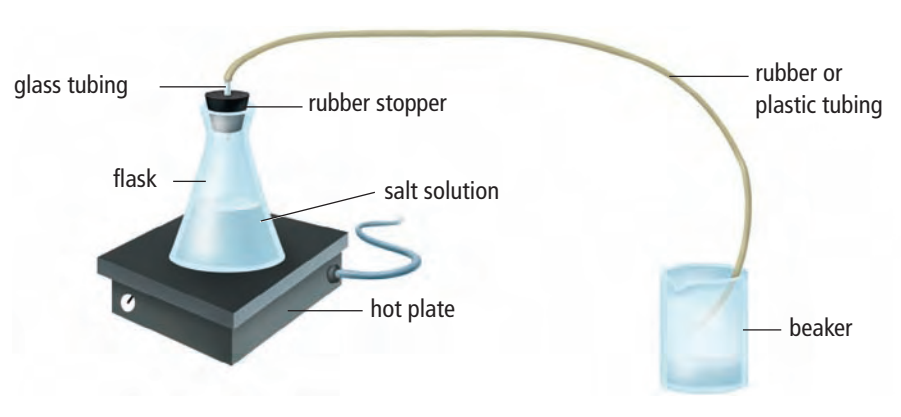
How can the parts of a salt water solution be separated and recovered?

Procedure

1. Measure 100 mL of tap water in a graduated cylinder. Pour the water into a 250 mL beaker.
2. Add 10 mL of salt, and stir until the mixture is dissolved.
3. Pour almost all of this solution into a 500 mL flask. (Save a few drops to use for testing in step 5.)
4. Using the other beaker, set up the equipment shown in the diagram below.
   (a) Make sure your hands are dry. Plug in the hot plate, and turn it on. Heat the mixture until about half of the liquid has boiled away.

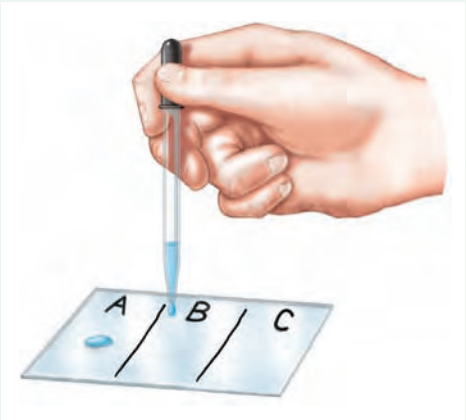
   Caution: Turn off the hot plate when *half* of the liquid is gone. Then carefully remove the end of the tubing from the beaker. (Be sure to wear gloves. The tubing will be hot.)

   (b) Let the apparatus cool completely before taking it apart.



5. In this step, you will test for the presence of dissolved salt by letting three samples of liquid evaporate. Be sure to use the same amount of liquid for all three samples.
   (a) With the marker, divide the microscope slide into three parts. Label them A, B, and C as shown in the diagram on the next page.
   (b) Use the dropper to put three drops of the solution you saved in step 3 on the part of the microscope slide marked A.

Inquiry Focus



(c) Clean the dropper, and rinse it a few times with some of the liquid that you collected in step 4. Then use the dropper to collect a small amount of the liquid that you collected in step 4. Put three drops on the part of the microscope slide marked B.

(d) Clean the dropper, and rinse it a few times with some of the distilled water. Then use it to put three drops of distilled water on the part of the slide marked C.

(e) Set the microscope slide in a place where it will not be disturbed. When the liquid has evaporated, observe the slide to see what material, if any, is left on it. Make a sketch to record your observations.

6. Clean up and put away the equipment you have used.

Analyze

1. (a) What did you see in the top half of the flask after the water started to boil?

(b) What change of state must have occurred inside the flask? Explain how you know.

2. (a) Describe what you saw at the end of the rubber tubing in the beaker (step 4).

(b) What change of state must have occurred inside the tubing?

3. After the drops of liquid evaporated from the microscope slide, what (if any) material remained on the slide for

(a) the salt solution?

(b) the liquid collected in step 4?

(c) the distilled water?

4. In steps 4(c) and (d), you rinsed the eye dropper with the liquid that you were going to collect and then put on the microscope slide. What do you think was the purpose of this rinsing process?

Conclude and Apply

1. In step 4, which substance collected in the beaker: the solute or the solvent? Explain how you know.

2. What happened to the substance that was not collected in this beaker?

3. Which of the three samples in step 5 were probably pure water? Explain your answer.

4. In your opinion, would distillation be a suitable method for producing large amounts of pure water, for a large city? Give reasons to justify your opinion.

Part 3: Paper Chromatography

Safety

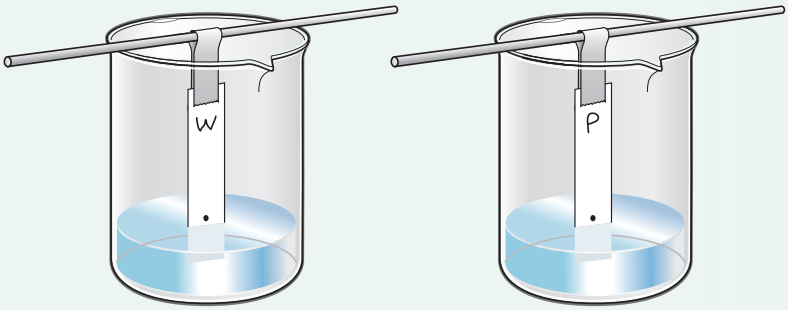
- Do not sniff the markers. Their fumes can irritate and damage the lining of the nose, throat, and lungs.
- Handle the scissors carefully.
- Dispose of all waste materials as directed by your teacher.

Materials

- 2 beakers (250 mL)
- filter paper
- black marker pen (water-soluble)
- black marker pen (permanent)
- water
- 2 plastic straws
- scissors
- ruler
- tape
- waxed paper

Procedure

1. Cut the filter paper into a narrow strip, about 2 cm wide. Make the strip long enough to fit inside the whole height of the beaker. Then make a second paper strip the same way.
2. Add water to each beaker until it reaches a depth of about 1 cm.
3. Use the water-soluble marker to make a dot of ink that is about 1.5 cm from the end of one paper strip. The dot of marker ink should be about 3 mm in diameter. At the other end of the strip, use a pencil to write the letter W (for water-soluble).
4. Repeat step 3 with the permanent marker and the other paper strip, but write the letter P (for permanent).
5. Tape the end of each strip to the centre of each straw so that the strips form a T-shape with the straws.
6. Place each straw across the top of a beaker so that the bottom of each strip hangs in the water and the ink dot is a few millimetres above the water. You might have to adjust the length of the paper strips so that the end with the ink dot is above water level.
7. Leave the beakers undisturbed until the colours have moved a few centimetres up the paper strips. Then remove them and leave them to dry on some waxed paper.
8. Clean up and put away the equipment you have used.



Analyze

1. Sketch and describe what you observed on each paper strip.
2. If you had forgotten to label the paper strips, how could you know which marker you had used to make the ink dots?

Conclude and Apply

1. Is ink a mixture of different substances? Justify your answer.
2. Do you think you could put the separated colours together again? Describe what you would do and explain why you think it would work.

Wild, Weird, Wonderful

www Science

Cleaning Up for Peat's Sake

In the early 1930s, politicians assessed and debated the state of the Newfoundland and Labrador economy. One very large component of the landscape was dismissed as being of little value. Bog lands, according to the Newfoundland Royal Commission of 1933, "extend over a large part of the Island, and their occurrence may be observed in every district of the country…. These soils are not suitable for the production of crops."

It is true that bogs are not suited for growing food crops such as fruits, vegetables, and grains. But there is a crop that forms naturally in bogs, and one company in the interior of the island of Newfoundland has learned how to harvest it with great success. That crop is peat.

Peat is a compacted mass of slightly or partly decomposed moss and other plant material that grows in the high-moisture, low-oxygen environment of bogs. Many gardeners use peat to condition their soil. One way that peat helps garden soil is by absorbing and holding onto moisture. At Hi-Point Industries in Bishop's Falls, this same property of absorption is used for other purposes as well.

Hi-Point makes and sells peat products for gardeners. But the company's main claim to fame is a range of products that help international oil companies clean up water and land that has been polluted by oil spills. More than 24 countries on nearly every continent benefit from Hi-Point's high-absorbency home-grown material.

Hi-Point's oil-absorbing peat is good for more than just the environment. It also benefits the province's economy. In 2006, Newfoundland and Labrador's Minister of Innovation, Trade and Rural Development announced that Hi-Point Industries Ltd was the winner of the Exporter of the Year Award.

Checking Concepts

1. What types of mixtures is the colander shown in the photo designed to separate? Name three other ways that you separate mixtures in your daily life.

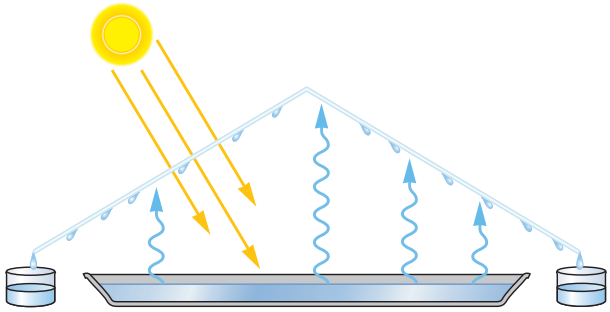
2. A mixture contains marbles of three different sizes. How could you use two different types of filter to separate this mixture? Draw sketches to show your method.
3. Explain how you could separate each of these mixtures.
   (a) wood chips and pieces of granite rock
   (b) iron filings and wood sawdust
   (c) salt and pepper
4. Explain how evaporation and distillation are similar and how they are different.

Understanding Key Ideas

5. The small pitcher shown in the photo is used to separate fat from gravy juices.

   (a) What property of fat and gravy juices lets you separate them?
   (b) The pitcher is designed so that gravy juices, not fat, pour out of the spout. Gravy juices are mostly water. Why does the spout come from the bottom of the pitcher?

   If you did not have a gravy pitcher, suggest two methods that you could use to separate the fat from the gravy juices. Assume that you have plenty of time. (Hint: If you are having trouble coming up with one method, think about how liquids behave during paper chromatography.)
6. The diagram shows how you could get clean drinking water from salt water. What separation method is used to collect pure water from salt water?
   (a) Describe *how* this method works.
   (b) Use the particle theory to explain *why* this method works.



Pause and Reflect

In 2001, a group of scientists who specialize in studying fog met in St. John's. One of the scientists was Canadian atmosphere specialist, Dr. Bob Schemenaur. He has designed a method to help people who live in dry regions collect water from the air by hanging large nets. When fog blows into a net, tiny water droplets in the fog catch on the fine plastic mesh of the net. These droplets then trickle down the net into a collecting vessel. What separation method is used to separate drinkable water from fog? Give reasons to justify your answer.

9.2 Separating Mixtures from Underground

Petroleum is a mixture that is made up of many solid, liquid, and gas substances. Valuable substances in petroleum can be separated by fractional distillation, which is based on their boiling points. The separated parts of petroleum may be processed further to make hundreds of thousands of other products. Gold ore is a mixture of solid substances. Gold nuggets that are mixed with sand, gravel, and mud may be separated by panning, which is a filtering-like method.

Key Terms

fractional distillation
ore
petroleum

Earth is rich in natural mixtures. Over thousands of years, we have developed technologies to process these mixtures to make useful products. This section will focus on two natural mixtures and the products we derive from them. One of these mixtures is a liquid: petroleum. The other is a solid: gold ore.

A Liquid Mixture from Underground

Petroleum, also called crude oil, is a complex mixture of liquid, solid, and gaseous substances. Petroleum is the source of most of the fuels and lubricants that run the machines we depend on.

Oil exploration companies spend many millions of dollars to find deposits of petroleum. In Canada, some of these deposits are found underground mainly in Alberta and Ontario. Other deposits are found under the ocean bottom off the east and west coasts. Figure 9.12 shows an oil rig pumping oil from beneath the ocean floor off the coast of the island of Newfoundland.

Pumping petroleum to the surface is just the first step in making use of this valuable mixture. To make useful products, the petroleum must be processed to separate and refine its components.

Figure 9.12 This oil rig is extracting crude oil from the Hibernia oil field, which is the fifth-largest source of petroleum ever found in Canada.

Fractional Distillation

You know that simple distillation is a way to separate a single solute and a single solvent from a solution. The solution is heated so that at least one part starts to change state to become a gas when it reaches its boiling point. Meanwhile, the other part stays liquid because its temperature is below its boiling point. Look again at Figure 9.9 on page 283. Notice that the gas travels up and away from the mixture and from the source of

heat. In a separate chamber, the gas is cooled, and it changes state back into a liquid. The condensed liquid is then collected.

Petroleum is a much more complex mixture than salt water. Petroleum contains hundreds of different substances. Each of these substances has its own boiling point. This is the key to separating petroleum into its parts. **Fractional distillation** is a process that uses the boiling points of substances to separate a complex mixture into its parts. The process is done in a two-tower structure like the one shown in Figure 9.13. In the shorter tower, the petroleum is heated strongly enough to change it into a mixture of gases. Then this gas mixture is pumped into the bottom of the taller tower.

Inside the tall tower, the hot gases rise. As they rise, they cool. As the temperature of each part cools to just below its boiling point, it condenses. That is, it becomes a liquid. The parts of the gas mixture that have a high boiling point will condense near the bottom of the tower, because they are still very hot. Different gases condense at different levels, depending on their boiling points. Near the top (the coolest part of the tower), a few parts of the original mixture remain in the gas state. (Why would these parts of the mixture stay in the gas state?)

Each part (or fraction) of the mixture is collected in pipes at its own level and is sent to a different part of the oil refinery to be processed further. All the products that are made from the original petroleum are known as petrochemicals.

Word Connect

The "fractional" part of the term fractional distillation comes from the same root word as "fracture", meaning "break up." The fractional distillation of petroleum "breaks up" the mixture in separate parts, or "fractions."

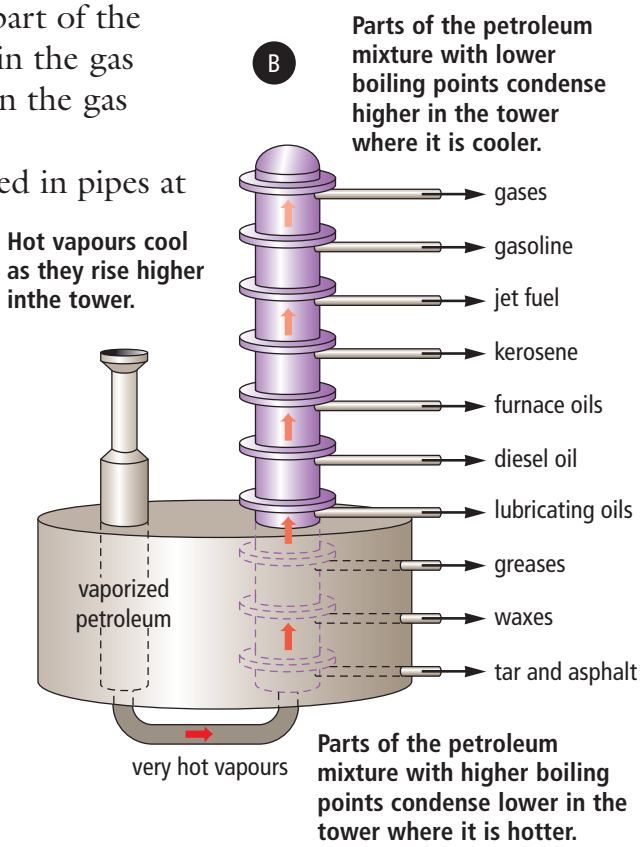


Figure 9.13 Fractional distillation towers (A) are common sights in the oil-producing regions of North America. The diagram (B) shows some of the products that are made from each separated part of the original petroleum mixture.

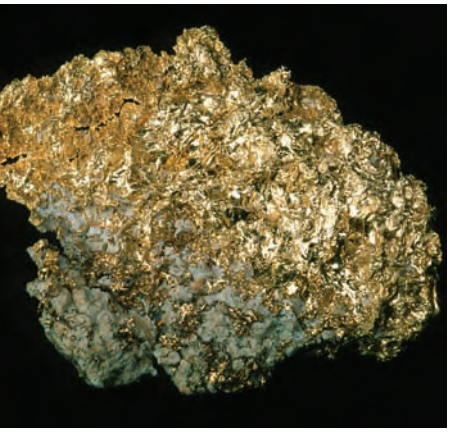


Figure 9.14 Gold is one of the few metallic pure substances that may be found in its pure form in nature. Most metals are combined with other metals in ways that require a lot of processing to separate them out in their pure form.

A Solid Mixture from Underground

Most underground materials are solids—solid rocks. Rocks are mixtures. For example, the rock shown in Figure 9.14 is a mixture that contains a highly desirable substance: gold. Rock that contains gold is called gold ore because it can be processed to get pure gold. An **ore** is a rock mixture that contains one or more valuable substances. Another example of an ore is iron ore—a rock that contains iron.

Gold is valuable because it is beautiful and rare. It is also valuable because of its properties. Gold resists wear and corrosion. It is also fairly soft, so it can be made into jewelry easily.

Gold is so valuable that some people are willing to spend a lot of time, energy, and money to get it. In the nineteenth century, reports of newly discovered gold deposits led to gold rushes. A gold rush is a situation in which many people "rush" to an area that has gold so they can claim some for themselves. The first gold rush in North America started in 1848 in California. There was another famous gold rush in the Yukon Territory in 1897. Nova Scotia had a smaller-scale gold rush in the mid-1800s.

During the gold rushes, miners did not have to dig to find gold. They looked in and around streams. The simplest way to find gold in streams was by panning. A miner dug out material from the stream bed and swirled it in a pan with lots of water. Gold is very dense. Even tiny pieces of gold have more mass than pieces of sand or gravel. As the miner swirled the mixture from the stream bed, sand, gravel, and mud were washed away. If the miner was lucky, a nugget or two of pure gold would be left at the bottom of the pan.

internet connect

Aspirin™, basketballs, chewing gum, duct tape, eyeglass lenses, and fertilizer are some of the products that are made from petrochemicals. Can you keep this alphabetical list going? Find a petrochemical product for each letter of the alphabet. Start your search at **www.discoveringscience.ca**.

Reading Check

1. Is petroleum a mixture or a pure substance? How do you know?
2. What is fractional distillation?
3. Why is fractional distillation used to process petroleum?
4. Is gold ore a mixture or a pure substance? How do you know?

9-2A Panning for "Gold"

Find Out ACTIVITY

Make a working model to show how panning for gold works.

Safety

- Turn off the hair dryer when you are not using it.

Materials

- about 1 L Styrofoam packing chips
- about 1 L marbles
- large paper bag
- large basin
- hair dryer

What to Do

1. Pour the foam chips and marbles into the large paper bag. Mix them thoroughly.
2. Place the mixture in a large basin. Use a circular motion to swish and swirl the basin steadily. Have a partner aim a hair dryer across the top of the basin. Your partner should aim away from you, for safety.

What Did You Find Out?

1. Identify the part of your model that represents:
   (a) gold nuggets
   (b) gravel
   (c) running water
2. How is your model similar to the method that was used to pan for gold? How is it different?

internet connect

The hydromet (hydrometallurgical) process is used to separate desired substances such as nickel and copper from their ores at mining operations such as the Voisey's Bay Project. How does this process work? You can start to find out by going to **www.discoveringscience.ca**.

Explore More

Is there gold in your province? Make a poster or write a report to outline the history of gold mining in Newfoundland and Labrador. Is gold still mined today? Start your search at **www.discoveringscience.ca.**

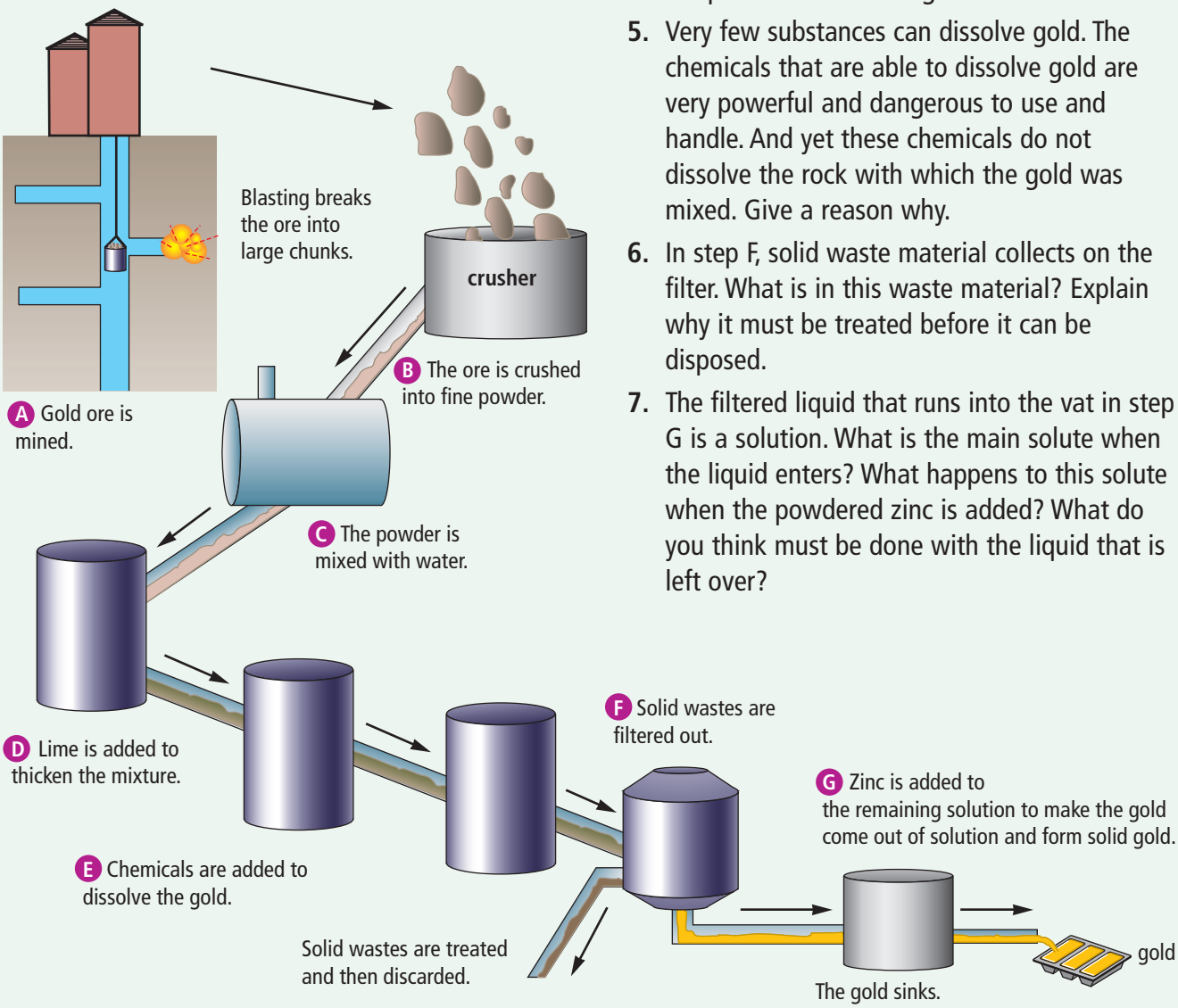
9-2B Mining for Gold

Think About It

Gold panning was so easy to do, even for amateurs, that most stream-bed deposits have now been exhausted. Very little gold is found this way any more. Instead, gold ore must be brought up from underground and then processed to extract the gold from the rock.

What to Do

Study the diagram. Use it to answer the What Did You Find Out questions.



What Did You Find Out?

1. Is the gold still part of a mixture after step A? How do you know?
2. What do you think is the purpose of step B?
3. How does step C make it easier to pump the ore through the system?
4. The liquid mixture in step C is very runny. The powdered ore will settle out quickly unless something is done. How does step D prevent the powder from settling?
5. Very few substances can dissolve gold. The chemicals that are able to dissolve gold are very powerful and dangerous to use and handle. And yet these chemicals do not dissolve the rock with which the gold was mixed. Give a reason why.
6. In step F, solid waste material collects on the filter. What is in this waste material? Explain why it must be treated before it can be disposed.
7. The filtered liquid that runs into the vat in step G is a solution. What is the main solute when the liquid enters? What happens to this solute when the powdered zinc is added? What do you think must be done with the liquid that is left over?

Checking Concepts

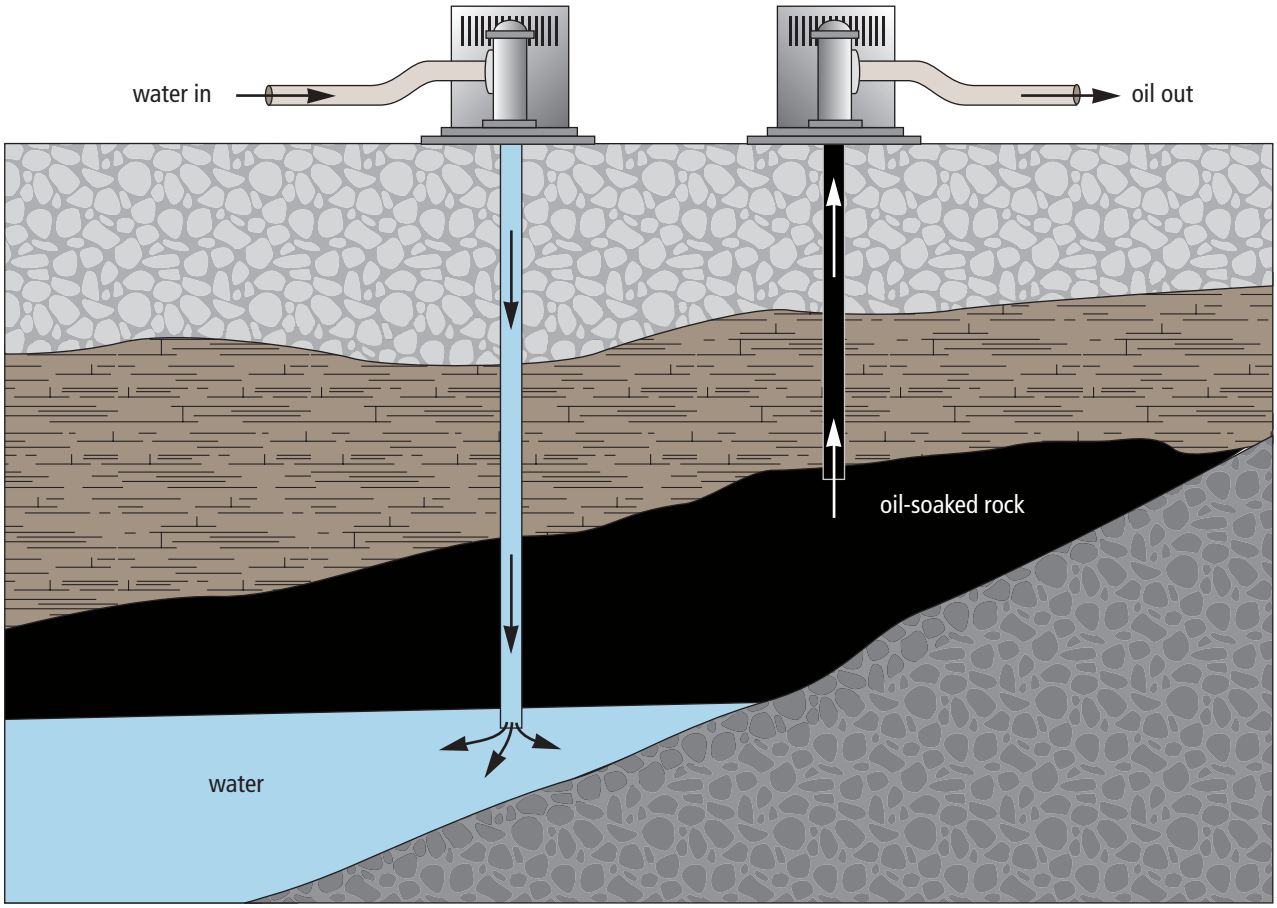
1. Petroleum is a mixture. Describe this mixture.
2. Name two places in Canada where deposits of petroleum may be found.
3. What happens to petroleum after it has been pumped to the surface?
4. How is fractional distillation of petroleum similar to the distillation of a salt water mixture? How is it different?
5. What is a petrochemical?

Understanding Key Ideas

6. Design a flowchart to describe the changes that occur to petroleum as it enters and leaves a distillation tower at an oil refinery.
7. Explain why an ore is a mixture.
8. Explain why panning was a useful method for separating gold nuggets from the rock material of stream beds.

Pause and Reflect

Like water wells, oil wells use pumps to bring petroleum deposits to the surface. Pumping petroleum is not as easy as pumping water because the oil often is a very thick liquid. It is found in small, sponge-like pores of underground rock. The diagram shows how petroleum is brought up to the surface. Which of the two pumps is lifting oil up to the surface? What is the other pump doing? How do you think it helps to separate the oil from the rock?



Career Connect

Oil Spill Adviser

The words "chocolate mousse" and "blowout" may make you think of a decadent dessert and a terrific electronics sale. These terms are also used to describe oil spills. Hesham Nabih knows all about oil spills. He runs a company that helps government agencies and oil companies prevent, manage, and contain them.

Q. How did you get interested in cleaning up oil spills?

A. I started my career as an oceanographer. An oceanographer measures water currents and studies the chemistry and ecology of bodies of water. Twenty years ago, while at a Red Sea resort in Egypt, I stepped on a ball of tar on the beach. After that, I decided to focus my efforts on fighting oil pollution. Now I develop computer software that is used to train people on how to clean up oil spills.

Q. What is an offshore blowout?

A. An offshore blowout occurs at sea when gas or oil, under high pressure, bursts out of an underwater reservoir during oil drilling or production. Oil rigs have control valves known as "blowout preventers" to stop the flow of oil if problems occur during drilling. Blowouts still happen, though.

Q. How do oil spills affect the environment?

A. Oil spills can have a serious impact on ecosystems. Oil can contaminate and smother both plants and animals. The chemical parts of oil are toxic and can cause birth defects. The environment can also be physically damaged by the methods used to clean up a spill.

Q. Cleaning up oil spills, especially cleaning up oil after it has been spilled in the water, is an example of separating a mixture. What are some of the methods used to clean up oil spills?

A. You can divide cleanup techniques into two general categories: mechanical and chemical. Mechanical devices include pressure washers, used on land, and skimmers, used on water. Skimmers remove oil from the water's surface. The two major types of skimmers are suction skimmers and adhesion skimmers. Suction skimmers float on the surface of the water and use a vacuum to suck up the oil. Adhesion skimmers soak up the oil using drums, belts, or ropes.

Q. What about chemical cleanup?

A. With chemical cleanup, chemicals are applied to the oil to break it up into tiny droplets. Micro-organisms such as bacteria can more easily convert the tiny droplets of oil into less harmful substances. Breaking up the oil into droplets also prevents the oil and water from forming "chocolate mousse", the term given to mixtures of oil and water that look like oily, reddish-brown pudding.

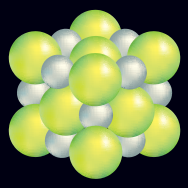
NATIONAL GEOGRAPHIC

VISUALIZING SALT

The salt you use every day comes from both the land and the sea. Some salt can be mined from the ground in much the same way as coal, or salt can be obtained by the process of evaporation in crystallizing ponds.

MINING SALT Underground salt deposits are found where there was once a sea. Salt mines can be located deep underground or near Earth's surface in salt domes. Salt domes form when pressure from Earth pushes buried salt deposits close to the surface, where they are easily mined.

EVAPORATION PROCESS Workers fill evaporation ponds, like these near San Francisco Bay, California, with salt water, or brine. They move the brine from pond to pond as it becomes saltier through evaporation. (Red-tinted ponds have a higher salt content.) The saltiest water is then pumped from evaporation ponds into crystallizing ponds, where the remaining water is drained off. In the five years it takes to produce a crop of salt, brine may move through as many as 23 different ponds.



Unit cell of sodium chloride (NaCl)

TABLE SALT Raw sodium chloride is washed in chemicals and water to remove impurities before it appears on your dining-room table as salt. Iodine is added to table salt to ensure against iodine deficiency in the diet.

SALT MOUNDS When the crystallizing ponds are drained, the result is huge piles of salt, like these on the Caribbean island of Bonaire.

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated methods that may be used to separate the parts of heterogeneous and homogeneous mixtures. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Separating Heterogeneous Mixtures
2. Separating Homogeneous Mixtures
3. Separating a Liquid Mixture from Underground
4. Separating a Solid Mixture from Underground

Checking Concepts

1. What is the function of the filter used in each of the following situations?
   (a) A nurse wears a surgical mask while examining a patient's mouth.
   (b) The air filter in a vacuum cleaner has to be changed every so often.
   (c) An auto mechanic changes the gasoline filter during a maintenance checkup.
   (d) An archeologist passes soil through a sieve while looking for ancient pottery fragments.
   (e) A hanging basket for plants has small holes in the bottom through which water can pass.
   (f) Some people wear a mask made of mesh that covers their whole head when they walk through an area with lots of mosquitoes.
2. Could you use mechanical sorting to separate and recover all the parts of a homogeneous mixture? Explain why or why not.
3. Could you use evaporation to separate and recover all the parts of a heterogeneous mixture. Explain why or why not.
4. The membrane (skin-like covering) of a cell prevents most substances from entering the cell and most substances from leaving it. Only water particles and particles of some salts are able to pass unassisted through the cell membrane. Is the cell membrane a type of specialized filter? Give reasons to justify your answer.
5. Explain why (a) magnetism and (b) sorting by hand are examples of mechanical sorting.
6. In a restaurant, several kilograms of dried rice are poured into a large pot filled with water. Soon, small specks of dust and dirt are visible on the surface of the water. The rice is on the bottom of the pot, below the water's surface.
   (a) Identify the type of mechanical sorting that is described in this case.
   (b) Identify the property on which this separating technique depends, and explain why it works.
7. Use the particle theory of matter to explain why distillation can separate pure water from a sample of tap water.

Understanding Key Ideas

8. People who get lots of unwanted e-mail, called spam, may install a computer program called a spam filter. Compare a spam filter to another type of filter of your own choosing, and explain how the two filters are similar and different.
9. You have a mixture of clean sand and pure table sugar. How can you get pure sugar from this mixture? Describe your method in detail and list the equipment you would need.
10. The term "volatile" is used to describe a substance that changes state to become a gas at a low temperature. The list below shows products of fractional distillation of petroleum. Refer to Figure 9.19. Sort these products in order of their volatility, from lowest to highest.
    - diesel oil
    - gasoline
    - kerosene
    - propane
    - aviation fuels
    - asphalt and tar
    - greases
    - lubricating oils
11. You are thirsty and ask for a glass of apple juice. You are given two glasses of apple juice. One appears to be homogeneous. The other is heterogeneous, because you can see bits of sediment-like material at the bottom of the glass.
    (a) Which of the glasses of apple juice is a solution?
    (b) Describe what you could do to make the other mixture into a solution.
12. Imagine that you place the following materials into a large container: 100 mL of water, 100 mL of vegetable oil, a handful of marbles, a tablespoon of gravel, a handful of puffed wheat, a tablespoon of iron filings. Describe the methods that you would use to remove as many of the parts of this mixture as you can.
13. Describe how you might separate the sugar from a solution of vinegar and sugar.
14. "Campfire" coffee is made by boiling ground coffee beans in water over a campfire or a special butane burner. Then the coffee mixture may be poured through a strainer. Other methods of making fresh coffee at home also involve filtering.
    (a) Describe the role of filtration in making coffee.
    (b) What enables the coffee filter to do its job?

Pause and Reflect

You are refilling a pepper shaker when it overflows into a sugar bowl. How can you recover the pepper from the sugar? If you did not have access to water or any other solvent, would you be unable to recover the pepper from the sugar? Explain why or why not.

Unit Summary

7 Matter can be classified as mixtures and pure substances.

- Matter can be either mixtures or pure substances.
- Mixtures may be either heterogeneous or homogeneous.
- Homogeneous mixtures (solutions) have the same properties throughout.
- Heterogeneous mixtures have different visible parts with different properties.
- Matter is either a mixture or a pure substance based on the types of particles that make it up.
- Each pure substance has its own type of particle, which is different from the kinds of particles that make up all other pure substances.

8 Some substances dissolve to form solutions faster and more easily than others.

- In a solution, the substance that dissolves is the solute, and the substance in which the solute dissolves is the solvent.
- A substance is soluble in a solvent if it dissolves in the solvent. A substance is insoluble in a solvent if it does not dissolve in the solvent.
- A concentrated solution has a larger mass of solute for certain volume of solvent. A dilute solution has a smaller mass of solute for a certain volume of solvent.
- Solution concentration may be expressed in units of grams of solute per litre of solvent (g/L).
- A solution is saturated when as much solute has dissolved in a solvent as it can, at a certain temperature.
- Different solutes have different solubilities, which may be increased by increasing the temperature.
- Stirring a solution increases the rate of dissolving but not the solubility of the solute.

9 Many useful products depend on technology for separating mixtures and solutions.

- Heterogeneous mixtures may be separated by methods that include sorting by hand, mechanical sorting, and filtration.
- Mechanical sorting of a mixture is based on properties such as particle size and magnetism.
- Homogeneous mixtures may be separated by methods that include evaporation, distillation, and paper chromatography.
- Petroleum is a complex mixture that can be separated by fractional distillation.
- An ore is a rock mixture that has one or more valuable substances.

Key Terms

- alloy
- mixture
- heterogeneous mixture
- homogeneous mixture
- pure substance
- solution

Key Terms

- concentrated solution
- concentration
- dilute solution
- dissolves
- insoluble
- saturated solution
- solubility
- soluble
- solute
- solvent
- unsaturated solution

Key Terms

- evaporation
- filtration
- fractional distillation
- mechanical sorting
- ore
- paper chromatography
- petroleum
- simple distillation

Purifying Mixtures

Each step of a separation may cost a company a great deal of money. This is why materials and products that are pure or nearly pure can be costly to buy. As companies develop methods that can separate a mixture more effectively, the cost can come down.

Problem

In this project, you will find the most effective manner to separate a mixture.

Saftey

- Be careful if you use a hot plate. Unplug it when it is not in use.
- Wipe up any spills as soon as they occur.

Materials

- variety of mixtures prepared by your teacher
- cups or beakers of various sizes
- magnet
- plastic wrap
- variety of filters
- funnels
- hot plate
- evaporating dishes
- water
- paper
- labels or grease pencil

Criteria

- In small groups, separate a mixture into its parts.
- Include the fewest number of separation steps as is needed to produce purified parts.
- Design a flowchart to show the steps and methods that you used in your final separation procedure.

Procedure

1. Obtain a dry mixture from your teacher. With your group, identify as many substances in the mixture as you can. Record these in a list. Be alert to substances that might be present but not clearly visible. (For instance, salt and white sand can look alike.)
2. Brainstorm the types of methods you could use to separate your mixture. As a group, decide on which methods you will use and in which order.
3. Outline the steps in each method of separation and the substance that you plan to isolate at each step. You may need to revise your outline a few times before you come up with the best sequence of steps.
4. Separate your mixture. Collect each part in a separate, labelled container. Note: If any parts are contaminated (sand stuck to larger pieces of gravel, for instance), you must purify them further.
5. Do several trials to come up with the procedure that will give you the best results in the fewest steps. Make a flowchart to record your final method.

Report

1. How well did you obtain purified parts of the mixture? How did the order of steps affect how completely you were able to separate them?
2. Which methods did you use to separate parts that were not clearly visible? How did you know that each method worked?
3. How could you improve your methods of separation? What other equipment or methods might have helped you improve the quality and effectiveness of your separations?

Safe, Clean Water for Everyone

If you live in a large city or town, you may not realize that the water running down your sink or toilet eventually ends up in a river, a lake, or the ocean. What about the rain and snow that fall to the ground? On the ground, rain and snow carry oil from the roads and dissolved salt from melted slush in winter. Look along the gutters on every city street. Where does the run-off water go after it trickles down storm sewers and out of sight? What other substances might be carried in this water? In rural areas, were does the wastewater go?

Background

Water is one of the most plentiful mixtures on Earth. It is also the most essential for all living things. Many different natural and human activities add substances to water that require us to treat it so that it is safe to drink and wash with. Many of these treatments involve separation methods that you have been studying.

Find Out More

Unless you get your water from a well and this source has been tested to prove its safety, all the water in your community is treated in some way to make it safe. Use the Internet (start at **www.discoveringscience.ca**), books, magazines, and newspapers to find out the methods that are used to make water safe to drink and wash with in your community.

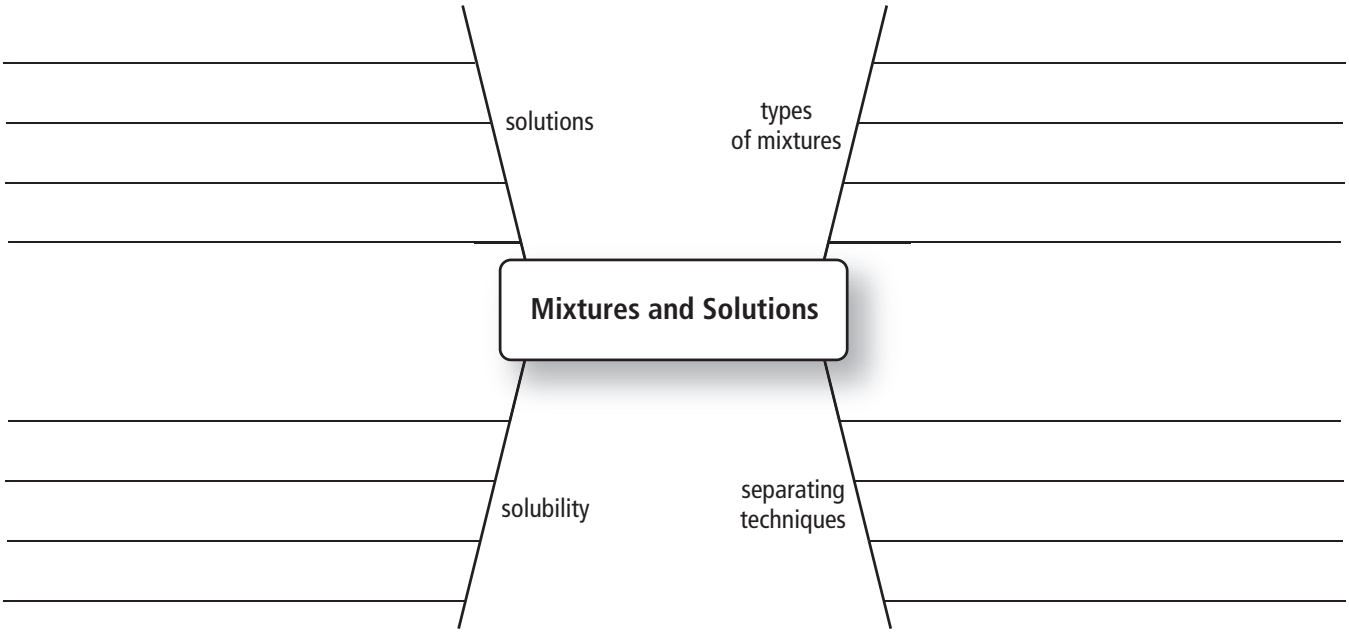
Report

1. Create a poster to display the results of your research.
2. Design an Internet page (such as a FAQ) that has additional information and links to sources for more information about water treatment.

In what ways do the process shown in these photos contribute to pollution of water resources such as wells, rivers, lakes, and the ocean?

Visualizing Key Ideas

Copy the following spider map into your notebook. Beside each topic, fill in as many words as you can that are related to that topic. Do not look at your textbook. When you have completed the map, go back through this unit and look for other words that you could include. Add these words to your spider map in a different colour of pen.



Using Key Terms

2. In your notebook, say whether the following statements are true or false. If a statement is false, rewrite it to make it true.

(a) A solution is a heterogeneous mixture.

(b) The particles that make up a pure substance are the same types of particles that make up all other pure substances.

(c) Mechanical sorting may be done to separate the parts of a heterogeneous mixture.

(d) The concentration of a solution may be expressed as the volume of solvent that can dissolve in a certain mass of solute (g/L).

(e) A saturated solution cannot allow more solute to dissolve at a certain temperature.

(f) An unsaturated solution cannot allow more solute to dissolve at a certain temperature.

(g) All matter can be classified as either a mixture or a pure substance.

(h) Filtration is one method that can be used to separate a solution.

(i) Units of ppm tell you the concentration of a solution in grams per millimetre.

(j) There are very few examples of mixtures in the world around you.

(k) In a solution, the solute is the substance that does the dissolving and the solvent is the substance that dissolves.

(l) A solution of salt and water is a homogeneous solution because the salt will settle if it is left undisturbed.

Checking Concepts

7

3. Explain the difference between a mixture and a pure substance.
4. What is a heterogeneous mixture? How is it different from a homogeneous mixture?
5. Describe a homogeneous mixture using the particle theory of matter.
6. What is an alloy?
7. Is a solution a heterogeneous or a homogeneous mixture? How do you know?

8

8. Contrast a solute with a solvent.
9. What is the difference between a saturated solution and an unsaturated solution?
10. Use an example to explain what the term "solubility" means.
11. Explain the difference between a dilute solution and a concentrated solution.
12. What happens to the solubility of a gas in a liquid as temperature increases?

9

13. Why are magnetism and flotation examples of mechanical sorting?
14. Why is a fishing net a type of filter?
15. What is the name of the method that is used to separate the parts that make up petroleum?
16. Is separating gold nuggets from stream-bed gravel a type of mechanical sorting? Why or why not?

Understanding Key Ideas

17. Identify the following as a mixture or a pure substance, and give a reason to explain your choice.
    (a) oatmeal-and-raisin cookie
    (b) gold
    (c) petroleum
    (d) carbon dioxide gas
    (e) ink
    (f) tomato juice
18. Classify each of the mixtures you identified in question 17 as heterogeneous or homogeneous. Explain your decisions.
19. Explain how the particle theory of matter distinguishes between a mixture and pure substance.
20. Agree or disagree with the following statement, and justify your answer: "Many mixtures are neither clearly heterogeneous nor clearly homogeneous. Instead, they are mixtures of mixtures."
21. Explain why pizza is a heterogeneous mixture, while clean air is a homogeneous mixture.
22. Identify the solute and the solvent in each of the following solutions. (Note: There may be more than one solute in one or more of the solutions.)
    (a) soda water
    (b) vinegar
    (c) brass
    (d) ice tea
    (e) instant coffee
    (f) lemonade
23. Draw sketches to show how the particle theory of matter could explain the difference between a concentrated solution of sugar and water and a dilute solution of sugar and water.

24. Is there a limit to the concentration of a solution? Explain your answer.

25. It takes longer to dissolve 5 g of granulated sugar in water at 25°C than to dissolve 5 g of powdered sugar in water at the same temperature. Explain why.

26. How does pressure affect the solubility of a gas such as carbon dioxide in a liquid such as water?

27. Give three examples of mechanical sorting being used to separate a mixture.

28. You want to separate a solution and collect both the solute and the solvent. Explain why distillation will let you do this but evaporation will not.

29. (a) Explain how a filter works.
(b) Give five examples of filtration being used to separate mixtures.

30. Use the terms *dilute* and *concentrated* to describe how the sap from maple trees becomes maple syrup.

Thinking Critically

31. (a) Identify three substances that are soluble in water.
(b) Identify three substances that are insoluble in water.
(c) If a substance is insoluble in water, could it be soluble in another solvent? Use an example to support your answer.

32. Explain how you could tell if a solution of salt and water is saturated or not.

33. One type of iron ore is composed of rock and a pure substance called magnetite. Magnetite is made up of iron particles and oxygen particles.
(a) Magnetite is a magnetic substance, as you can see in the photo. How could you separate magnetite from the rock it is mixed with?
(b) Magnetite and iron share the property of magnetism. How are they different?
(c) How is iron ore different from gold ore? Explain your answer.

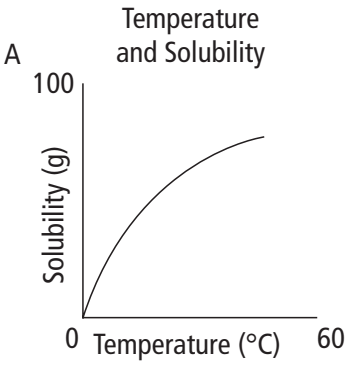
34. You are given two samples of water—one from Lake Ontario and one from the Atlantic Ocean. The labels have fallen off the sample bottles. Outline a procedure you could use to determine which sample is which. (Note: Tasting is not allowed.)

Developing Skills

35. Use drawings to model the difference between the following:
(a) a dilute solution and a concentrated solution
(b) a saturated solution and an unsaturated solution
(c) a substance in water that is soluble and a substance in water that is not soluble

36. Which graph shows the relationship between increasing temperature and solubility?

A



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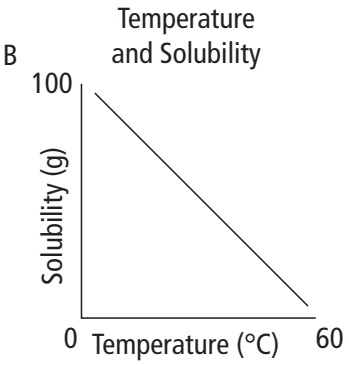

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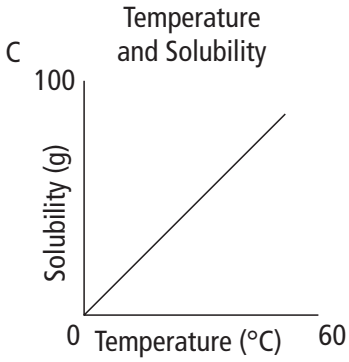

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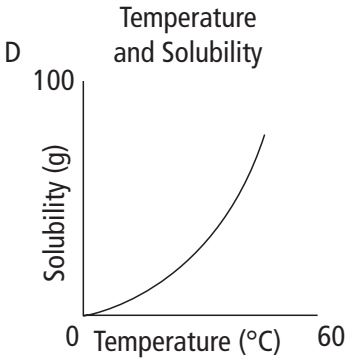


37. Convert the following concentrations to units of grams per litre.

(a) 15 mg/L
(b) 20 g/100 mL
(c) 159 mg/L
(d) 0.14 g/100 mL

38. The intensity of colour can be used to compare the concentration of two or more solutions. The illustration below shows three cups of tea. Which cup holds the most concentrated tea solution? Which cup holds the most dilute tea solution? Explain your reasoning.

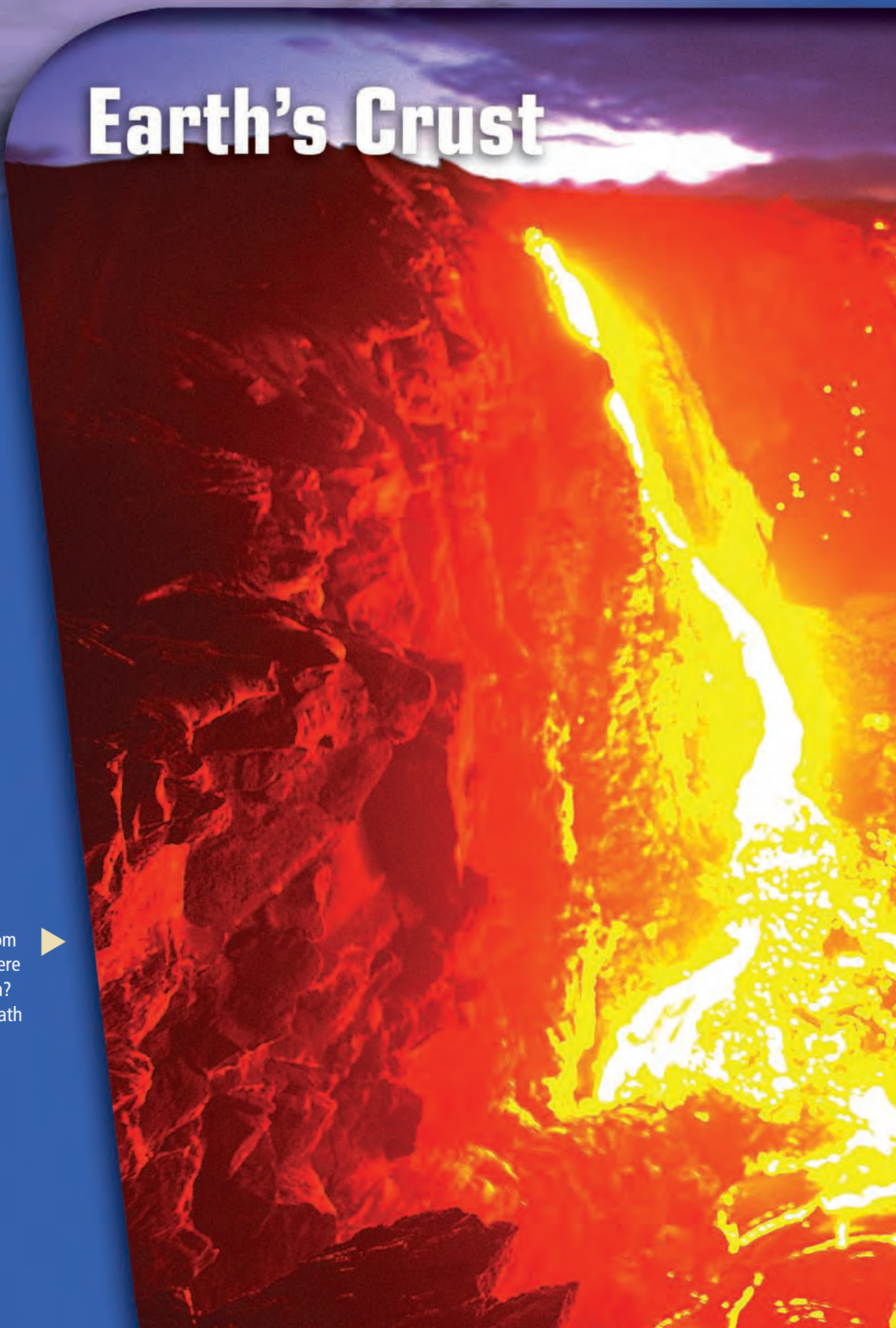
Pause and Reflect

Which of the main points of the particle theory of matter are most useful for explaining each of the following?

(a) why water is different from sugar
(b) why nail polish is insoluble in water
(c) why water evaporates
(d) why fractional distillation of petroleum works

UNIT

4 Earth's Crust



White-hot lava pours from an erupting volcano. Where does the heat come from? What is happening beneath Earth's surface?

Key Ideas

10 **Earth's crust is made up of rocks and minerals.**

10.1 Investigating Minerals
10.2 Investigating Rocks
10.3 The Rock Cycle and Rock and Mineral Resources

11 **Earth's crust is constantly changing.**

11.1 A Moving, Changing Crust
11.2 How Earthquakes and Volcanoes Shape Earth's Crust
11.3 Mountain Building and Geologic Time

12 **Soil is the living component of Earth's crust.**

12.1 Weathering, Erosion, and Soil Formation
12.2 Soil Types and Characteristics
12.3 Sustaining Fertile Soils

Getting Started

Gilbert Hay's sculpture "Dance of Joy" is made from rock found near Nain, Labrador.

Why is the island of Newfoundland called "The Rock?" Finding the answer is as easy as looking beneath your feet. The province of Newfoundland and Labrador is built on rock, covered in places by a thin layer of soil. That rock includes some of the oldest and most beautiful minerals on Earth.

The rock that makes up Newfoundland and Labrador is put to many uses both in our province and around the world. For example, the anorthosite quarry shown in the photograph above is the source of stone that decorates buildings in Italy and art that is shown throughout North America.

The Ten Mile Bay quarry is situated near Nain in Labrador and is operated by the Labrador Inuit Association. The anorthosite rock in the quarry formed about 1.3 billion years ago, deep in Earth's crust. Anorthosite is used as a decorative covering for buildings, called dimension stone. The Ten Mile Bay quarry at Nain produces about 1000 m^3 of dimension stone each year. Much of the anorthosite quarried at Ten Mile Bay and Igiak Bay is sold to markets in Europe. Anorthosite is also used for other decorative purposes, such has counter tops, table tops, monuments, and furniture.

Gilbert Hay is a senior Inuit carver who creates sculptures in anorthosite. He gathers his stone from the edges of the Ten Mile Bay quarry. Gilbert practises a traditional lifestyle. The images he sculpts are inspired by his love of the land and the sea and pride in his Inuit heritage.

internet connect

Find out more about Gilbert Hay and other artists who work with rocks and minerals. Start your search at **www.discoveringscience.ca.**

What Makes a Rock a Rock?

Find Out ACTIVITY

It is perfectly easy to describe a rock. Or is it? In this activity, you will examine some common objects and determine which ones are rocks and which ones are not.

Materials

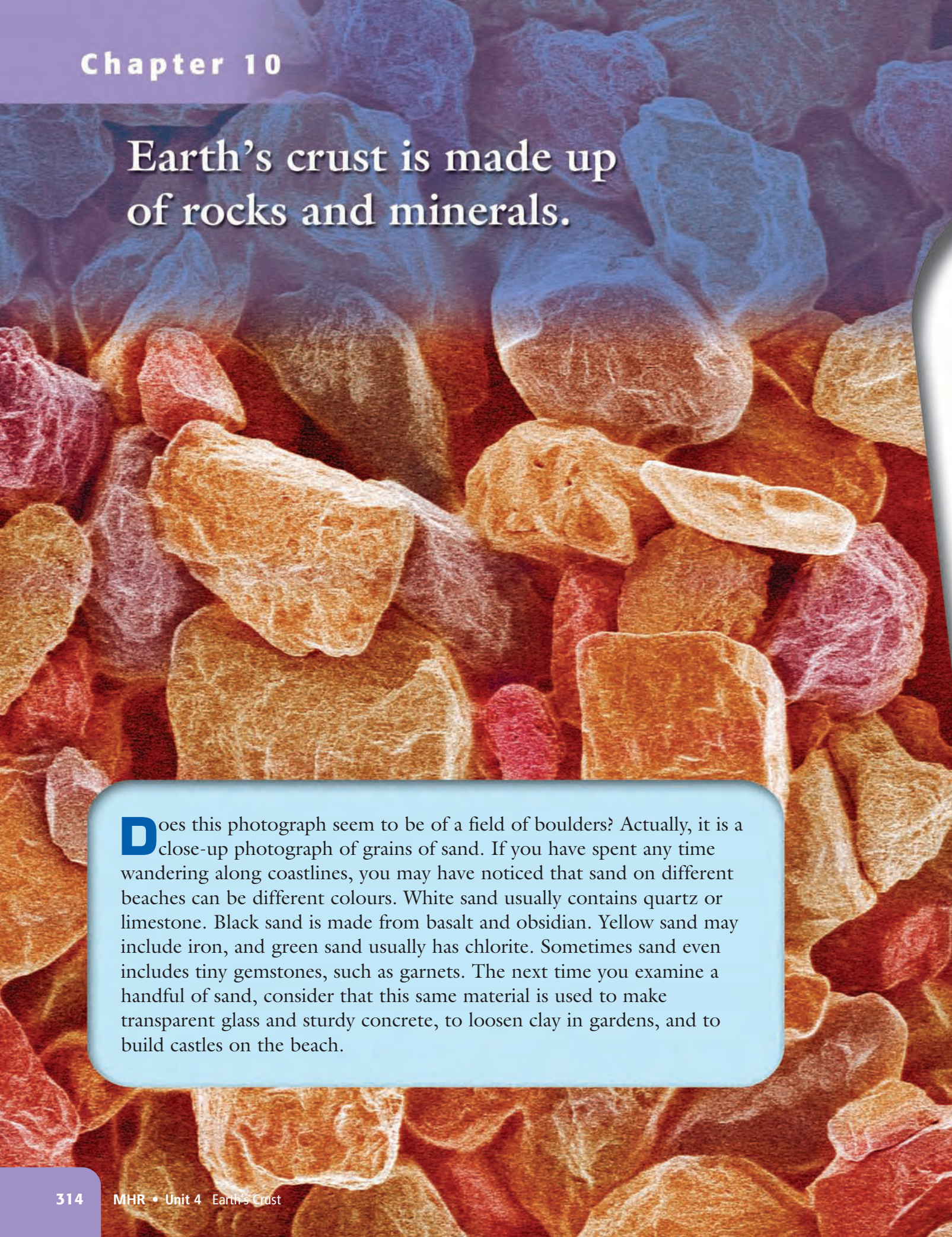
- selection of materials provided by your teacher

What to Do

1. Your teacher will give you a variety of materials to examine. Some materials are rocks; others are not.
2. With a partner, examine the materials. Make a list of characteristics that you could use to group or classify these materials.
3. Classify all the materials into two groups using your list of characteristics. Compare your classifications with those of other students.
4. Discuss with your partner what makes a rock a rock. Record your ideas.

Chapter 10

Earth's crust is made up of rocks and minerals.



Does this photograph seem to be of a field of boulders? Actually, it is a close-up photograph of grains of sand. If you have spent any time wandering along coastlines, you may have noticed that sand on different beaches can be different colours. White sand usually contains quartz or limestone. Black sand is made from basalt and obsidian. Yellow sand may include iron, and green sand usually has chlorite. Sometimes sand even includes tiny gemstones, such as garnets. The next time you examine a handful of sand, consider that this same material is used to make transparent glass and sturdy concrete, to loosen clay in gardens, and to build castles on the beach.

What You Will Learn

In this chapter, you will

- **classify** minerals based on their physical properties
- **classify** rocks based on their characteristics and how they formed
- **identify** relationships between rocks in the rock cycle
- **explain** how society's needs lead to new uses of rocks and minerals
- **research** the uses of rocks and minerals in Newfoundland and Labrador

Why It Is Important

Rocks and minerals have been used by humans for many thousands of years for everything from tools and building materials to paints and jewellery. Almost every product we use either comes from a mineral or has minerals involved in its manufacture.

Skills You Will Use

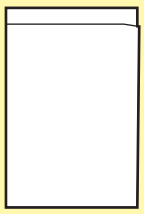
In this chapter you will

- **select** methods and tools for collecting and organizing data to identify minerals
- **use** a classification key to identify common minerals
- **observe** differences in the properties of rocks and minerals

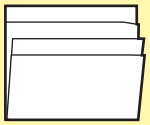
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 10.

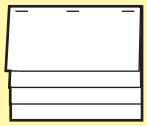
STEP 1 **Stack** two sheets of 8.5″ × 11″ paper so that the back sheet is 2 to 3 cm higher than the front sheet. (**Hint:** From the tip of your index finger to your first knuckle is about 2.5 cm.)



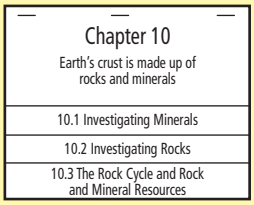
STEP 2 **Bring** the bottom of both sheets upward and **align** the edges so that all of the layers or tabs are the same distance apart. **Fold** the paper and **crease** well.



STEP 3 **Staple** the papers along the fold.



STEP 4 **Label** the Foldable as shown.



Organize As you read the chapter, take notes and define terms under each tab.

10.1 Investigating Minerals

A mineral is a pure, naturally occurring, inorganic, solid substance. There are thousands of types of minerals, and many look alike. Colour alone is not a reliable way to tell them apart. You can identify a mineral by examining its other properties, such as streak, hardness, lustre, cleavage, and fracture.

Key Terms

cleavage
fracture
hardness
lustre
mineral
streak

Imagine a day at the beach. You have a few buckets, a shovel, and several tonnes of building material: sand! If you look closely at the sand, what will you see? Sometimes there are crushed shells and seaweed mixed in with the particles of sand. If you remove those from the sand, you will see that the sand is made up of many tiny coloured grains. Those coloured grains are mineral crystals. A **mineral** is a pure, naturally occurring, inorganic (non-living), solid substance.

You have probably seen and used many metals that come from minerals, such as silver, aluminum, and tin. You may enjoy ground up halite (table salt) on your food. Perhaps you have used ground up talc in talcum powder. Your bones and teeth are strong thanks to the mineral calcium. Copper and iron help keep your blood healthy. Do you think you could identify these minerals if you saw them?

Did You Know?

If you pass a magnet through sand, it may attract tiny, black particles called micrometeorites, which have fallen to Earth from space.

10-1A Sand Detective

Find Out ACTIVITY

In this activity, you will take a close-up look at the minerals in sand. Most of the grains in sand are quartz, one of the most common minerals on Earth. Quartz can be white, pink, brown, or other colours. Thin black flaky grains in the sand are probably mica. Some white or grey particles may be feldspar.

Polished agates. Agates are a type of quartz.

Materials

- sand
- white cardboard (for dark sand) or dark cardboard (for light sand)
- hand lens
- tweezers

What to Do

1. Remove any pieces of shell or seaweed from the sand.
2. Observe the sand through the hand lens. Record your observations.
3. Use the tweezers to separate the sand crystals into piles based on their colour.
4. Observe the grains in each pile. How are the grains different from and similar to other grains of the same colour?
5. Within each colour pile, separate the sand according to the shape of the grains.

What Did You Find Out?

1. Describe the mineral grains that you found.
2. Which minerals do you think you found in your sand?
3. How could you find out for sure which minerals they are?

Properties of Minerals

The minerals in sand are just a few of the more than 4000 minerals that are found on Earth. Most minerals are very rare, but about 150 minerals are common, and many of those minerals are found in Newfoundland and Labrador.

Many minerals look alike, but you can examine their properties to get clues about which mineral is which. Some properties of minerals include lustre, colour, streak, hardness, cleavage, and fracture.

Lustre

One clue to the identity of a mineral is how shiny it is. The shininess, or **lustre**, of a mineral depends on how light is reflected from its surface. If a mineral shines like a polished metal surface, it has a metallic lustre. If a mineral reflects light like a piece of glass, it has a glassy lustre. If the mineral does not reflect light well, it has a dull lustre. Table 10.1 shows examples of three kinds of lustre.

Table 10.1 Classification of Lustre

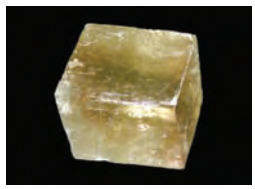
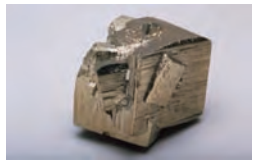
Kind of Lustre	Appearance	Example
Dull	Does not reflect light	Chalk
Glassy	Has a surface reflection like a piece of glass	 Calcite
Metallic	Looks like metal	 Pyrite

Figure 10.1 All of these gems are formed from corundum. Corundum is white when it is pure, but when it contains iron it is blue. When corundum contains chromium, it is red.

Colour

Colour may seem like an easy way to identify minerals, but colour alone is not reliable. The valuable mineral gold has a golden colour, but so does the much less valuable mineral pyrite. Quartz, calcite, and corundum can all be white. One type of mineral may have different colours (Figure 10.1).

Streak

A more reliable way to identify a mineral is to rub it across a piece of unglazed porcelain tile (Figure 10.2). The mark it makes is called a **streak**, which is the powdered form of the mineral. You can tell gold from pyrite using a streak test. Gold makes a yellow streak. Pyrite makes a greenish-black or brown-black streak.

Figure 10.2 The mineral hematite can be dark red, grey, or silvery in colour. Its streak, however, is always dark red-brown.

Did You Know?

Graphite is a soft mineral that is used in pencils. The pencil marks you make on a piece of paper are actually graphite streaks.

Hardness

Another important clue to the identity of a mineral is its hardness. **Hardness** is a measure of how difficult it is to scratch a mineral. How can you use hardness to identify minerals? German scientist Friedrich Mohs asked himself this question in 1812. He tested many minerals and developed a scale of 10 minerals that he ranked with a hardness value of 1 to 10 (as shown in Table 10.2). The higher the number on the Mohs Hardness Scale, the harder the mineral.

Table 10.2 Mohs Hardness Scale

Mineral	Mineral Hardness	Hardness of Common Objects
Talc	1 softest	Soft pencil point (1.5)
Gypsum	2	Fingernail (2.5)
Calcite	3	Copper penny (3.5)
Fluorite	4	Iron nail (4.5)
Apatite	5	Glass (5.5)
Feldspar	6	Steel file (6.5)
Quartz	7	Streak plate (7)
Topaz	8	Sandpaper (7.5)
Corundum	9	Emery paper (9.0)
Diamond	10 hardest	

Suppose that you have an unknown mineral that you think is either calcite or quartz. Notice that calcite is 3 on the scale and quartz is 7. You could try to scratch your mineral with an iron nail, which has a hardness value of 4.5. If the iron does not scratch your mineral, then you know it must have a hardness greater than 4.5, and so your mineral is not calcite.

Cleavage and Fracture

You can get important clues to a mineral's identity by breaking it apart. Sometimes a mineral has **cleavage**, which means it splits along smooth, flat surfaces called planes. Mica (shown in Figure 10.3) is an example of a mineral with cleavage. Separating the layers of mica is a bit like separating the pages in a book. Not all minerals have cleavage.

Minerals may have **fracture**, which means they break with rough or jagged edges. Quartz (shown in Figure 10.4) is an example of a mineral that fractures when it is broken apart. In order to examine cleavage and fracture, you need to look at a freshly broken surface of a mineral.

Figure 10.3 Mica is a mineral with a single cleavage that allows it to be pulled apart into sheets.

Figure 10.4 Quartz is a mineral that has fracture. Notice the jagged edges on the bottom and the crystals on top.

Word Connect

The word "crystal" comes from *krustallos*, a Greek word that means "ice crystal." Many mineral crystals look like coloured ice.

Other Properties of Minerals

Most minerals form crystals. Sometimes you can see the crystal structure in a mineral (Figure 10.4). However, in many minerals the crystals are too small to be seen.

Some other properties of minerals include heft (how heavy it feels), odour, magnetism (Figure 10.5), and whether the surface feels powdery, soapy, or greasy.

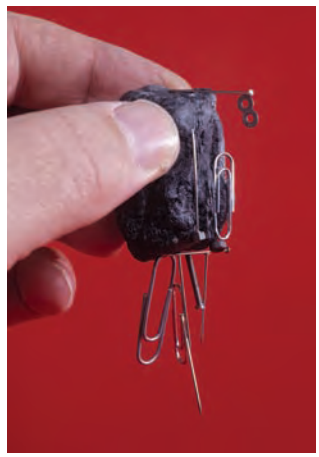
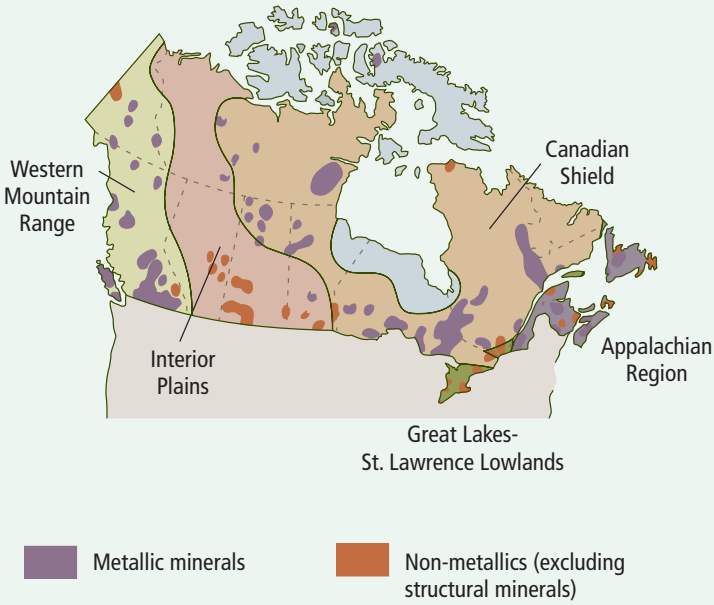


Figure 10.5 Some minerals, such as magnetite, are magnetic.

10-1B Mapping Minerals and Their Uses

Think About It

Minerals are found across Canada and are used in many different ways. Some minerals are used in building homes and offices. Some minerals are used to make jewellery and other works of art. Other minerals are used for fertilizers or in industries. In this activity, you will discover where minerals are found in Canada and some of the ways they are used.



What to Do

1. Your teacher will give you a map of where minerals are found across Canada. In a group, research and list all the minerals found in Canada.
2. Choose one mineral. Research what it is used for. You can begin your research at **www.discoveringscience.ca.**
3. Share the information you learned. Prepare a booklet or poster about your mineral, or create a commercial or advertisement for it. Be sure to include a picture of your mineral.

Reading Check

1. What are three types of lustre?
2. What is the name of the scale used for measuring the hardness of a mineral?
3. What is the property of a mineral that splits along smooth, flat surfaces?
4. What is the property of a mineral that breaks along jagged edges?

Explore More

Transparency is another property of minerals. If you can see through the mineral clearly, it is transparent. If some light can pass through it, it is translucent. If you cannot see through the mineral, it is opaque. Find out more about properties of minerals. Begin your search at **www.discoveringscience.ca.**

10-1C A Mineralogist's Mystery

Core Lab

Skill Check

- Observing
- Classifying
- Interpreting data
- Evaluating information

Safety

- Be careful when handling materials with sharp points or edges.

Materials

- numbered mineral samples
- streak plate
- copper penny
- iron nail
- glass plate or jar
- steel file
- sandpaper
- emery cloth
- hand lens
- optional: magnet
- Tables 10.1 and 10.2 from pages 318 and 319

Science Skills

For help in making observations, turn to Science Skill 5.

Imagine that you are a mineralogist, a person who studies minerals. You have just received a package of minerals from your company's field team in northern Labrador. The attached note reads: "New mine discovered. Enclosed are samples of minerals found there. Please identify." In this activity, you will investigate how the properties of minerals can help you solve the mystery of the unknown minerals.

Question

How can you identify different minerals?

Procedure

1. Prepare a table of observations like one below. Give your table a title.

Mineral Number	Colour	Lustre	Streak	Hardness	Other Properties	Mineral Name

2. (a) Record the number of the first mineral sample in the first column of the table.
   (b) Observe the colour of the first mineral sample. Record your observations in the column under "Colour."
   (c) Observe the lustre of the mineral. Refer to Table 10.1. Record your observations.
   (d) Scrape the mineral once across the streak plate. Brush off the excess powder. Record the colour of the streak. If the mineral is too hard to leave a streak, write "none" in the column under "Streak."
   (e) Scratch the sample with your fingernail. If your fingernail does not leave a scratch, use a copper penny to scratch the sample. If the penny does not leave a scratch, use the iron nail, followed by the glass plate, followed by the steel nail, followed by the sand paper, followed by the emery cloth until something leaves a scratch. Refer to Table 10.2. Record the hardness from 1 to 10.
   (f) Record any other properties you can observe such as cleavage, fracture, crystals, smell, magnetism, heft, feel, and transparency under "Other Properties."
3. Repeat all of step 2 for the remaining mineral samples.

4. Try to identify each mineral by using the Mineral Identification Guide. Record the name of each sample.
5. Wash your hands thoroughly after completing the investigation. Clean up and put away the equipment you have used.

Mineral Identification Guide

Mineral	Colour	Lustre	Streak	Hardness	Other Properties
Feldspar	orange, pink, or white	glassy	white	6	2 cleavage planes
Hematite	brick red or grey	dull	brick red	5	heft
Magnetite	black	metallic	black	6	magnetic
Pyrite	gold	metallic	green/black	6.5	cubic crystals
Quartz	white	glassy	white	7	transparency
Gypsum	white	dull	white	2	powdery feel
Sphalerite	dark brown	glassy	pale brown	4	rotten egg odour
Fluorite	colourless or blue/green	glassy	white	4	heft
Galena	lead grey	metallic	lead gray	2.5	cubic crystals
Mica	black	glassy	white	2.5	1 cleavage plane
Sulphur	yellow	dull	white	2	rotten egg odour
Calcite	colourless	glassy	white	3	double refraction
Coal	black	dull/glassy	black	1	fracture
Pyrophyllite	yellow	dull	white	2	soapy feel
Talc	brown	dull	white	1	soapy feel

Analyze

1. Before testing, which minerals looked the same?
2. (a) Which mineral was the softest?
   (b) Which mineral was the hardest?
3. (a) Which minerals were the same colour as their streak or powder?
   (b) Which minerals had streaks with colours that surprised you?
4. What other features or properties helped you identify the samples?

Conclude and Apply

1. (a) Were you able to identify all the mineral samples?
   (b) If not, what other tests could you use to identify them?
2. (a) Which property was the most useful for identifying a mineral? Explain.
   (b) Which properties were not very useful for identifying a mineral? Explain.
3. If your mineral was harder than your streak plate you would be unable to observe the colour of its streak. What would be another way to determine the streak of the mineral?

Wild, Weird, Wonderful

www Science

Labradorite

Sometimes the beauty of a mineral is hidden beneath its surface. For example, suppose someone gave you a mineral with the following properties:

Colour: dark grey

Streak: white

Lustre: dull

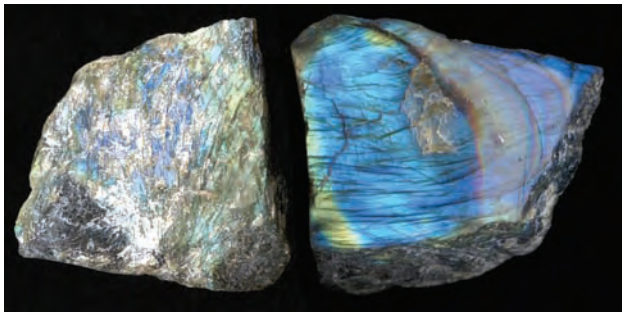
Hardness: 6–6.5

Cleavage: yes

You might at first think this is a dull, dark-looking mineral with no special quality. But as you turn the piece around in the sunlight you may suddenly notice a flash of blue light. Move the mineral again, and green light plays across its surface. You might see flashes of violet light and then yellow light.

What you are holding in your hand is a piece of labradorite, the provincial mineral of Newfoundland and Labrador. This mineral is found in only a few places in the world, most notably in our province.

The play of colours on the surface of labradorite has fascinated people for a long time.



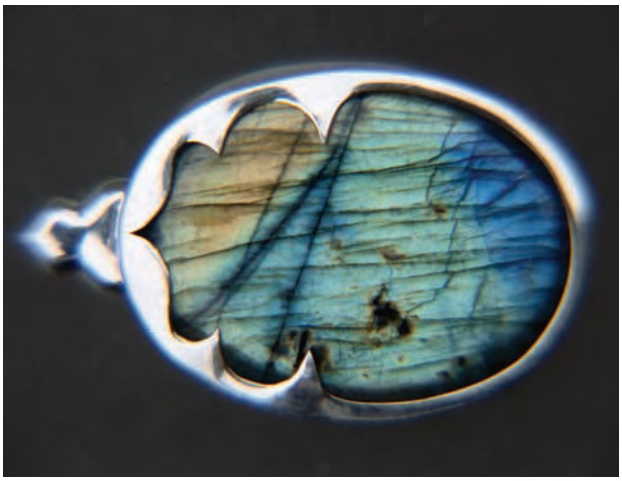
Specimens of labradorite are usually polished or sliced to display the colours.

As early as 1770, this mineral was collected by missionaries and early visitors to the area. It was taken to Europe where it was called *firestone*. In Europe, labradorite was prized for its beauty and thought to have special powers to cure disease.

The shimmering light of labradorite does not come from its surface colour. The colours in labradorite are due to the internal refraction of light in the mineral. When a ray of light enters the cleavage layers, it is bent back and forth between the layers. The colours depend on the thickness and angle of the layers. If the layers are too thick or too thin, you will not see the colours.

The play of light across its cleavage plane is called *labradorescence*. The colours mainly range from blues and violets through greens, but sometimes yellows, oranges, and even reds can be seen.

Samples of labradorite are on display in many countries, bringing a bit of the "light" of our province to the world.



High quality specimens of laboradorite are used in jewellery.

Check Your Understanding

Checking Concepts

1. What is a mineral?
2. (a) What are three types of lustre?
   (b) Give an example of a mineral for each type of lustre.
3. Why is streak a useful way to identify a mineral?
4. (a) What is the softest mineral on the Mohs Hardness Scale?
   (b) What is the hardest mineral on the Mohs Hardness Scale?
5. How would you use the Mohs Hardness Scale to help identify a mineral?
6. What is the difference between cleavage and fracture?

Understanding Key Ideas

7. Why is colour alone not a reliable clue for identifying minerals?
8. Glass is made from the mineral quartz, so it is very hard to scratch. Would you recommend cutting glass with a metal blade? Explain. (Hint: You may want to check Table 10.2.)
9. Suppose you were given several minerals that look similar. Write a note to another student describing several tests that may help to tell them apart.
10. You can use a sentence to help you remember the order of minerals in the Mohs Hardness Scale. For example, you could write "The good cop from Avondale fought quickly to catch Dave." The beginning letters in that sentence are "t, g, c, f, a, f, q, t, c, d." Those letters start the names of the minerals: talc, gypsum, calcite, fluorite, apatite, feldspar, quartz, topaz, corundum, diamond. Write your own sentence to help you remember the names and order of the minerals in the Mohs Hardness Scale.

Pause and Reflect

Can ice be classified as a mineral? Explain the reasons for your answer.

10.2 Investigating Rocks

Rocks can be grouped into three families, depending on how they formed. One family of rocks is igneous rocks, which are formed when magma or lava cools. The crystal size in igneous rocks depends on whether the rocks formed quickly or slowly. Another family of rocks is sedimentary rocks, which are formed by the processes of compaction and cementation into visible layers called beds. A third family, called metamorphic rocks, are formed when heat, pressure, and hot fluids are applied to igneous, sedimentary, or other metamorphic rocks.

Key Terms

beds
cementation
compaction
extrusive rock
igneous
intrusive rock
lava
magma
metamorphic
parent rock
rock
sedimentary

Figure 10.6 These streams of red-hot lava will cool to form rocks.

Figure 10.7 Pillow lava at Snook's Arm on the north central coast of Newfoundland is an example of rock formed from lava.

A **rock** is a mixture of two or more minerals. Where do you think rocks come from? The red-hot lava shown in Figure 10.6 is melted rock that comes from below Earth's surface. At the surface it cools and hardens into solid rock (Figure 10.7). Did all rocks form this way? Can you tell how a rock formed by comparing it with other rocks?

Rock Families

Rocks can form deep inside Earth, on Earth's crust, or in the waters found on Earth's surface. Some of the processes that make rocks happen quickly. Other processes take millions of years.

Scientists have grouped rocks into three major families, or types, based on how they form. The three families are igneous, sedimentary, and metamorphic rocks. Each type of rock can usually be identified by its appearance and by the arrangement of mineral grains within it.

10-2A Write about Rocks

Find Out ACTIVITY

In this activity, you will examine the properties of rocks and look for clues about how they formed.

Safety

- Be careful using the knife.

Materials

- rock samples
- clear adhesive tape
- marker
- hand lens
- plastic knife or other scraping tool
- index cards
- sand in plastic cup (optional)

What to Do

1. Tag each rock sample with an ID number using the tape and marker.
2. Look carefully at each sample. Use a hand lens to observe details.
3. How rough is the surface of each sample? Try scratching each rock gently with a plastic knife.
4. What properties can you use to tell your rocks apart? Colour? Size of pieces that make up the rock? Other properties?
5. Make a data table to record the properties of your samples.
6. Write a description of each sample on a card. Do not include the ID number. Ask a partner to match the cards and the samples. The better your partner does, the better your descriptions are.
7. Together with your partner, record three questions that you could investigate about how different types of rocks are formed.

What Did You Find Out?

1. Do you think all rocks have a similar history? Explain your answer based on your observations.
2. How could you turn a cup of sand into a rock? Share your ideas with others and your teacher before trying it.

Did You Know?

Pumice is a volcanic rock with a very interesting property—it floats! Pumice forms when gases cause the lava to foam up. The rock hardens quickly before the bubbles in the foam disappear. Pumice is very porous and lightweight. It is the only rock that floats.

Igneous Rock

Igneous rock results from the cooling of molten (melted) rock material. As this material cools, crystals are formed. The crystals are different sizes depending on whether the rock cools quickly or slowly. The longer the molten material takes to cool, the larger and more organized the crystals will be. The shorter the cooling time, the smaller the crystals will be.

Magma is molten material found below Earth's surface, where temperatures and pressures are high. Any rock heated at these great depths can melt into magma. Under high pressure, the magma can push away or dissolve the surrounding rock, making room for itself. Sometimes fingers of hot magma push up to the surface through cracks in Earth's crust (Figure 10.8).

Word Connect

The word "igneous" comes from the Latin word *ignis*, meaning fire, which also gives us the word "ignite."

Intrusive rock

Geologists classify igneous rock based on whether it was formed above or below Earth's surface. Magma can cool and harden below the surface. The resulting rock is called **intrusive rock.** Granite is an example of igneous rock that forms very deep and very slowly in Earth's crust (Figure 10.9).

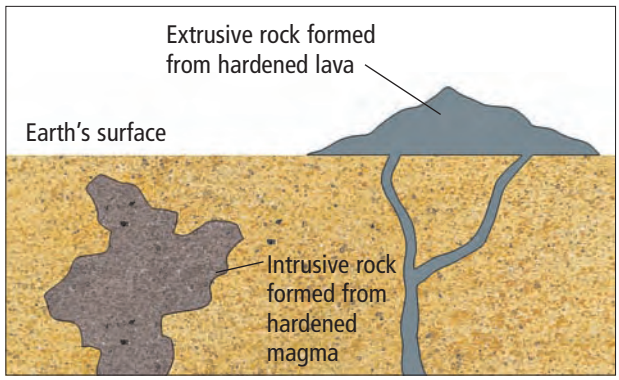


Figure 10.8 Igneous rocks are divided into two groups, depending on where the rocks cooled.

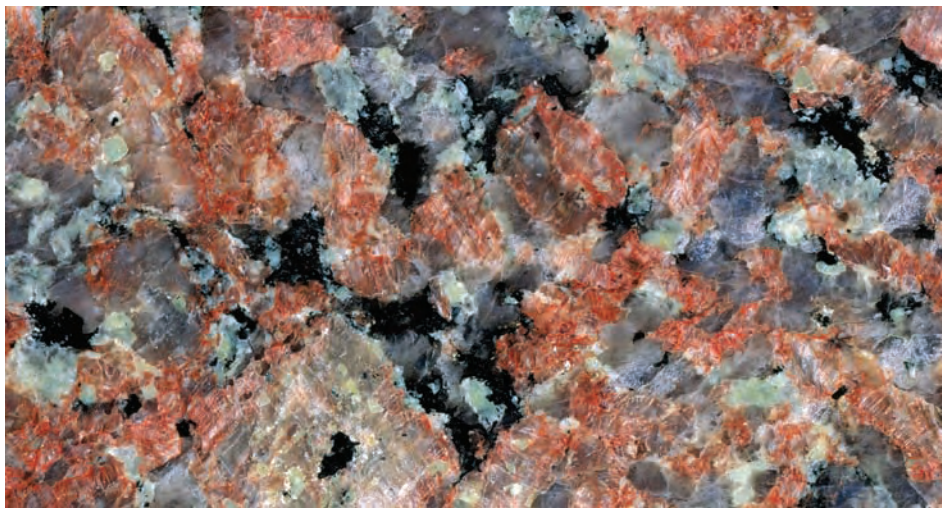


Figure 10.9 Granite is one of the most common igneous rocks found in Earth's crust.

Extrusive rock

Lava is molten material that breaks through Earth's surface in the form of a volcanic eruption. Rock that forms when lava cools on Earth's surface is called **extrusive rock**. Basalt is an example of igneous rock that forms relatively quickly at Earth's surface (Figure 10.10A). Obsidian forms when lava cools so quickly that no crystals can develop (Figure 10.10B).

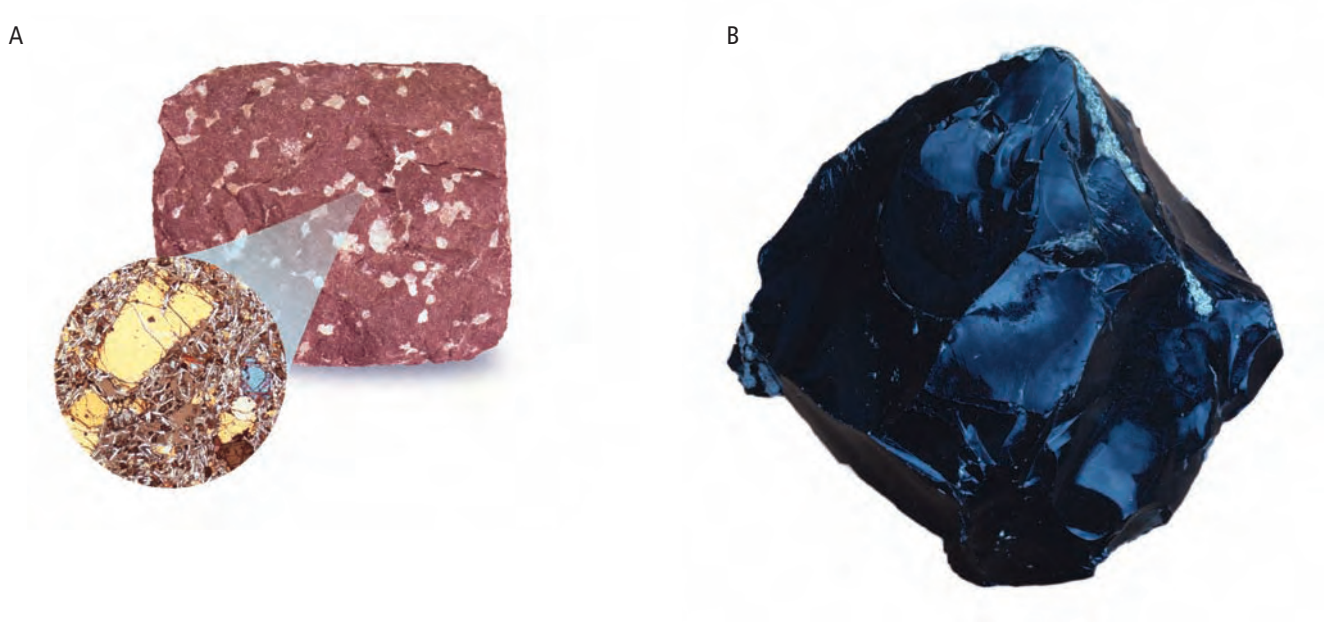


Figure 10.10 The time it takes for lava to cool determines the size of crystals in the rock, or whether crystals will form at all. For example, basalt has small crystals (A). The grains in obsidian are so fine that it looks like smooth, black glass (B). How does their size compare with the size of the crystals in granite?

Reading Check

1. Where is intrusive rock formed?
2. Where is extrusive rock formed?
3. What is the difference between magma and lava?
4. What are three examples of igneous rock?

Suggested Activity

Conduct an Investigation 10-2B on page 334

Sedimentary Rock

Sediment is loose particles, such as bits of rocks and minerals and decaying plants and animals. What happens to sediment? Water, wind, ice, and gravity can move sediment from place to place until it finally settles. Sediment slowly settles on top of other sediment, forming visible layers (Figure 10.11). Each layer is squeezed together by the weight above it. The process of squeezing together layers of sediment is called **compaction.**

Figure 10.11 You can see layered sedimentary rock at the end of Lighthouse Road on the east end of Bell Island.

In some rocks, minerals dissolve as water soaks into the rock. The dissolved minerals form natural cement that sticks the larger pieces of sediment together. The process in which pieces of sediment are held together by another material is called **cementation.**

Sedimentary rocks form from the compaction and cementation of sediments into visible layers called **beds.** Sedimentary rocks are often made in oceans and lakes where the larger, heavier sediments settle first. The appearance of sedimentary rock can reveal what type of sediment formed it. Sedimentary rocks are classified according to the size of their grains (Figure 10.12).

A. Shale has the smallest particles and is formed from fine grains of clay or mud.

B. Sandstone has medium-size particles that you could roll between your fingers. It is harder than shale and is usually made from quartz.

C. Conglomerate has large particles such as rounded pebbles and small stones. The particles are cemented together.

D. Limestone has particles made up of the remains of shells and skeletons from organisms that were once alive.

Figure 10.12 Four examples of sedimentary rocks

Did You Know?

Limestone can include fossils, which are the remains of plants and animals. Ocean animals, such as mussels and snails, make their shells mainly from the mineral calcite. When the animals die, their shells accumulate on the ocean floor, where most sedimentary rock is formed.

Reading Check

1. What are three examples of sediments?
2. What are the two main processes that form sedimentary rocks?
3. What do we call layers of sedimentary rocks?
4. What is an example of sedimentary rock that has
   (a) small particles?
   (b) medium particles?
   (c) large particles?
   (d) plant and animal particles?

Suggested Activity

Find Out Activity 10-2C on page 336

Metamorphic Rock

The third family of rock is called metamorphic (meaning "changed form") rock. A **metamorphic rock** is made when heat, pressure, or hot fluids change one type of rock into another type of rock. Metamorphic rock can be made from igneous and sedimentary rock and from other metamorphic rock. The formation of metamorphic rock is a long, slow process.

For example, granite is an igneous rock found deep below Earth's surface. In Figure 10.13, you can see what can happen to the mineral grains of granite as the pressure of heavy, overlying rock squeezes them closer together. The result is the metamorphic rock gneiss (pronounced "nice").

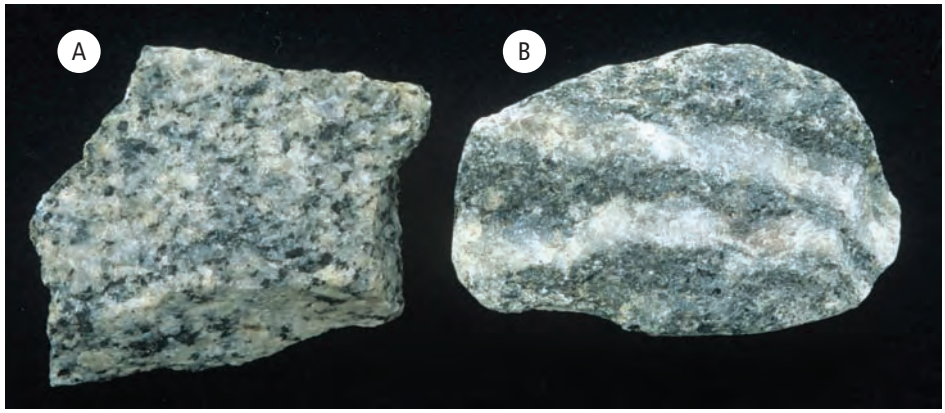


Figure 10.13 The change from igneous rock (A) to metamorphic rock (B) is a long, slow process caused by heat and pressure over time.

Metamorphic rocks form below the surface of Earth where heat and pressure are very high. Hot fluids can flow into igneous, sedimentary, or other metamorphic rock and change the rock both physically and chemically. The type of rock that has been changed into metamorphic rock is called the **parent rock**. For example, shale, a parent rock, can change into slate (see Figure 10.14).

Figure 10.14 Slate (shown) can be formed when pressure is applied to shale.

A metamorphic rock can change so completely that it no longer looks like the parent rock (Figure 10.15). Think of changes that happen when cookie dough is baked or snow is packed together. Metamorphism may change the colour, lustre, hardness, and the way in which a mineral breaks.

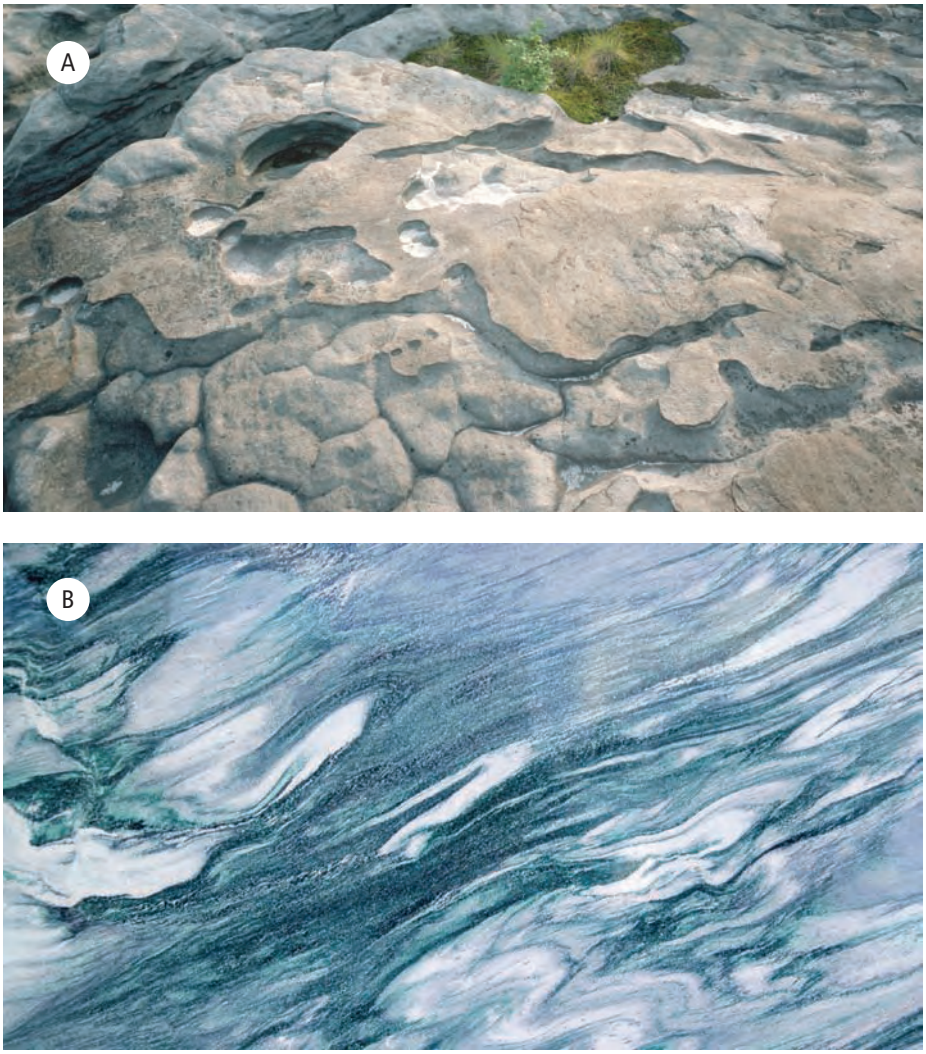


Figure 10.15 Heat and pressure can turn the parent rock limestone (A) into marble (B).

Reading Check

1. What types of rock can become metamorphic rock?
2. What are three conditions that can form metamorphic rock?
3. What is a parent rock?
4. What are three examples of metamorphic rocks and their parent rocks?

Explore More

Much of the central and eastern part of Canada consists of the Canadian Shield, a huge area of ancient igneous and metamorphic rock. Find out more about the rocks of the Canadian Shield. Start your research at **www.discoveringscience.ca.**

Suggested Activity

Find Out Activity 10-2D on page 337

10-2B Cool Crystals, Hot Gems!

Skill Check

- Observing
- Classifying
- Controlling variables
- Evaluating information

Safety

- Heat is used in this activity. Handle heated items carefully.
- Do not eat anything in the science classroom.
- Be careful pouring hot liquids.
- Wash your hands after each day's activity.

Materials

- measuring cup or graduated cylinder
- tap water
- small pot
- heat source
- measuring spoons
- 90 mL Epsom salts
- stirring rod or stirring spoon
- two small beakers
- two bowls
- hot water
- ice (crushed or broken)
- labels
- hand lens

Could you turn small crystals into larger, dazzling gemstones? Yes, if you could re-create the formation of igneous rocks and, at the same time, control the conditions for crystal growth. In this activity, you will use a liquid solution to represent the melted rock. The crystal size and different rates of cooling represent igneous rock formation.

Question

How does the rate of cooling affect crystal size?

Step 3

Step 4

Procedure

Day 1

1. Make sure that all containers and spoons are very clean.
2. Measure 100 mL of tap water using the measuring cup or graduated cylinder. Put the water in the pot.
3. Add 90 mL of Epsom salts to the water in the pot. Stir over low heat. DO NOT boil.
4. When most of the Epsom salts are dissolved (not all crystals may dissolve), remove the pot from the heat. Carefully pour off equal amounts of the solution into each beaker (about 50 mL in each). Make sure that none of the undissolved crystals get into the beakers.
5. Place one beaker in a bowl of ice and the other in a bowl of hot water. Label each beaker. Wash your hands.
6. Leave the beakers for 24 h to allow crystals to form.

Day 2

Step 7

7. Tilt each beaker slightly, and, using a hand lens, examine the crystals. Make a drawing of what you see.
8. Clean up and put away your equipment. Wash your hands thoroughly after completing this investigation.

Analyze

1. In which beaker did the larger crystals form?
2. Did you observe in which beaker the crystals took longer to form? If so, which one?
3. For a fair comparison of crystal size based on rate of cooling, all of the other conditions had to be the same, or controlled. List all of the conditions, or variables, that were controlled for each beaker in this investigation.
4. What was the manipulated variable (the feature you changed)?
5. What was the responding variable (the feature that changed as a result of the experiment)?

Conclude and Apply

1. How did the rate of cooling affect the size of the crystals?
2. Which sample of crystals could represent extrusive rock? Why?
3. What is more likely to happen to crystal size in intrusive rock?
4. Where might larger crystals be found, on the surface of Earth or deep in the ground?

10-2C Settling Sediments

Find Out ACTIVITY

Sediments of different rocks can get churned up and mixed together in a rushing river or in larger lakes and oceans by the action of waves. How does the sediment settle into organized layers of rock? In this activity, you can observe the process of how sediments settle.

Safety

- Avoid inhaling dust from the clay and gravel.
- Be careful using the glass jar.
- Wipe up any spills immediately.

Materials

- dampened clay powder
- sand
- fine gravel
- coarse gravel
- clear glass jar or soft drink bottle (2 L or larger) with a screw-cap lid
- water

What to Do

1. Half fill the container with water.
2. Place 100 mL of each type of sediment into the container. Top up the container with water.
3. Cap the container tightly, and shake it until all the sediments are moving about. Make a prediction about how the sediments will settle.
4. Set the container down, and observe the sediments settling. Record your observations.
5. Let the container sit undisturbed for 30 min to 1 h. Then, record your observations. Include a drawing of what you observe. Label the layers in your drawing.

What Did You Find Out?

1. Which sediments started to settle immediately?
2. Which sediments took the longest to settle out of the water?
3. (a) Does the water look the same as when you first poured it into the jar?

   (b) Why or why not?
4. What properties do the bottom sediments have that caused them to settle first?

Sometimes sediments settle with the finer grains deeper than the coarser grains. This photograph shows a bed of sediments washed out from a glacier in British Columbia.

10-2D Sort It Out

Find Out ACTIVITY

How do the crystals or minerals form in a rock? Why do some rocks have layers? Why do some rocks have rounded particles and other rocks have angular particles? These and other questions can give you clues to the history of rocks. In this activity, you will classify rocks based on their characteristics and on how they were formed.

Materials

- a set of rocks, including rocks from your geographic area
- rocks you have found and brought to class
- hand lens or binocular microscope

What to Do

1. Compare the rocks you brought in with the samples provided. How are they similar? How are they different?
2. Use a magnifying glass to examine the minerals that make up these rocks.
3. Create your own classification system based on your observations. These points may help you get started:
   - Sedimentary rocks are often made up of small or large rounded particles that are compacted or cemented together.
   - Igneous rocks often have small or large angular crystals of minerals visible and the minerals appear to be interlocking.
   - Metamorphic rocks are created under a great deal of heat and pressure, causing them to have thin, flattened particles and layers that are easily visible.
4. Try to classify each of the rocks into one of the three groups. Do not be discouraged if some rocks are difficult to classify. The system you develop is more important than how accurately you sort the rocks.

What Did You Find Out?

1. Which characteristics did you use to classify igneous rocks?
2. Which characteristics did you use to classify sedimentary rocks?
3. Which characteristics did you use to classify metamorphic rocks?
4. Were there any rocks you were unable to classify? If so, describe their characteristics.

Science Skills

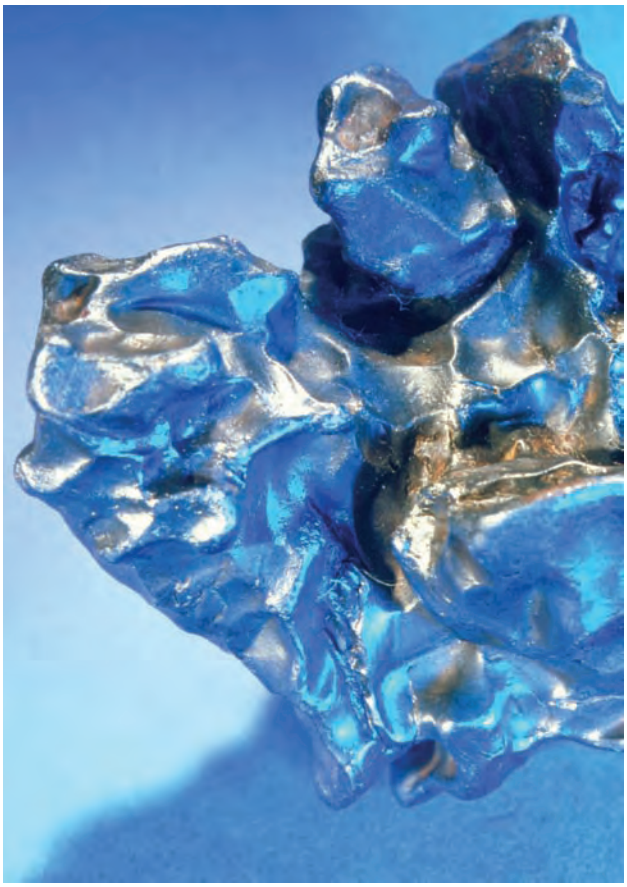
For help in making observations, turn to Science Skill 5.

Wild, Weird, Wonderful

www Science

Space Rocks on Earth

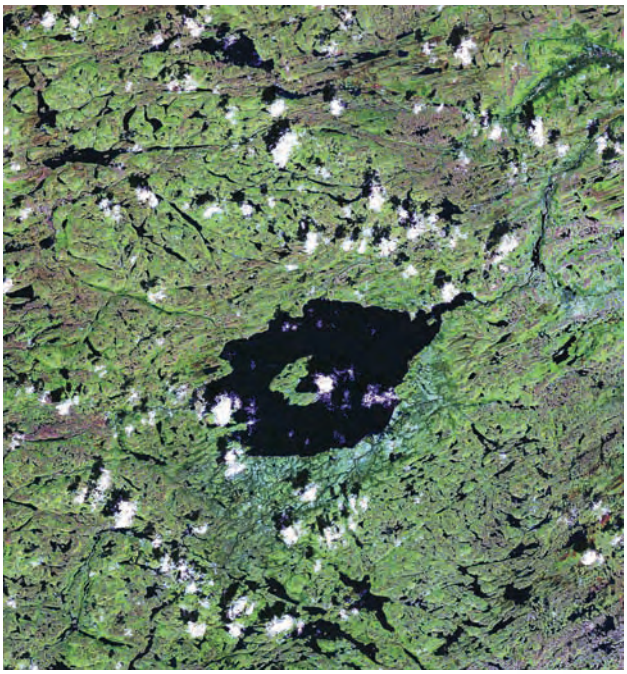
When you are outside walking about or digging in the ground, take a good look at the rocks you find. One of them might be from outer space.



A meteorite is irregular in shape.

Meteorites are pieces of rock that reach Earth's surface without getting burnt up in the atmosphere. Every year, Earth is showered by meteorite material falling from space, ranging from tiny particles of dust to larger pieces of rock. Billions of tiny meteorites have fallen to Earth. Larger meteorites have also fallen, including some that weigh several tonnes.

A meteorite may be made of iron and have a crust and smooth pits. The crust may be dull black or brown, very soft, and may have partly flaked off. The smooth pits may look a bit like thumbprints. Meteorites often are strongly magnetic and may contain nickel. They are often more dense than Earth rocks and tend to feel heavy for their size.



Mistastin Lake in Labrador is formed in a meteor crater. The meteor fell to Earth about 36 million years ago.

You can find a meteorite almost anywhere. It may be near the surface or buried underground, depending on how long ago it fell to Earth and how much of an impact it created.

By examining a meteorite, you can learn not only how it formed but also more about how Earth formed. Evidence indicates that Earth, the Moon, and meteorites all formed at about the same time from the same material that formed all the planets of our solar system.

Check Your Understanding

Checking Concepts

1. Define rock.
2. (a) Define igneous rock.
   (b) Describe how igneous rock forms.
3. What is the difference between magma and lava?
4. (a) What is the difference between intrusive and extrusive rocks?
   (b) What is an example of each type?
5. Define sedimentary rock.
6. (a) What are four examples of sedimentary rock?
   (b) What type of particle does each example have?
7. Define metamorphic rock.
8. How are metamorphic rocks formed?
9. (a) List two examples of metamorphic rocks.
   (b) What is the parent rock of each of the examples?

Understanding Key Ideas

10. Explain how the crystal size in igneous rocks can help you predict how it was formed.
11. (a) Describe compaction and cementation.
    (b) Make a drawing of each process.
12. Suppose you were asked to identify whether a rock specimen was igneous, sedimentary, or metamorphic. What steps would you use to identify it?
13. (a) What family of rocks do you think is shown below?
    (b) How did you make your decision?

Pause and Reflect

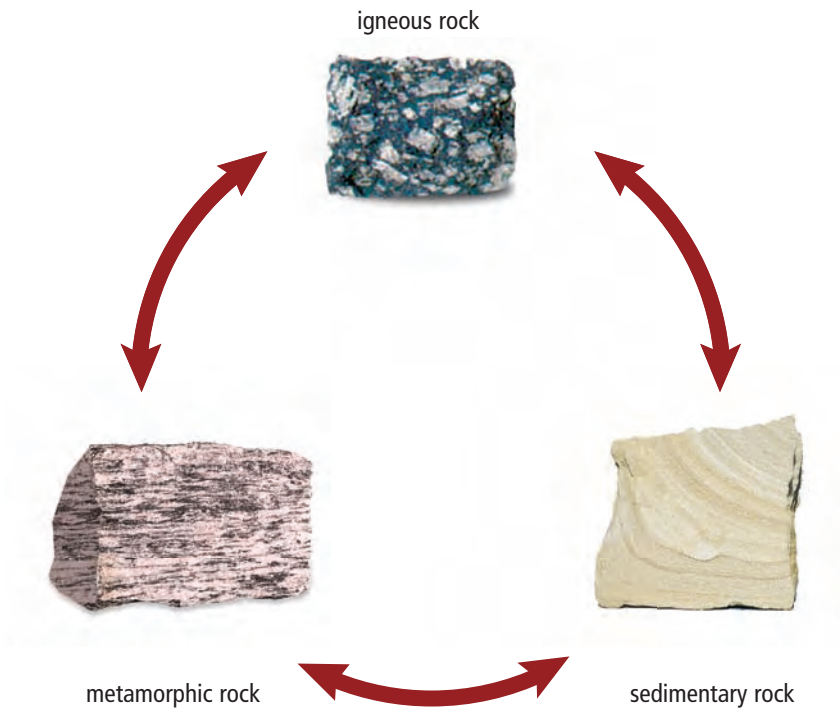
What questions could you ask in order to investigate differences in rocks? Make a list of at least five questions.

10.3 The Rock Cycle and Rock and Mineral Resources

In the rock cycle, different conditions produce different types of rocks. Rocks are constantly changing as they are heated up, cooled down, worn away, and placed under pressure. The processes that change rocks do not occur in a set order. Each process may take thousands or millions of years. Rock and mineral resources have been used by humans throughout history. We continue to find more uses for them that improve our lives.

Key Terms

resource
rock cycle



Rocks are always changing. All rocks can be broken down to form smaller rock fragments called sediments. Sediments can be compacted and cemented to form sedimentary rock. How else can rocks change?

Rocks can be broken apart, chemically altered, dissolved, and even carried away by water or ice. Although human activity is responsible for some of the breakdown process, most of it occurs naturally. Once a rock has reached a new location, the rock can undergo even more drastic changes and become part of an entirely different family of rocks. Sedimentary and igneous rocks can become metamorphic rocks. As metamorphic rocks sink back into the depths of Earth's crust, the heat and pressure can turn them back into magma.

Rocks continue to change in ongoing processes called the **rock cycle.** The rock cycle, like any natural cycle, represents a process of change where the same materials are cycled throughout. The materials found in rocks undergo constant change to produce new types of rocks under different conditions. The changes that take place in the rock cycle never destroy or create matter. The matter is just recycled in other forms.

Did You Know?

All the rocks around you, including the rocks used to build homes and schools, are part of the rock cycle.

10-3A Recycling the Rocks

Think About It

Rocks are always changing in the rock cycle. For example, to form igneous rock from sedimentary rock, the sedimentary rock has to be changed to metamorphic rock first. Then, the metamorphic rock is melted to form magma, which is then cooled to form igneous rock. In this activity, you will create a flow chart to show what happens in the rock cycle.

Materials

- index cards or other pieces of paper
- coloured pencils or felt pens
- poster paper
- glue
- optional: yarn, string, and other materials

What to Do

1. Make a card for each of igneous, sedimentary, and metamorphic. On each card, draw or glue a picture of that type of rock. Arrange your cards on a piece of poster paper with plenty of space between them. Do not glue them yet.
2. Think about the processes involved as each type of rock becomes another type of rock. Make a list of the processes, such as heat, pressure, compaction, and so on.
3. Decide how to show the effect each process has on each type of rock. You may wish to use yarn and labels or use colours to show the processes that change rocks from one type into another.
4. Experiment with placing your labels and rocks in different places on the poster paper. Keep moving them around until you are satisfied that you have a way to show how all the processes act on all the rocks. Then, glue them into place.
5. Add any additional colours, labels, or details that will help make your poster clear and easy to understand.
6. Share your poster with your classmates and observe the details on their posters. There are many ways to represent the rock cycle!

Science Skills

For help in organizing information, turn to Science Skill 9.

Processes in the Rock Cycle

The rock cycle consists of the processes in which rocks are continually changed over long periods of time. Examine the models of the rock cycle in Figures 10.17A and 10.17B. Notice that all three families of rocks are shown, along with the processes that make them. Weathering and erosion are processes that break rock down and carry it away. You will learn more about weathering and erosion in Chapter 12.

The processes in the rock cycle do not occur in a set order. Each of these processes can take thousands or even millions of years.

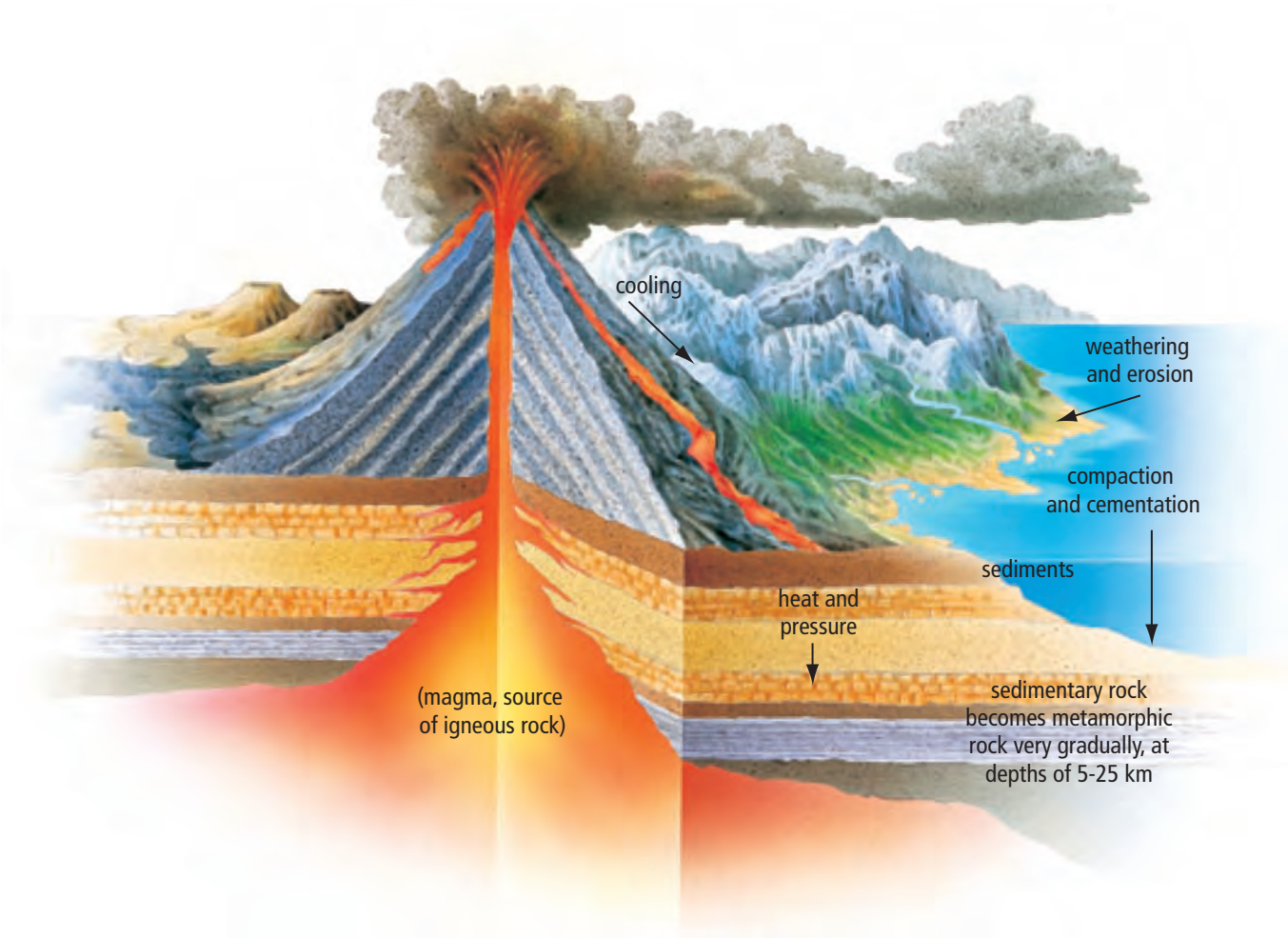


Figure 10.17A This model shows part of the rock cycle. Notice that the diagram is not drawn to scale. Hot molten magma and lava metamorphoses surrounding rocks due to their tremendous heat. Rocks can change from one type into another type.

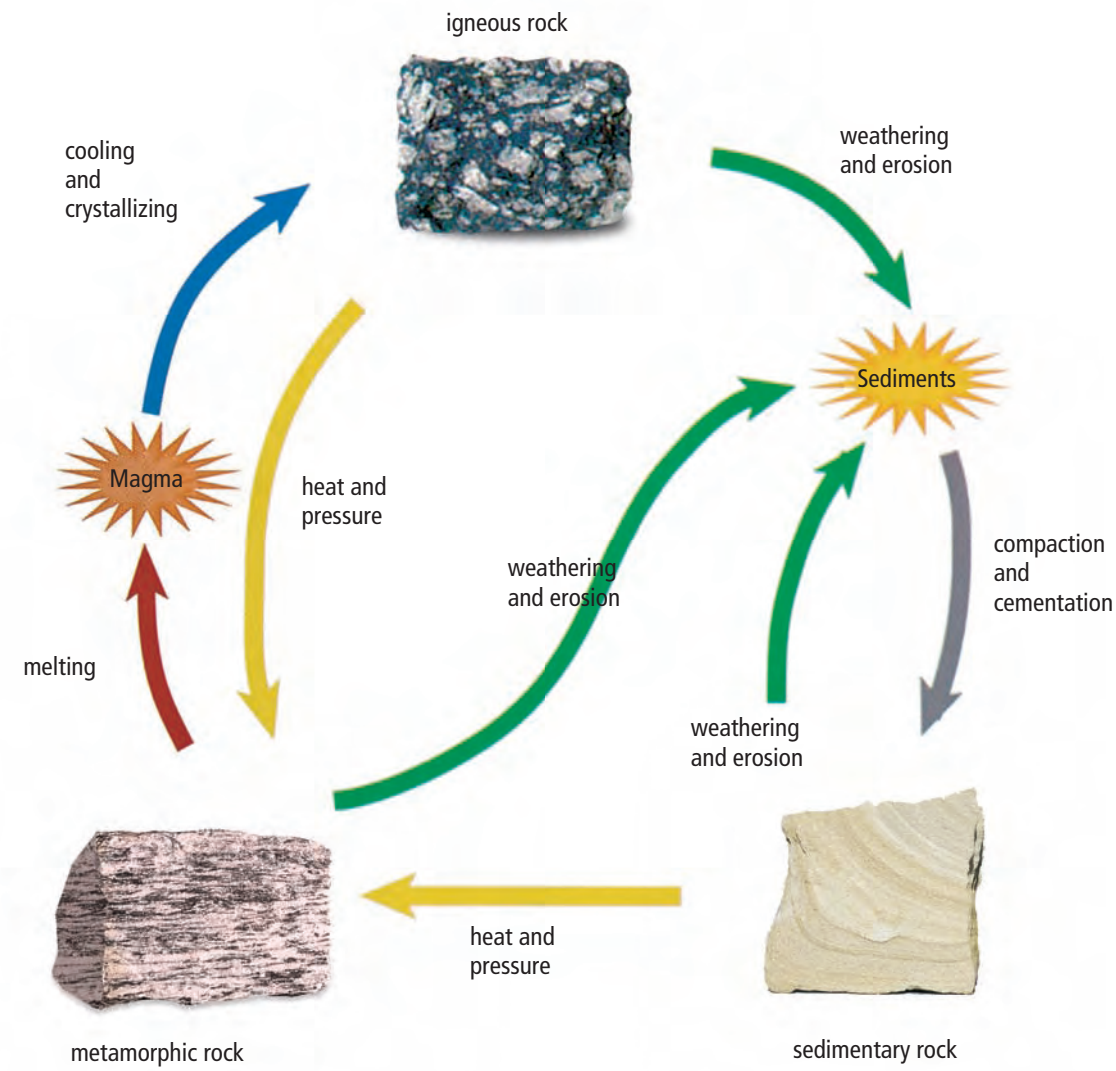


Figure 10.17B This model is one way to represent the rock cycle. Follow each of the arrows through the rock cycle.

Reading Check

1. What is the rock cycle?
2. How do igneous and metamorphic rocks become sedimentary rocks?
3. How do igneous and sedimentary rocks become metamorphic rocks?
4. How do metamorphic rocks become igneous rocks?

Suggested Activity

Conduct an Investigation 10-3C on page 348

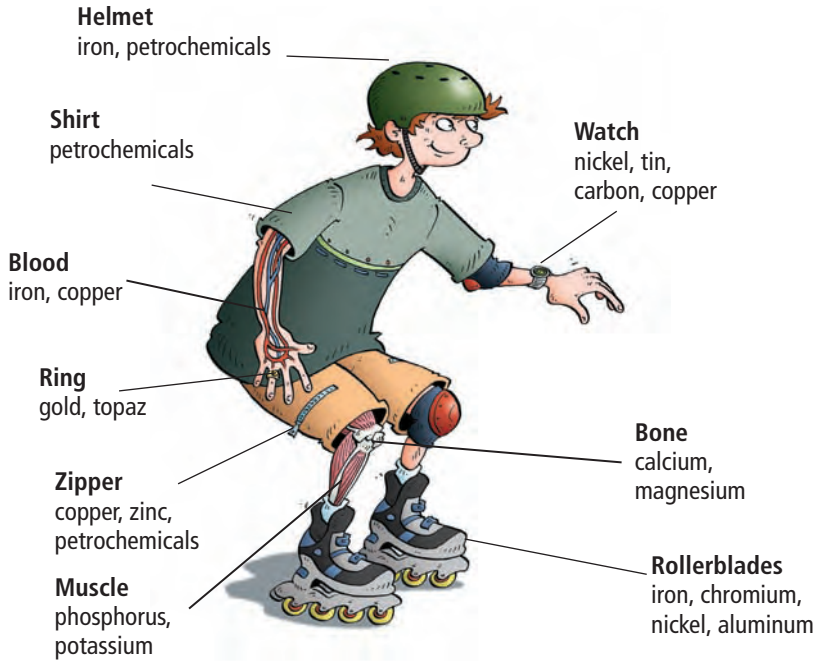


Figure 10.18 Which parts of your clothes and your body come from rocks and minerals?

Rock and Mineral Uses

In what ways do you use rocks and minerals? The answer might surprise you. Many of the things you wear come from rocks and minerals. The same is true of the bikes, cars, buses, and other vehicles you use for transportation. Even your bones, your blood, and other parts of your body contain substances that come from rocks and minerals! Look at Figure 10.18 to discover just a few of the many ways in which rocks and minerals are a part of your life.

People have used rocks and minerals since the beginning of our existence. Some of the first shelters our ancestors used for protection from weather and wild animals were made from rocks. Today, most homes around the world include rocks or rock materials such as soil in their structure. The foundation on which your home and school were built may be made from concrete, which comes from limestone. The bricks used to make buildings and the cement used to pave sidewalks that lead to those buildings are also made from rocks.

internet connect

Learn about the history of limestone production in our province in Chapter IV of Once Upon a Mine, the Story of Pre-Confederation Mines on the island of Newfoundland. Visit **www.discoveringscience.ca.**

Rock and mineral resources

A rock or mineral **resource** is a rock or mineral that can be mined and used for a specific purpose. For example, petroleum, metals, and gems are all resources.

- *Petroleum* and coal are examples of mineral resources that are made from the remains of once-living plants and small plant-like and animal-like organisms that lived in the ancient ocean. Petroleum (crude oil) is used to make fuels, plastics, and many other useful products.

- *Metals* are among the most useful products that come from rock and minerals resources. Commonly used metals include gold, silver, copper, iron, zinc, aluminum, and nickel. We use metals to make cars, applicances, computers, and tools.
- *Gems* are highly prized minerals because they are rare and beautiful. Gems are brighter and more colourful than common samples of the same mineral (Figure 10.20). Diamond, a very valuable gem, also has practical uses. Because diamonds are the hardest of all minerals, they are used on drill bits and other instruments to cut through hard substances, such as steel and rock. Scientists apply tiny rows of diamonds on the edges of surgical scalpels, razor blades, dental drills, and computer parts.

Figure 10.20 Unpolished amethyst (A). Polished amethyst (B). Many gems are cut and polished for use in jewellery

Putting Rocks and Minerals to Work

Much of the exploration of Earth's crust is done for economic reasons. Geologists search for minerals, ores, and rocks that can be mined and used. As technologies improve and are refined, we are able to use rocks and minerals for more and more purposes.

For example, iron is one of the most common and most used elements on Earth. Yet for thousands of years, meteorites were the only source of useable iron because people did not yet know how to extract iron from iron ore. Once humans discovered a process for extracting iron, they could make many more tools and structures. Over the past thousand years, the extraction process has been refined, resulting in a better and more useful quality of iron.

We are still discovering new ways to use rocks and minerals to improve our lives. Some common uses of rocks and minerals are listed in Table 10.3 on the next page.

Figure 10.20 Hematite is mined as the main ore of iron.

Connection

Section 9.2 has information about gold ore.

Table 10.3 Some Rock and Mineral Resources of Newfoundland and Labrador

Rock or Mineral Resource	Examples of Uses
Barite	drilling muds, paints, chemicals, television screens
Calcite	limestone, crystals
Coal	fuel
Copper	electrical wires, water pipes
Fluorite	fluoride for toothpaste, chemicals
Galena	lead
Gold	coins, jewellery, electrical components, medical uses
Granite	building stone, monuments
Gypsum	chalk, plaster, fertilizer, paint filler, cement
Halite	table salt, fertilizer, soap, food preservative
Hematite	iron and steel, jewellery
Iron	steel, appliances, motor vehicle parts, machinery, transportation, buildings, pots and pans
Limestone	cement, building stone, construction
Marble	building stone, monuments
Mica	insulation, spark plugs
Nickel	stainless steel, batteries, coins, electronics, building and construction, transportation
Pumice	skin cleanser
Pyrophyllite	insecticides, glazing ceramic tiles, crafts
Quartz	glass, silicon chips, jewellery, radio transistors, crystals for computers and watches, lenses for glasses, binoculars, and telescopes
Slate	floors, roofing, blackboards
Sphalerite	zinc, cadmium
Sulphur	fertilizer, chemicals, industrial uses
Sylvite	potassium for fertilizer
Talc	talcum powder, paint, crayons, paper, rubber, table tops, sinks

Explore More

Find out which metals are used in Canadian coins. You can start your research at **www.discoveringscience.ca.**

Reading Check

1. What is a resource?
2. Name two examples of rock or mineral resources.
3. What are gems?

10-3B Research the Resource

Think About It

The properties of the rocks and minerals make them useful in many ways. For example, granite is very hard and stable and is used in the construction industry. Pumice, a very abrasive rock, is used in skin cleansers.

Many rock and mineral resources are found in Newfoundland and Labrador. In this activity, you will discover how the rock and mineral resources that are near your community are mined and used.

Materials

- map of Newfoundland and Labrador mines
- red and black pens
- research materials

What to Do

1. Your teacher will give you a map of Newfoundland and Labrador that has symbols for the locations of mines. Mark the community where you live on the map.
2. Divide the names of mines among your group members. Each person should have at least three mines.
3. Research each mine of your assigned mines to find out what rock and/or mineral resource is mined there. Record the rock and/or mineral resource, and give one use for it.
4. Record the names of your mines on your map in black pen. Record the names of the rock and/or mineral resources and their uses on your map in red pen.
5. Share the information you collected with your group. Add the names of the other mines, as well as the rock and/or mineral resources and their uses, to your map.
6. Choose one of the mines to research further. Find out how the resource is mined and what effects the mining processes have on the surrounding environment.

What Did You Find Out?

1. (a) Which mine is closest to where you live?
   (b) What resource is mined there?
   (c) What is one use for the resource?
2. (a) What are five common mineral resources that are found in Newfoundland and Labrador?
   (b) Give one use for each resource.
3. What effects does mining have on the surrounding environment?

Open pit mine near Labrador City

10-3C Rolling Out the Rock Cycle

SkillCheck

- Observing
- Classifying
- Modelling
- Explaining systems

Rocks can be broken down into sediments when they are exposed to rain, wind, and ice. The sediments can then be compacted or cemented to form new sedimentary rocks. If the new sedimentary rocks are buried deep underground, they can be changed into metamorphic rocks by the processes of heat and pressure. Metamorphic rocks can melt and become igneous rocks. In this activity, you will model the rock cycle and the processes that form and change rocks.

Safety

- Use care when handling the hot water and when working around the heat source.
- Carefully unplug the hot plate at the end of the investigation. Let it cool completely before you put it away.

Materials

- different colours of wax crayons
- coin
- aluminum foil
- rolling pin or heavy weight
- hot mitts
- tongs
- water
- hot plate or electric kettle
- plastic spoon
- small aluminum dish
- beaker or small glass bowl

Question

Which of the processes of the rock cycle can you model?

Step 7

Step 15

Procedure

Part 1

1. Choose three different colours of crayons. Remove the paper coverings from the crayons.
2. Use the edge of a coin to scrape off small bits ("sediments") of each crayon into a pile on a piece of aluminum foil.
3. Place some of the coloured sediments in a neat pile in the centre of a 10 cm by 10 cm piece of aluminum foil. Fold the piece of foil over the sediments to enclose them completely.
4. Roll the rolling pin (or heavy weight) to apply mild pressure to the foil package. Roll the rolling pin back and forth several times.
5. Open the foil, and observe the sediments. Record your observations. Save the sediments and foil for use in Part 2.

Part 2

6. Fold the foil securely around the sediments once again.
7. Put on your safety glasses, apron, and hot mitts. Your teacher will supply you with a source of boiling water. Use the tongs to place the foil package in the boiling water. CAUTION: Be very careful near the boiling water. It is very hot and can severely burn your skin.
8. Carefully remove the foil package with the tongs after 20 s.
9. Immediately use the rolling pin to apply a lot of pressure to the package.
10. Open the foil, and observe your "rock." Record your observations.

Part 3

11. Create more sediments by scraping the crayons with the coin.
12. Warm up a hot plate. Be sure to wear your safety glasses and hot mitts. CAUTION: Be very careful when using the hot plate.
13. Collect a spoonful of sediments. Put your sediments in a small aluminum dish. Place the dish on the hot plate.
14. Heat the sediments just until they melt. Do not overheat them.
15. Hold the aluminum dish with the tongs. Pour your heated sediments into a beaker or small glass bowl of cold water. Leave the sediments in the water for 1 min.
16. Use the plastic spoon to remove your newly formed "rock." Observe your rock, and record your observations.
17. Clean up and put away the equipment you have used.

Analyze

1. (a) What processes of the rock cycle were you modelling in Part 1 of the investigation?
   (b) How do you know?
2. (a) What processes of the rock cycle were you modelling in Part 2 of the investigation?
   (b) How do you know?
3. (a) What processes of the rock cycle were you modelling in Part 3 of the investigation?
   (b) How do you know?

Conclude and Apply

1. (a) What processes in the rock cycle were you not able to model in this investigation?
   (b) Why were you not able to model these processes?
2. How might you change this investigation so that you could model all the processes in the rock cycle?

Science Watch

Holding History Together

What holds a building together for thousands of years? If you are looking at an impressive building such as the Colosseum of Ancient Rome, then the answer is "Roman cement."

Cement is used to bond or glue rocks and bricks together in building construction. Modern cement is a mixture of mineral resources, mostly limestone and sand or clay. The ingredients are burnt together in a kiln, which changes the chemicals in the mixture. The mixture is then finely ground and mixed with sand to use as an ingredient of concrete and mortar. When water is added, the mixture hardens, just as natural cement hardens when sedimentary rock is formed.

Cement has a long history. In early civilizations of the Middle East, people made walls for their homes from moulded clay. They discovered that if they coated the clay with a moist coating of thin, white, burnt limestone, the walls would be protected from crumbling.

This Roman wall is several thousand years old. The wall is made from limestone and red Roman tiles, held together by a coarse cement mortar.

The ancient Romans knew that burnt limestone could be mixed with river sand to make cement. The cement was useful, although it could not be used to make structures that were built in water. Then, the Romans discovered a secret ingredient.

The Colosseum was built almost 2000 years ago. It has been damaged in earthquakes, but the cement is still holding strong.

An ancient architect named Vitruvius described a powder that came from natural sources and produced astonishing results. He wrote that when the powder was mixed with lime and rubble, it could be used to strengthen buildings and to make piers under water.

What was the mystery powder? The powder was ash from a nearby volcano. The ash had already been heated by the volcano, so the chemicals in it had been changed. It was ready to be mixed with the limestone.

Roman cement was a mixture made from equal portions of lime (calcium oxide) and volcanic ash or crushed tiles, mixed with a little water. Many buildings, like the famous Colosseum in Rome, were made from huge rocks glued together thousands of years ago with long-lasting Roman cement.

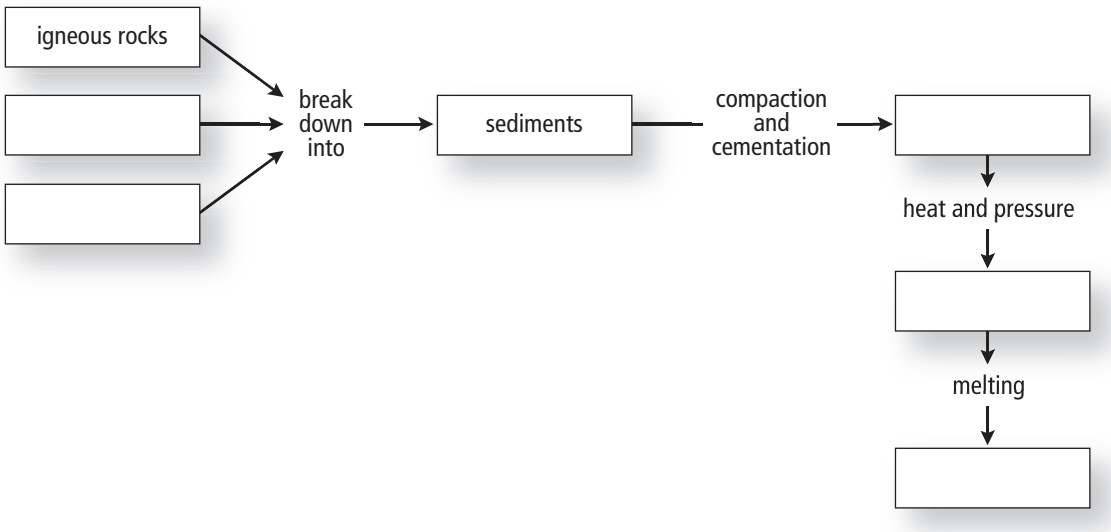
Questions

1. What is cement?
2. Why do the ingredients need to be heated to make modern cement?
3. Why did the ancient Romans not have to heat their cement ingredients?

Check Your Understanding

Checking Concepts

1. Sketch and label a diagram of the rock cycle.
2. How are igneous and sedimentary rocks related?
3. How are sedimentary and metamorphic rocks related?
4. How are metamorphic and igneous rocks related?
5. (a) What are three minerals or mineral resources you have used today?
   (b) How did you use them?
6. (a) Name two mineral resources found in Newfoundland and Labrador.
   (b) How are they used?
7. This flow chart shows part of the rock cycle. Copy and complete the chart in your notebook.



Understanding Key Ideas

8. How is the rock cycle similar to the recycling of matter?
9. How do society's needs lead to developments in technologies designed to use rocks? Explain your ideas using an example.

Pause and Reflect

How has your life been improved by the rock and mineral resources found in Newfoundland and Labrador?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated minerals, rocks, the rock cycle, and the uses of rocks and minerals. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Properties of Minerals
2. Three Families of Rocks
3. The Rock Cycle
4. The Uses of Rocks and Minerals

Checking Concepts

1. Define the following:
   (a) rocks
   (b) minerals
2. (a) List the properties used to identify minerals.
   (b) Explain how to use each property.
3. What is the difference between cleavage and fracture?
4. Explain why a diamond does not leave a streak on a streak plate.
5. What hardness does a mineral have if it can be scratched by glass but it can scratch an iron nail?
6. What is the difference between magma and lava?
7. What are two differences between intrusive and extrusive rocks?
8. Where do sediments come from?
9. What are three examples of sedimentary rocks?
10. Draw a flow chart of the rock cycle.

Understanding Key Ideas

11. Use the rock cycle to explain why pieces of granite (igneous) and slate (metamorphic) can be found in the same piece of conglomerate (sedimentary).
12. (a) Which family does the rock below belong to?
    (b) How did you decide?

13. Copy and complete the following table in your notebook.

	What It Is Formed From	Where It Is Formed	Distinguishing Features	Examples
Igneous rock				
Sedimentary rock				
Metamorphic rock				

14. Draw sketches to show how baking cookies in the oven represents what happens to mineral crystals in sedimentary and igneous rocks when they are subjected to great heat.
15. Create a diagram to show how metamorphic rock is formed from its parent rock (e.g., limestone to marble, shale to slate, and granite to gneiss). Label the changes that the rock undergoes.
16. Diamonds are the hardest natural substance known. You can, however, easily break a diamond into several pieces if you hit the diamond with a small hammer. What does this indicate?
17. (a) Why do you think some igneous rocks have bubbles or pores?
    (b) Do you think such rocks are likely to be intrusive or extrusive?
    (c) Explain why.
18. Why are metamorphic rocks created deep in Earth's crust, not on the surface?
19. Suppose you had a piece of paper, a piece of steel, and a glass bottle. Explain how you could use these materials to distinguish between calcite and quartz.

Pause and Reflect

How is the formation of ice in a glacier or snowbank similar to the formation of sedimentary rock beds? Use a sketch in your answer.

Chapter 11

Earth's crust is constantly changing.

Earth's crust is similar to pizza dough. In some places it stretches and in another places it breaks. Pieces of Earth's crust are moving past each other at the San Andreas Fault in southwestern California. Many notable earthquakes have happened along the fault's 1300 km length. Work is underway to install instruments 1.5 km deep along the fault. The instruments will collect data to monitor changes in Earth's crust and to help predict future earthquakes.

What You Will Learn

In this chapter, you will

- **describe** the structure of Earth
- **identify** evidence to support the theory of plate tectonics
- **explain** why earthquakes and volcanoes occur and how mountains are formed
- **describe** the geologic time scale

Why It Is Important

Understanding how Earth's crust moves can help prevent many disasters. If we know where and when an earthquake might happen or a volcano might erupt, we can save lives and reduce damage and destruction.

Skills You Will Use

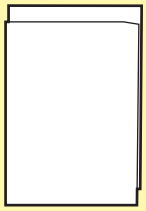
In this chapter you will

- **model** the structure of Earth
- **evaluate** evidence of the movement of continents
- **classify** patterns in earthquake and volcano locations
- **communicate** how people in the past explained volcanoes and earthquakes
- **explain** mountain building systems

FOLDABLES™ Reading & Study Skills

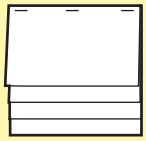
Make the following Foldable to take notes on what you will learn in Chapter 11.

STEP 1 **Stack** two sheets of 8.5″ × 11″ paper so that the back sheet is 2 to 3 cm higher than the front sheet. (**Hint:** From the tip of your index finger to your first knuckle is about 2.5 cm.)

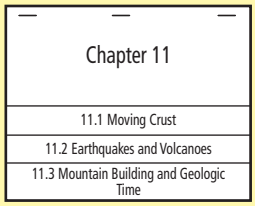


STEP 2 **Bring** the bottom of both sheets upward and **align** the edges so that all of the layers or tabs are the same distance apart. **Fold** the paper and **crease** well.

STEP 3 **Staple** the papers along the fold.



STEP 4 **Label** the Foldable with the chapter title on the top section and the three lesson titles on the small tabs as shown.



Organize Take notes and define lesson terms under each tab as you learn new information throughout the chapter.

11.1 A Moving, Changing Crust

Earth's crust is made up of a series of crustal plates that are always moving. Early theories suggested that only the continents move, but it is now known that the crust under the ocean moves as well. Our knowledge of the moving crust is based on evidence from the continents, including fossils, rocks, climate change, and the shape of the continents. We also have obtained evidence of moving crust from the sea floor by using sonar, magnetometers, and deep-sea drilling. Convection currents beneath the plates may be the cause of the movement of the crust.

Key Terms

continental drift
convection currents
convergent boundary
crust
divergent boundary
inner core
magnetometer
mantle
outer core
pangaea
plate tectonics
sonar
subduction zones
transform boundary

Word Connect

Geo- is from a Greek word meaning "Earth." A geologist studies the rocks on Earth's crust. A geographer may study how climate affects Earth's crust. A geochemist studies the chemical elements that are found in Earth's crust. A geophysicist studies the interactions between matter and energy that produce Earth's features.

Imagine that you are a geologist. You study the rocks and minerals found near Earth's surface and find valuable deposits of metals, gems, oil, and coal. One of your jobs is to learn about the rock layers below Earth's surface. You use a drill to obtain a core sample, which is a long, cylindrical sample of rock.

The deepest hole that has been drilled into Earth's crust is about 12 km deep and took about 20 years to drill. The centre of Earth is about 6000 km below Earth's surface. No one has ever seen the inner layers of Earth, and no tools are yet able to be sent that deep. How can you find out what all those other layers are like?

The Structure of Earth

What is deep inside Earth? Scientists have many answers to this question, but there are still mysteries waiting to be solved. Since we cannot observe Earth's inner layers directly, we can use clues from earthquake waves and satellite images to predict what the layers of Earth might be like. Clues about something that cannot be seen directly are called *indirect evidence*.

We can also use *direct evidence* to learn about Earth's inner layers. Geologists obtain direct evidence by studying rock samples from volcanoes, from mountain ranges, and from deep within the sea floor. Perhaps, during your lifetime, scientists will develop a technology for collecting direct evidence from even deeper inside Earth.

11-1A Examine the Evidence

Find Out ACTIVITY

How well can you describe something you cannot see? In this activity, you will work with group members to infer the identity of something that is out of sight.

Materials

- sealed containers provided by your teacher

What to Do

1. Your teacher will give your group several containers. Each container will have a marble inside it. Some containers will have another substance as well. Examine the containers. Without looking inside, try to figure out the contents.
2. As a group, make a table to record your observations. Record what you think is inside each container. Describe the evidence you used to make your decisions.
3. Discuss your observations and decisions with the other groups. Discuss: How is this activity similar to how scientists determine what is deep inside Earth? How is this activity different?

What Did You Find Out?

1. Which were the easiest contents to identify? Why?
2. Which were the most difficult contents to identify? Why?
3. Which evidence was confusing or misleading? (For example, the contents sounded like one item but were actually something else.)

A Model of Earth

Scientists have used direct and indirect evidence to make a model of Earth's structure. Figure 11.1 on the next page is a model of the four main layers of Earth: the crust, the mantle, the outer core, and the inner core.

Some layers of Earth are solid and some are liquid. Why do you think the layers are different states? In Earth's crust and the upper mantle, temperatures are cool enough for iron and nickel to be in the solid state. In the lower mantle and outer core, temperatures are so high that iron and nickel are in the liquid state. In the inner core of our planet there is such enormous pressure that the very hot iron and nickel are compressed into the solid state.

Did You Know?

Vibrations travel at different speeds through different kinds of matter. Scientists study vibrations from earthquakes to help determine the type and state of matter in Earth's inner layers.

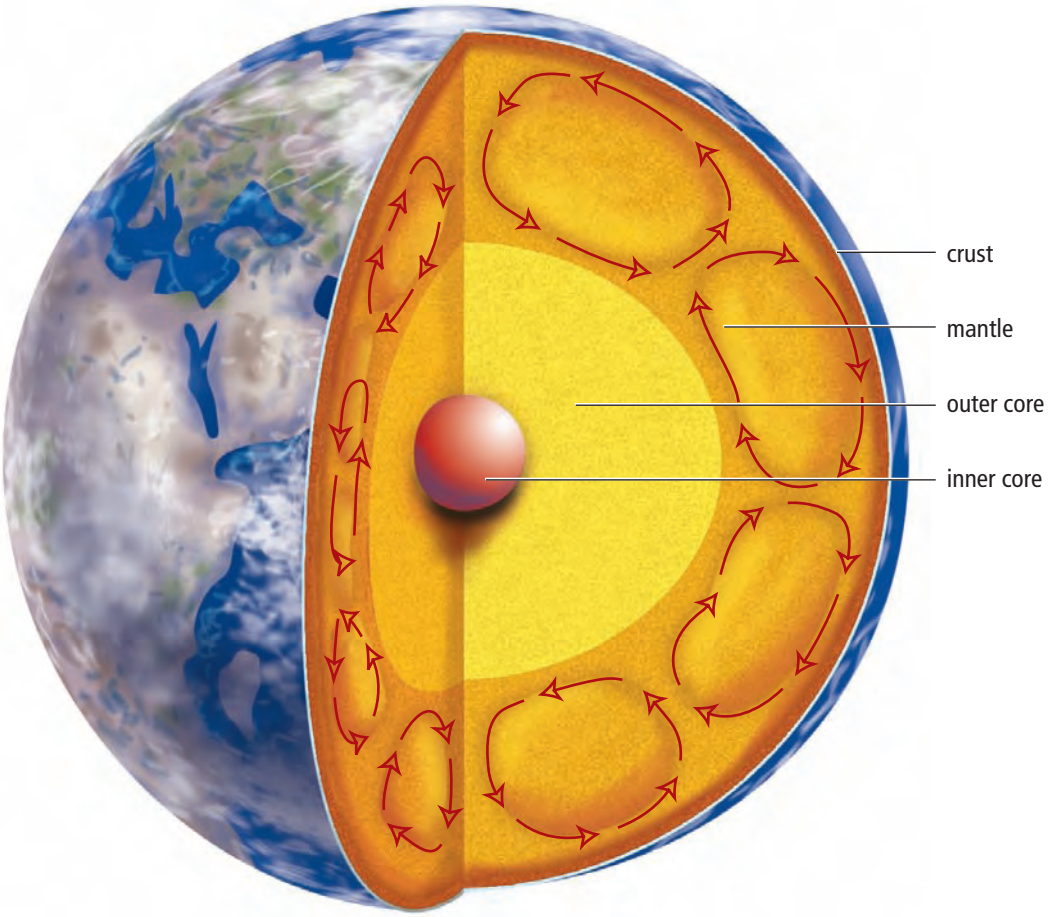


Figure 11.1 A model of Earth

Inner Core

The **inner core** is the deepest and hottest layer of Earth. Many scientists believe the inner core is made of iron and nickel, and possibly other elements, such as silicon and carbon.

Outer Core

The **outer core** is probably made of liquid iron and nickel. Sulphur and oxygen could also be present. The outer core is so hot that the iron and nickel are melted.

Mantle

The **mantle** is the largest and most complex layer of Earth. Most of the upper part is solid rock, made from minerals rich in iron, magnesium, silicon, and oxygen. In the lower part of the mantle the temperature is so high that the rock is partly melted. Scientists picture the rock in the lower mantle as being plastic-like, similar to taffy or caramel.

internet connect

Scientists have discovered an area on the seafloor where the mantle is exposed without a covering of crust. They have sent a submersible to take photographs of the area and drill into the olivine rock found there. You can find out more about the expedition. Begin your search at **www.discoveringscience.ca**.

Crust

On the outside of Earth is a thin layer of solid rock called the **crust.** The crust is where valuable rock and mineral resources are found. The depth of the crust varies from less than 5 km to about 70 km thick. Earth's crust is thinner under the oceans (the oceanic crust) and thicker under the continents (the continental crust). The oceanic crust is mostly made of basalt. The continental crust is mostly made of granite. The crust is broken up into pieces, called plates, which "float" on Earth's mantle and are always moving.

11-1B A Model Planet

Think About It

In what ways is Earth like an apple? The seed core of the apple could represent Earth's outer and inner core. The thin skin of the apple could represent Earth's thin crust. In this activity, you will make or choose a model to represent the structure of Earth.

What to Do

1. Make a model of Earth or find something that you can use as a model. Your model should show the four main layers and show that the crust is broken into pieces.
2. Present your model to the class. Explain how your model represents Earth's layers.

What Did You Find Out?

1. How did you choose the model?
2. How could you make a better model of Earth's layers?
3. How did making and using models help you understand Earth's layers?

Reading Check

1. What are the four main layers of Earth?
2. What are the two types of crust?
3. Why is the inner core of Earth solid?
4. In which layer is the rock plastic-like?

Earth's Moving Crust

Why does Earth's crust move? Scientists have been investigating this question for many years. One scientist who searched for answers was a German meteorologist named Alfred Wegener (1880–1930). A meteorologist is a scientist who studies weather and climate. Like other scientists before him, Wegener noticed something interesting about the shapes of the continents. Look ahead to the map in Figure 11.3. If you cut out the continents from a map, they almost fit together like puzzle pieces. Can you see where the bulge of South America could fit into the indented side of Africa? Are there other continents that might fit together?

Paleogeographic Evidence—Shape of Continents

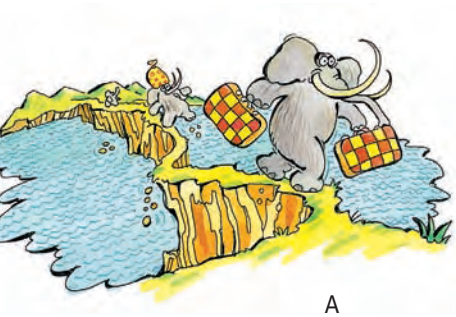
Figure 11.2 Pangaea. Try to name the seven biggest land masses on the map. Can you find India? (Hint: It is not yet connected to Asia).

Alfred Wegener thought that the fit of the continents was more than just a coincidence. He suggested that all the continents were joined together in a huge land mass called **Pangaea** (pan-JEE-uh), which means "all lands." He suggested that Pangaea broke apart about 200 million years ago, as shown in Figure 11.2.

Wegener proposed the **theory of continental drift**, which suggests that the continents change position very slowly, moving over the surface of Earth a few centimetres every year. Wegener could not explain *how* the continents moved, but he collected as much data as he could to support his theory.

The paleogeographic evidence showing that the continents appeared to fit together was Wegener's earliest clue. This led him to look for more information to support his theory. He collected evidence from fossils and rocks. He also studied clues about climate change to try to persuade the scientific world that his theory was valid.

Biological Evidence—Fossils



A

B

Alfred Wegener wondered why fossils of the same animals were found on different continents (Figure 11.3). For example, some fossils found in the Avalon Peninsula in Newfoundland are very similar to those found in Wales. The country of Wales is located 4000 km across the Atlantic Ocean from Newfoundland and Labrador. Many scientists of Wegener's time thought that perhaps there had been a land bridge that has now disappeared, that used to join the continents together (cartoon A). Wegner thought that this fossil evidence helped to support his theory of continental drift (cartoon B).

Figure 11.3 The map above shows the locations of fossils that have been found on many different continents.

Mesosaurus lived in and around fresh water, not salt water as is found in the ocean. Lystrosaurus was not able to swim at all. Glossopteris plants grew in tropical areas, but its fossils have been found in Antarctica, which is very cold and covered with thick ice. What possible reasons can you think of to explain how fossils of these three species have been found on different continents?

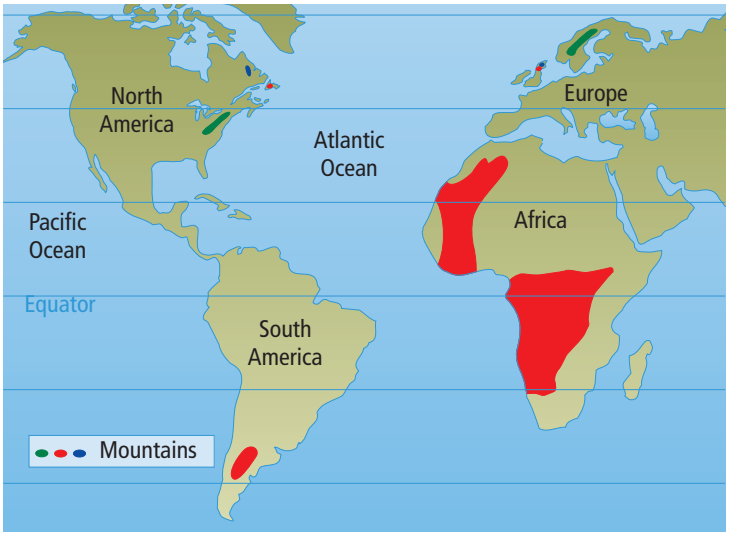


Figure 11.4 How could mountains formed from the same type of rock occur thousands of kilometres from each other across an ocean?

Geological Evidence—Rocks and Rock Layers

Wegener examined the findings of other scientists to see if there might be more evidence to support his idea of continental movement. He discovered that geologists had found similarities in rocks on both sides of the Atlantic Ocean (Figure 11.4). For example, the Appalachian mountain range in eastern North America is made of the same kind of rock as the mountain range that runs through Britain and Norway. The ages of rock in eastern North America and in Britain and Norway are the same as well.

To Wegener, this was additional evidence in support of his theory of continental drift. These rocks look as though they had been formed and pushed up into mountains together, but were now separated by the Atlantic Ocean.

Meteorological Evidence—Climate Change

More evidence came from the location of coal beds. In order for coal to form, there has to be rich, luxurious plant life in a tropical, swampy environment. When the plants die and are compressed under many layers of sediment, coal is formed. However, coal beds are found in places that now have moderate to cold climates, such as in Canada, Europe, and Antarctica. How did tropical plants ever grow in Antarctica? Was the climate once different there, or had Antarctica moved to its present cold location from a place nearer the equator?

Wegener also noted that some places that have warm climates now, such as Africa, India, and Australia, have evidence that they were once partly covered by glaciers. Was the whole world once cold, or had these land masses moved to their present warm locations from a place near the South Pole?

Figure 11.5 This is the last known photograph of Alfred Wegener (on the left) taken as he prepared to cross Greenland.

Rejection of Wegener's Ideas

To support his hypothesis about drifting continents, Wegener thought about what forces might be causing the movement. He proposed that the Moon might be responsible for continental movement, just as it influenced tidal movement. Other scientists disagreed with him. Because Wegener could not satisfactorily explain the origin of the force that was moving the continents, the scientific community rejected his ideas on continental drift. The fixed-continent model continued to be the most widely supported idea. Wegener died in Greenland in 1930, still searching for evidence to support his theory of continental drift (Figure 11.5).

Reading Check

1. What is Pangaea?
2. What theory did Wegener propose?
3. What four types of evidence did Wegener use to support his theory?
4. What could Wegener not satisfactorily explain about continental drift?

11-1C Pangaea Puzzle

Think About It

Most scientists now support the idea of continents moving. In Wegener's time, however, most scientists disagreed with his theory. In this activity, you will evaluate the evidence for continental drift. Imagine that you are part of a scientific panel in Wegener's time. Would you agree or disagree with his theory?

Safety

- Take care using scissors.

Materials

- world map with continental shelf boundaries
- blue paper
- coloured pencils
- scissors
- glue

What to Do

1. Examine Figure 11.3. Draw the three fossils from Figure 11.3 on your world map. Put a legend on your map showing the name and a picture of each of the three fossils.
2. Find other fossil evidence from other sources, such as the Internet, a CD ROM, or books from your library. (Hint: look for *Cynognathus*.)
3. Examine Figure 11.4. Add the three types of rock evidence to your map. Use a different bright colour for each type of rock evidence. Do not cover up your fossil evidence.
4. Label each of the seven continents.
5. Cut out the continents on the world map, around the edges of the continental shelves. Cut India away from Asia along the Himalayan Mountains.
6. Fit the pieces of the world map together to make Pangaea. Once the pieces are in place, glue them to the sheet of blue paper.
7. Transfer the legend to the blue paper by cutting it out or copying it.

What Did You Find Out?

1. What difficulties, if any, did you experience in fitting the pieces of land together?
2. (a) Which pieces were the hardest to fit together?
   (b) How might these pieces have looked 300 million years ago?
   (c) How could you test your ideas?
3. (a) Why was Wegener's theory of continental drift a reasonable theory?
   (b) Why did it make sense at the time?
4. (a) As a young child, what ideas did you have that you had to change as your knowledge increased?
   (b) Was it easy or hard for you to give up your old ideas?
   (c) How might your experience be compared to the experience of scientists?

Evidence from the Sea Floor

The evidence Wegener used to support the idea of continental drift was evidence that had been collected from the continents. In the 1940s, new technology became available that allowed scientists to gather evidence from the sea floor. Three new technologies provided a more detailed picture of the interior of Earth.

- **Sonar** is a sound wave technology that sends out sound waves and then records the time that the sound waves take to bounce back. The sound waves can be sent from a ship and reflected off the sea floor as shown in Figure 11.6. The longer the sound waves take to return to the ship, the deeper the water is. Sonar is used to map the depth and features of the sea floor.

When many sonar tests from Earth's oceans were studied, there was a surprising discovery. It was observed that many features found on the sea floor were similar to features found on land. In fact, there were mountains on the sea floor (Figure 11.7 on the next page).

There were long mountain ranges or ridges in some places, just like the mountain ranges that existed on land. Scientists identified a mountain ridge that stretched north to south along the middle of the Atlantic Ocean. They called this ridge the Mid-Atlantic Ridge. What was causing these mountains to form? The answer would come from another technology: magnetometers.

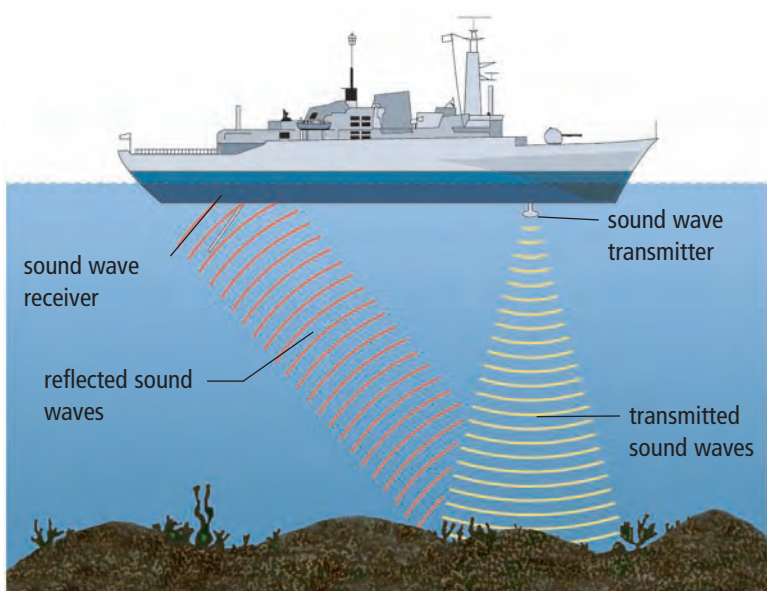


Figure 11.6 Sonar revealed that the sea floor was not flat, as was previously believed.

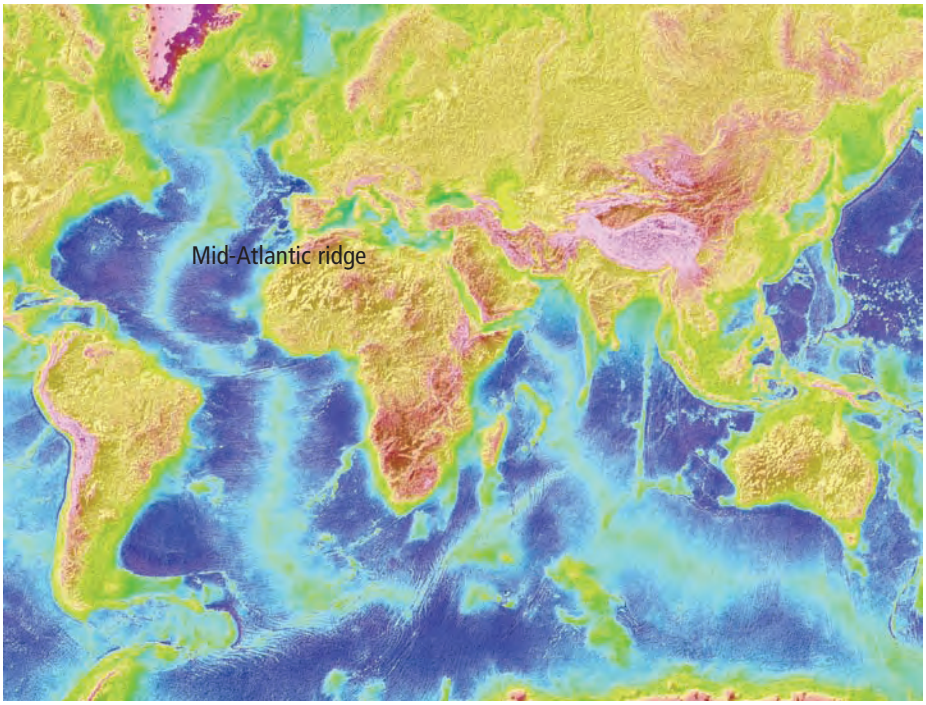


Figure 11.7 The sea floor. The long ridged structures are the mid-ocean ridges.

- **Magnetometers** are sensitive instruments that can detect the direction and strength of a magnetic field. Magnetometers were used to locate submarines during World War II. When ships carrying magnetometers crossed the Atlantic Ocean, the magnetometers usually pointed north, but sometimes they pointed south unexpectedly. The scientists noticed a pattern that looked like stripes of magnetic reversals travelling along a path parallel to the Mid-Atlantic Ridge on both sides of the ridge (Figure 11.8).

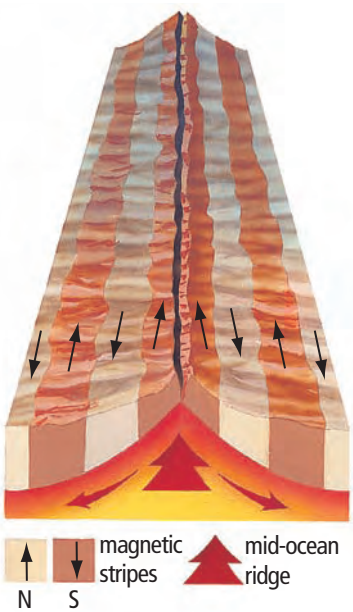


Figure 11.8 The pattern of magnetic reversals on the sea floor led scientists to suspect that the sea floor was spreading. As new crust forms, it takes on the magnetic polarity of Earth.

What was causing the magnetic reversals? You may recall that igneous rock forms from magma. As the magma cools, the iron-bearing minerals such as magnetite stay in line with the magnetic field. So, the stripes on the sea floor that are lined up to the south must have formed at a time when Earth experienced a reversal of its magnetic field. Since the stripes line up with the ridges, it meant that new rock was being formed at the mid-ocean ridges, and the sea floor was spreading.

- In *deep sea drilling*, core samples are collected by drilling deep into the oceanic crust using a drilling rig (Figure 11.9). Tests of the rock samples show that younger rock is closer to the Mid-Atlantic Ridge and older rock is closer to the continents. This was additional evidence that the Atlantic Ocean sea floor was spreading.

Figure 11.9 Scientists on the *Glomar Challenger* used oil drilling technology to sample the rock in one of the longest mountain ranges in the world, the Mid-Atlantic Ridge.

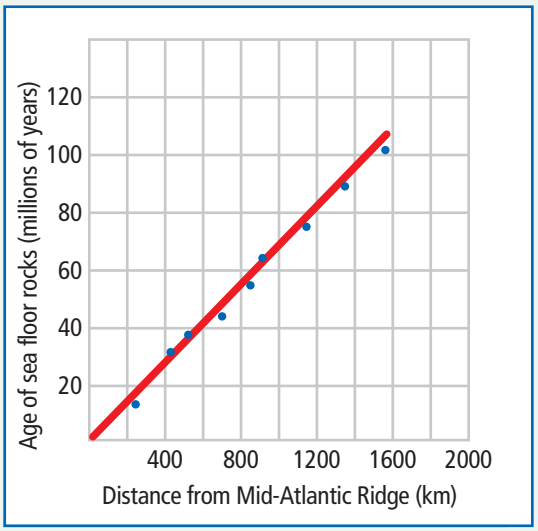
11-1D Evidence from the Sea Floor

Think About It

Science Skills

For help in reading graphs turn to Science Skill 1.

In this activity, you will discover what information rocks can provide about the sea floor. The graph below shows the ages and locations of samples of rock taken from the magnetic stripes at the bottom of the Atlantic Ocean. Each dot represents a sample of rock.



Ages and locations of rock samples

What to Do

Examine the graph and then answer the following questions.

What Did You Find Out?

1. What is the age of the oldest rock and the youngest rock on the graph?
2. How far would you have to travel east or west from the Mid-Atlantic Ridge before you found rocks that were 60 million years old?
3. Write a sentence that states the relationship between the age of rocks in the Atlantic Ocean and the distance they are from the Mid-Atlantic Ridge.
4. What does this evidence suggest is happening to the sea floor? Explain your answer.

Toward a New Theory

The new evidence collected by sonar, magnetometers, and deep-sea drilling indicated that Earth's crust was not fixed in place, as most people believed. If the sea floor was moving, then the continents must be moving, too. But what force was driving the crust to move?

Earlier in this chapter you learned that Earth's crust is broken into pieces called plates. Discoveries on the sea floor showed that when magma rises from an ocean ridge, the magma produces new crust, which pushes the plates apart. As these plates are pushed apart, other plates are pushed together. At some places, called **divergent boundaries,** plates move away from each other. At other places, called **convergent boundaries,** plates move toward each other.

J. Tuzo Wilson, a Canadian scientist, was one of the long line of scientists who have contributed to our understanding of Earth's crust (Figure 11.10). During the 1960s, most scientists still favoured the fixed continent model and dismissed the idea of continental drift. Wilson became a leading spokesperson for the idea of continental drift. He made an important addition to scientific observation when he developed the concept of a third kind of movement along plate boundaries. Instead of pushing together or pulling apart, he hypothesized that some plates were sliding past each other along what he called a **transform boundary.**

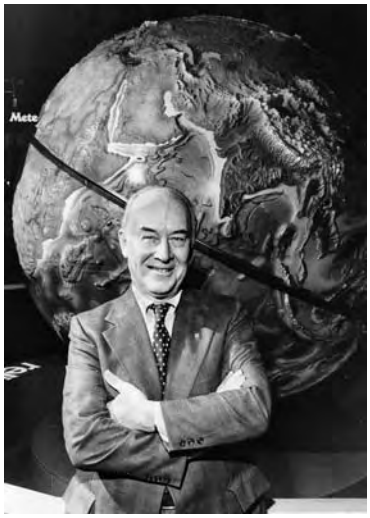


Figure 11.10 J. Tuzo Wilson (1908-1993)

internet connect

You can watch simulations of divergent, convergent, and transform boundaries on the Internet. Start your search at **www.discoveringscience.ca.**

Plate Tectonics

Together with the information about movement on the sea floor, Wilson's idea of transform boundaries brought about a rethinking of Earth's crustal movement. His discoveries helped form a new theory that completely revolutionized this branch of science in the 1970s. The name "continental drift" was no longer appropriate since the sea floor, as well as the continents, was moving. The new theory, called **plate tectonics,** states that Earth's crust is broken up into pieces, called plates that are always moving around on Earth's mantle (Figure 11.11 on the next page). Scientists now study the plates using satellites and lasers to measure plate movements.

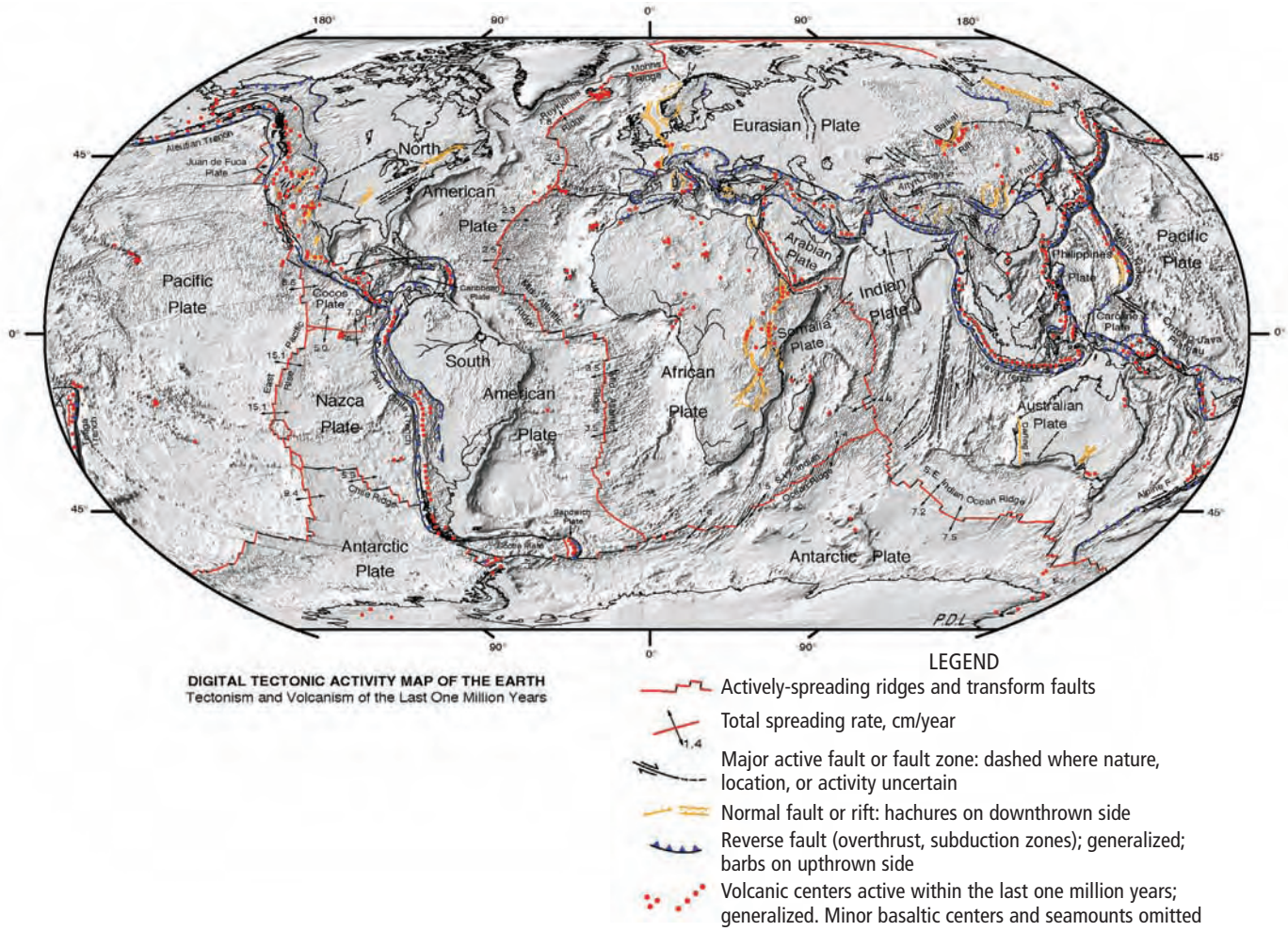


Figure 11.11 This diagram shows the major plates, their direction of movement, and the type of boundary between them. Notice that most plates include both continental crust and oceanic crust.

Convection Currents

The theory of plate tectonics provides the best explanation, up to now, for all of the evidence that has been gathered. However, scientists are still not sure what causes the plates to move. One explanation is that **convection currents** in the mantle under Earth's crust move the plates (Figure 11.12).

You may recall from earlier studies of heat that hot fluids tend to rise and cool fluids tend to sink. The same process might be occurring in Earth's mantle. Hot magma in the lower mantle moves upward after it is heated by the intense heat in Earth's core. At the upper part of the mantle, the heated rock moves horizontally under the plate above it, taking the plate along as if the plate were on a conveyer belt. When the rock finally cools, it sinks down farther into the mantle. As it does so, it pulls the edge of the plate down with it, forming a deep ocean trench.

Did You Know?

Plates that hold the greatest continental masses move more slowly than plates that hold smaller continental masses. The African, Eurasian, and American Plates move about 20 mm per year, in comparison with the Pacific, Nazca, and Cocos Plates, which can move up to 130 mm per year.

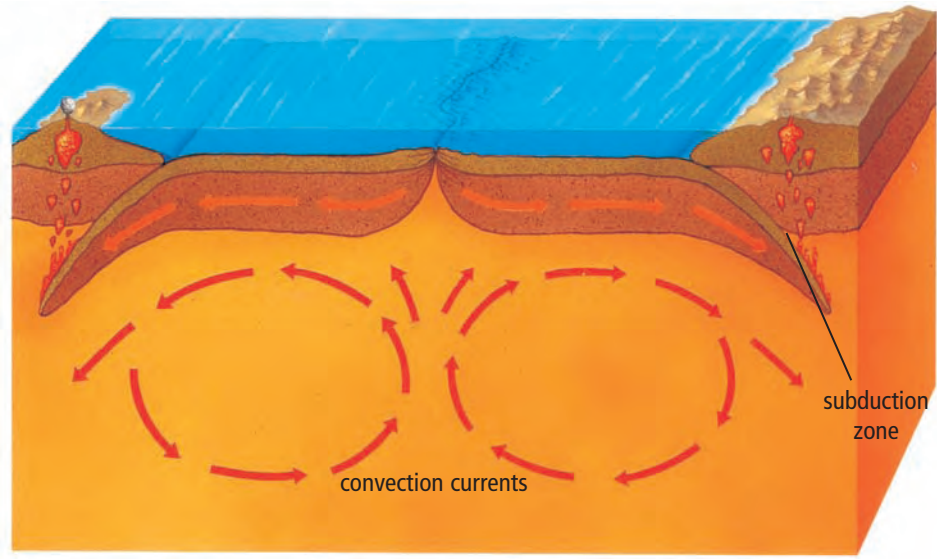


Figure 11.12 This model shows one way that convection currents might move plates.

Each plate touches several other plates, so each movement of one plate affects other plates. When two plates collide or converge, one plate is shoved under the other. The area where one part of the crust is forced below another part is called a **subduction zone** (Figure 11.12).

Convection currents might be the reason why the Atlantic Ocean is widening at the Mid-Atlantic Ridge. Does sea floor spreading mean that Earth's crust is getting bigger? No, because while new crust is forming in the ridge of the Atlantic Ocean, other crust is being pushed or pulled down into the ocean trenches and recycled back into the mantle as molten rock.

Explore More

Plate movements are an example of incremental change, which is change that happens slowly. Where might the plates be in a million years? In a billion years? Find a simulation of plate movements predicted for the next four billion years. Start your search at **www.discoveringscience.ca.**

Reading Check

1. What three new technologies provided information about the sea floor?
2. What are three types of movement that can happen at plate boundaries?
3. What theory did J. Tuzo Wilson help develop?
4. What is a subduction zone?

11-1E Building a Model of Plate Tectonics

Skill Check

- Observing
- Modelling
- Explaining systems
- Evaluating information

Geologists often have a difficult time duplicating the conditions found in Earth's crust in order to study them. So, as well as studying Earth's crust directly, geologists develop models and computer simulations to use in the laboratory. Models help them develop hypotheses about why Earth's crust behaves the way it does. In this activity, you and your partners may collect the same data, but each of you may develop a different hypothesis. Many geologists create different hypotheses based on the data they collect.

Safety

Materials

- 1 large plastic tub
- disposable gloves (optional)
- spoon
- two 1 kg boxes of cornstarch
- measuring container
- water
- 4 petri dishes
- puzzle pieces, marbles, building blocks, bingo chips, etc.

Question

What hypothesis about Earth's crust can you form based on your model?

Procedure

1. Clean the plastic tub.
2. Wear disposable gloves or wash your hands before beginning. It is important that the mixture stays clean. Only one person's hands should be in the mixture at one time.
3. Use the spoon to mix the cornstarch and 500 mL water in the tub. Continue adding water until the mixture is solid when you squeeze it between your fingers and it runs through your fingers when you hold it loose in the palm of your hand.
4. Investigate the properties of this mixture for several minutes. Then, squeeze as much cornstarch as possible from your hands back into the tub.
5. Meanwhile, your partners can work with small amounts of the mixture in petri dishes. Use the bingo chips, puzzle pieces, and any other objects approved by your teacher. Create a model of plate tectonics in the petri dishes while you wait your turn for the larger tub. Slide the objects slowly across the surface. Create different types of boundaries between continental plates. Form an hypothesis about Earth's crust based on your observations.
6. Record your observations and hypothesis.

Analyze

1. (a) State your hypothesis. Support it with evidence from your investigation.
   (b) Describe the appearance of a freshly broken piece of the mixture.
   (c) Explain how this appearance supports your hypothesis.
2. Why do some substances float and some sink in the mixture?

Conclude and Apply

1. In what ways does the mixture resemble a liquid?
2. In what ways does the mixture resemble a solid?
3. Explain why you think the mixture has these unusual properties.
4. How do you think your model helps to explain the concept of plate tectonics?
5. Draw a diagram of your model. Use arrows to show plate movement.

The North American plate and European plate meet in the country of Iceland. On the left side of the photograph is the eastern edge of the North American Plate. On the right is the western edge of the European plate. The two plates are slowly moving apart.

Career Connect

Dr. Charlotte E. Keen

Geophysicist

Charlotte Keen worked on LITHOPROBE, the largest earth science project ever undertaken in Canada, studying the geology of the sea floor. In 1995, she won the J. Tuzo Wilson Medal for her outstanding contributions to geophysics in Canada.

Q. What part of Earth do you study?

A. I look at the continental margin off the east coast of Canada that runs from Baffin Bay right down to south of Nova Scotia. This is the area where the North American continent, of which Canada is a part, once separated from neighbouring continental plates. Continental margins can tell us a lot about how Earth is changing, and the rock underneath them holds great potential for natural resources: oil, gas, and valuable minerals. I study the rock that lies up to 40 or 50 km below that margin.

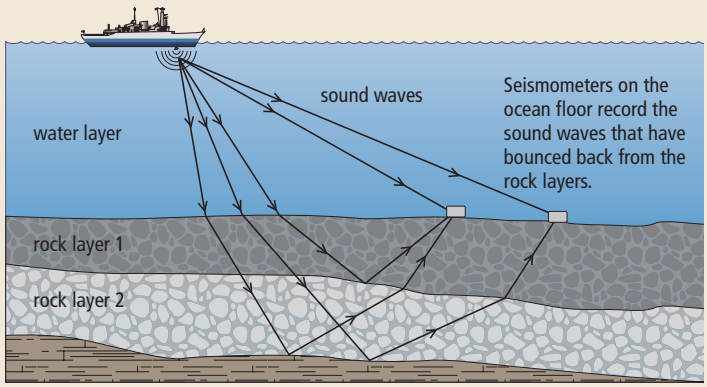
Q. How can you study rock so far below Earth's surface?

A. I look at the way vibrations from sound waves travel through that rock. My colleagues and I plan experiments for the area we want to study. We assemble a team of nearly 100 people, gather the necessary equipment, and then head out to sea. We lower sensitive recording devices called seismometers onto the ocean floor of the area we will study. The ship travels away from the devices, firing an air gun which makes a very loud sound. The sound waves go down through the water and into the rock. Some waves bounce up off layers of rock, others go deeper before they bounce back. When each sound wave reaches the device, it is recorded.

Q. Do the sound waves tell you something about the rock?

A. Yes. Sound waves travel through different types of materials at different speeds. The amount of time it takes for each sound wave to be recorded helps me figure out what kind of rock the sound wave may have passed through. We keep firing the air gun from many different distances, keeping track of exactly where we were and the time at which it was fired. Usually, we are at sea for two to four weeks to record everything that we need. Once we are back on land, I analyze the data from the recording devices to figure out what type of rock exists in each place and how thick the layers are. It is exciting to be able to explore areas where new observations can be made. Who knows what the ocean floor still has to tell us about Earth's crust!

An air gun is fired from the ship, making a loud sound.



Check Your Understanding

Checking Concepts

1. Sketch and label a model of Earth's layers.
2. (a) What two types of evidence do scientists use to determine what is inside Earth?
   (b) Give an example of each type of evidence.
3. (a) How does sonar work?
   (b) What information does sonar provide about the sea floor?
4. What evidence do we have that Earth's magnetic field has reversed over time?
5. What discovery was made when rock samples from deep-sea drilling were tested?
6. (a) What do scientists now think is causing the continents to move?
   (b) Give one reason why the term "continental drift" is no longer appropriate and why we now use "plate tectonics."

Understanding Key Ideas

7. Why are scientists not sure what is inside Earth's inner layers?
8. Copy this chart into your notebook. Complete the chart using the evidence Wegener collected to support his idea of continental drift.

Type of Evidence	Example of Evidence	Why the Example Suggests that Continents Have Moved

9. How is new rock being formed at the sea floor?
10. Draw a diagram to show how convection currents occur in Earth's crust and how they cause plate movement.
11. Describe two ways in which the plate tectonics theory is different from the theory of continental drift.
12. Could one plate move by itself, or do all plates need to move together? Explain your answer.

Pause and Reflect

Suppose that you could invent a way to gather direct evidence from Earth's inner core. Use a diagram to show how your invention would work.

11.2 How Earthquakes and Volcanoes Shape Earth's Crust

An earthquake is the shaking of the ground. When the crustal plates move, tension can build up in the rock, causing it to suddenly move or break, resulting in an earthquake. Most earthquakes occur along plate boundaries. A volcano is an opening in Earth's crust. Volcanoes can be found where plates collide, where plates separate, and where plates are thin. Volcanic eruptions have benefits as well as risks.

Key Terms

bedrock
earthquake
epicentre
fault
focus
Richter scale
Ring of Fire
seismic waves
seismograph
volcano

On Monday evening, November 18, 1929, a huge wave, travelling at over 100 km/h struck the Burin Peninsula in southern Newfoundland. Eyewitnesses described a wall of water 5 m high breaking over the houses around the harbours and pouring in through the windows and doors. Twenty-seven people were killed and many families lost their winter food supply, their heating fuel, their boats, their houses, and all their possessions. Over 10 000 people in more than 40 settlements were affected by the wave. The wave was a tsunami, which is a Japanese word for "harbour wave." The tsunami was caused by an underwater earthquake on the floor of the Atlantic Ocean about 250 km south of the Burin Peninsula.

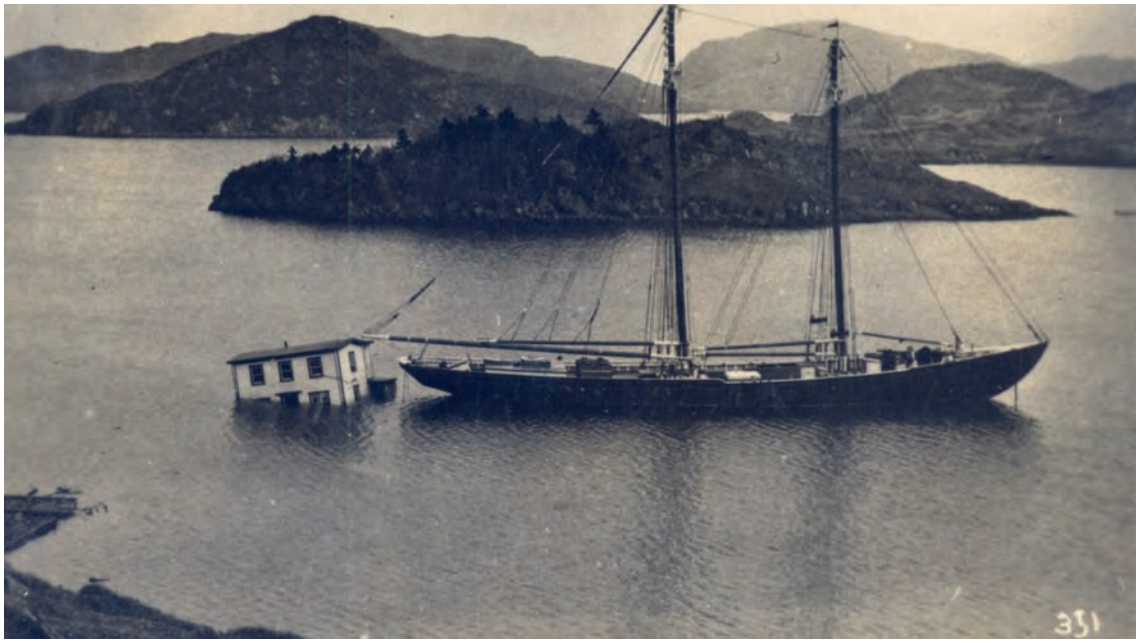


Figure 11.13 A washed-out house is retrieved by a schooner after the 1929 tsunami in Newfoundland.

Figure 11.14 A tsunami is actually a series of waves, and each wave can cause destruction.

Did You Know?

Tsunamis can be caused by underwater landslides and volcanoes, as well as by earthquakes.

On December 26, 2004, an underwater earthquake near Sumatra in Southeast Asia created a tsunami that reached the shores of countries bordering on the Indian Ocean. More than 200 000 people lost their lives and 1.69 million people lost their homes and possessions. This was the single worst tsunami in history.

Most geological processes take place very slowly, over thousands or millions of years. But some processes, like earthquakes, tsunamis, and volcanic eruptions can happen very quickly and with very little warning. Why does Earth's crust sometimes move quickly?

11-2A Seismic Sandpaper

Find Out ACTIVITY

In this activity, you will model how an earthquake can be caused.

Materials

- 2 wooden blocks, each about 5 cm by 10 cm by 15 cm
- 2 sheets of medium grade sandpaper
- masking tape

What to Do

1. Wrap a sheet of sandpaper around each block and secure with masking tape.
2. Hold the blocks straight up and down, one in each hand.
3. Push the blocks together tightly. While you push, try to slide the blocks past each other in different directions.

What Did You Find Out?

1. What happened when you tried to move the blocks?
2. How do you think this activity models an earthquake?

Figure 11.15 An ancient earthquake detector from China. The eight dragons on this urn have little balls inside them. Earthquake movements shake the balls into the toads' open mouths. The direction of the earthquake is determined by which toad swallows the ball.

Detecting Earthquakes

The rock in Earth's crust is under pressure from internal forces. The stresses of moving plates can cause the rock to bend and stretch. Tremendous amounts of energy build up in the rocks. When the pressure is too great, the rock breaks suddenly, creating an earthquake. An **earthquake** is the shaking of the ground. Devices for measuring earthquakes have been used for thousands of years (Figure 11.15).

Seismologists are scientists who study earthquakes. They use a special machine called a **seismograph** to measure earthquakes (Figure 11.16A). Seismographs must be attached to **bedrock**, which is the solid rock that lies beneath the soil, in order to detect the vibrations that result from an earthquake. Inside the seismograph, a marking pen hangs over a rotating drum, very lightly touching the drum. The drum is covered with paper to record the vibrations marked by the pen. When an earthquake strikes, the pen tip moves, making a jagged line. The record of vibrations detected by a seismograph is called a seismogram (Figure 11.16B). Most modern seismographs are electronic, but they are based on the same principles.

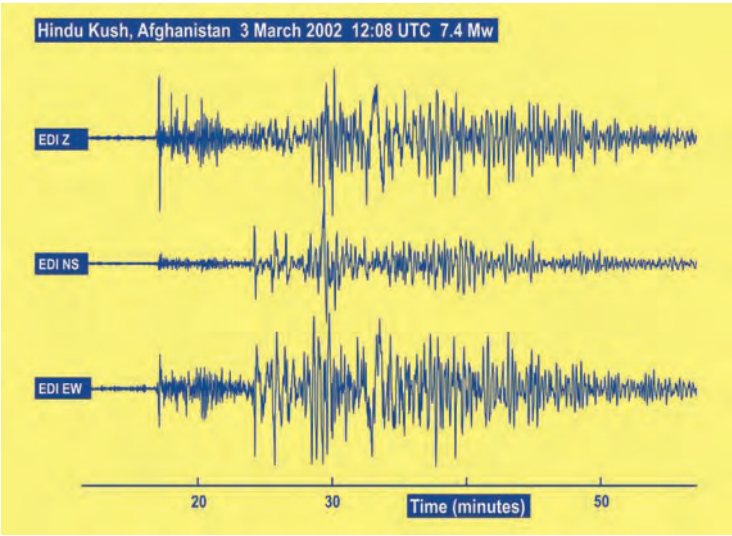


Figure 11.16B The jagged line on this seismogram represents earthquake waves.

Figure 11.16A Seismologists study earthquakes by reading seismographs.

Measuring Earthquakes

Seismologists use a method of measurement called the **Richter scale** to describe the strength of an earthquake (Table 11.1). The Richter scale starts at zero and can go as high as necessary. The amount of energy released increases greatly as the numbers increase. An earthquake that registered 7 would be about 30 times stronger than one that registered 6, and about 900 times stronger than one that registered 5. Most earthquakes that cause damage and loss of life register between 6 and 8 on the Richter scale. The earthquake that caused the Burin Peninsula tsunami measured 7.2 on the Richter scale.

Suggested Activity
Design an Investigation 11-2D on page 385

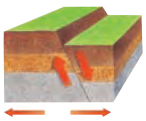
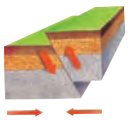
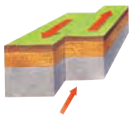
Table 11.1 Richter Scale

Richter Magnitudes	Earthquake Effects	Estimated Number per Year
< 2.0	generally not felt, but recorded	600 000
2.0–2.9	felt by few	300 000
3.0–3.9	felt by some	49 000
4.0–4.9	felt by most	6200
5.0–5.9	damaging shocks	800
6.0–6.9	destructive in populated areas	266
7.0–7.9	major earthquakes, which inflict serious damage	18
≥ 8.0	great earthquakes, which produce total destruction to communities near the source	1-2

Three Types of Faults

A **fault** is a break in rock layers. Table 11.2 shows that there are three types of faults along which rock can move: normal faults, reverse faults, and transform faults.

Table 11.2 Three types of faults

Fault	Where It Is Produced	How It Is Produced	How the Rock Moves
Normal fault 	divergent boundaries	plates move apart	rock above the fault moves downward
Reverse fault 	convergent boundaries	plates push together	rock above the fault moves up and over rock below the fault
Transform fault 	transform boundaries	plates move sideways past each other	rock breaks as the plates try to slide past each other

Word Connect

Seismic comes from a Greek word, meaning "shake."

Seismic Waves

If you have never experienced an earthquake, you might think that the ground shakes only once and then the earthquake is over. There can actually be many episodes of ground-shaking movement, however, caused by seismic waves. **Seismic waves** are the energy waves that travel outward from the source of the earthquake. These aftershocks are actually smaller earthquakes, and they produce even more ground movement. Aftershocks can cause damaged buildings to collapse.

You have probably thrown a small stone into water and watched the ripples spread out from the point where the stone entered the water. Seismic waves travel across Earth's surface in a similar way. They can cause parts of a building to move up while other parts move down. Rigid structures will collapse if the movement is too great.

The place deep in the crust where an earthquake begins is called the **focus** of the earthquake (Figure 11.17). The surface location directly above the focus is called the **epicentre.** Seismic waves travel outward from both the focus and the epicentre. You can use the arrival time of seismic waves to determine earthquake locations. The farther apart the waves are, the farther away is the earthquake.

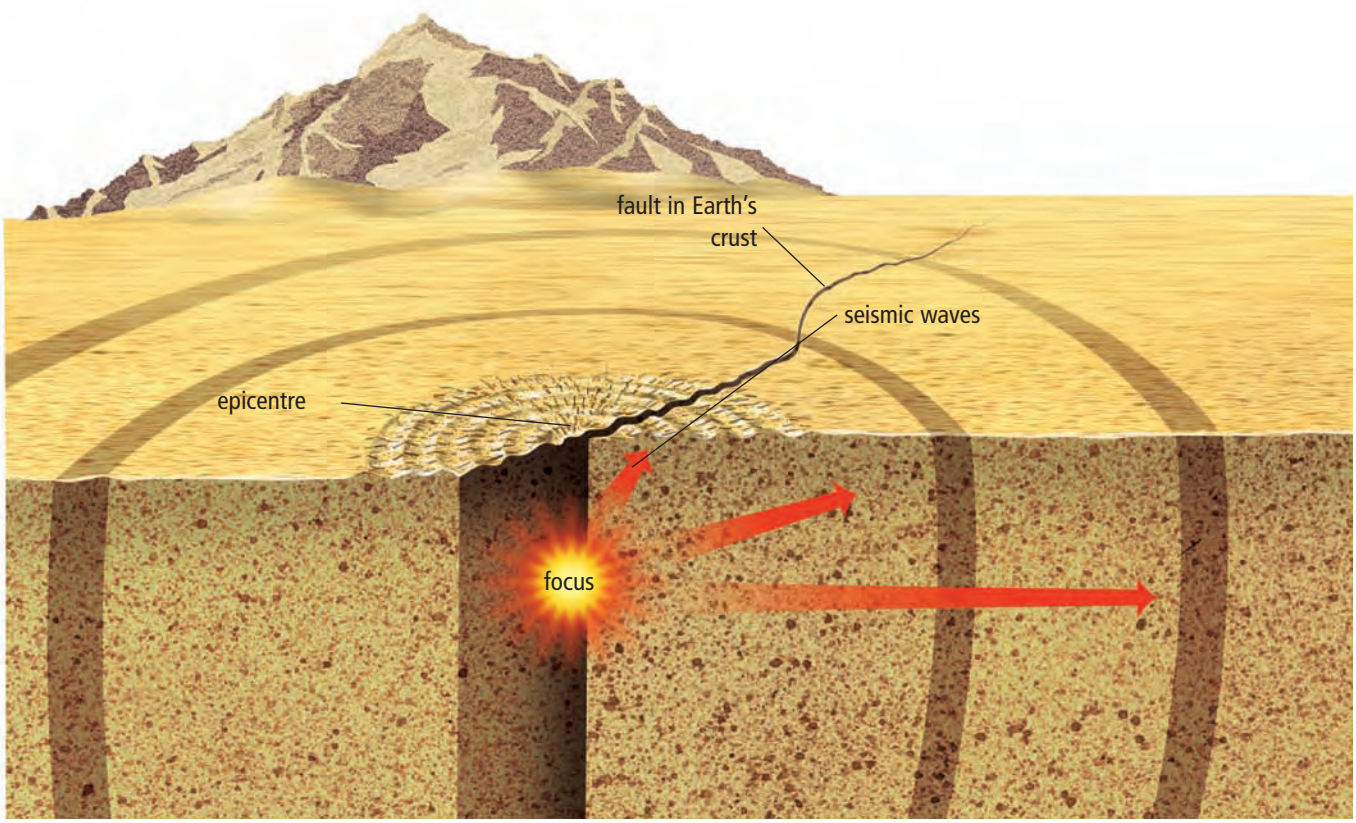


Figure 11.17 Some seismic waves travel out from the focus. Some seismic waves travel out from the epicentre, much like ripples in a pond.

Seismic waves provide some evidence of what might be inside Earth. For example, an earthquake that happened in Kobe, Japan in 1995 was measured at the University of Manitoba. The seismic waves had travelled right through the centre of Earth. Some seismic waves can travel through both liquids and solids and some waves cannot.

internet connect

You can compare arrival times of seismic waves and locate the epicentre of earthquakes online. Start your search at **www.discoveringscience.ca.**

Locations of Earthquakes

Most earthquakes occur along the active plate boundaries, such as off the British Columbia coast. Earthquakes in Canada also occur frequently in the Ottawa and St. Lawrence Valleys, in New Brunswick, and the offshore region to the south of Newfoundland. Earthquakes are less likely to happen at the centre of the plates. The Geological Survey of Canada (GSC) records and locates over 1500 earthquakes in Canada each year, but only a few of these earthquakes are strong enough to be felt by people (Figure 11.18).

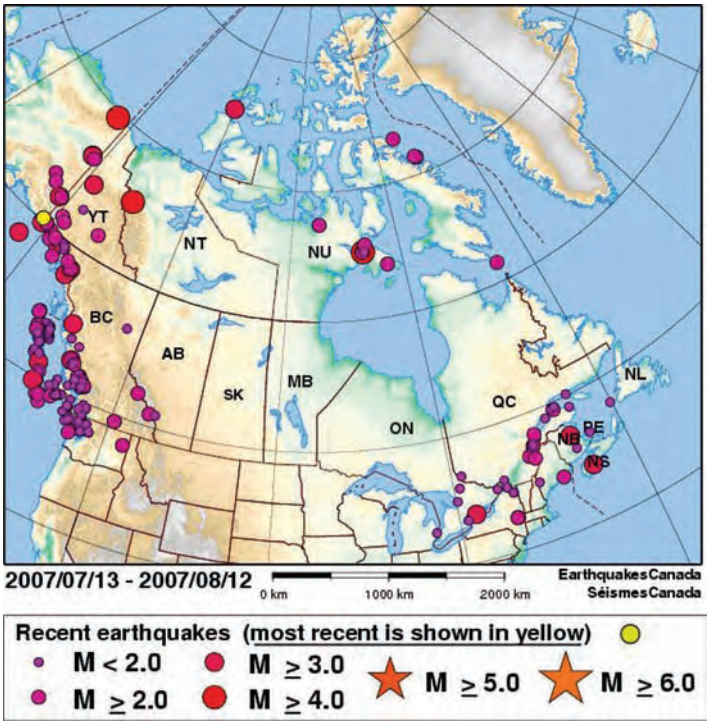


Figure 11.18 Every month there may be more than 100 earthquakes in Canada.

Reading Check

1. Why is a seismograph attached to bedrock?
2. Which is stronger: an earthquake measuring 7 or an earthquake measuring 5 on the Richter scale?
3. What are three types of faults?
4. Where do most earthquakes occur?

11-2B Seismic Safety

Think About It

In this activity, you will list your ideas about how you might prepare for a sudden movement in Earth's crust.

What to Do

1. Consider what changes might be necessary in your bedroom to prevent you from being injured if an earthquake happened while you were sleeping. For example, are there any shelves with heavy objects at the top? Make a list of changes to your bedroom.
2. Think about the items you might need in an emergency kit if an earthquake or tsunami occurred. How long might you need them? Where could you store your emergency kit? Make a list of items for your emergency kit.
3. Compare your lists with another student's lists. Make any changes that you feel would improve your own lists.

Figure 11.19 The volcano Parícutin, erupting

Volcanoes

Imagine watching a volcano appear right before your eyes. A farmer, his wife, and his son in Mexico had this experience in 1943 when the ground in their cornfield suddenly sent clouds of ash, stones, and glowing cinders into the air. The volcanic activity continued for almost ten years, eventually covering the nearby village in ash and lava. The volcano was named Parícutin, the name of the village it covered. Parícutin is now over four hundred metres high (Figure 11.19).

A **volcano** is an opening in Earth's crust. Scientists study volcanoes to learn more about the internal structure of Earth (Figure 11.20). What would you observe if you watched a huge volcano erupt? Imagine the terrific heat, the choking ash, and the streams of red-hot lava.

Figure 11.20 Scientists try to predict when volcanoes will erupt so people living near them can avoid injury or death.

Figure 11.21 The most active volcano on Earth is Kilauea in Hawaii. Kilauea has been continuously erupting since 1983. The lava from Kilauea has flowed into residential areas, causing many millions of dollars of damage.

Benefits and Risks of Volcanic Eruptions

Volcanic eruptions have created many valuable resources. For example, volcanic ash increases soil fertility. Forests and farm crops grow better because the ash adds nutrients and acts as mulch. Underground magma heats groundwater. The heated water can be used as a source of heat, or geothermal energy. Volcanoes release water and carbon dioxide from the interior of Earth, adding important gases to our atmosphere. Unfortunately, volcanoes can also destroy homes, trees, crops, and landscapes (Figure 11.21). The ash can travel great distances and cause breathing difficulties (Figure 11.22).

Did You Know?

A *dormant* volcano has not been active for a long time but has erupted in recorded history. An *extinct* volcano has not erupted in recorded history.

Figure 11.22A Ash from the eruption of Mount Pinatubo blocked the sunlight and buried fields and roads. Torrential rains caused mudflows that destroyed villages and left thousands of people homeless.

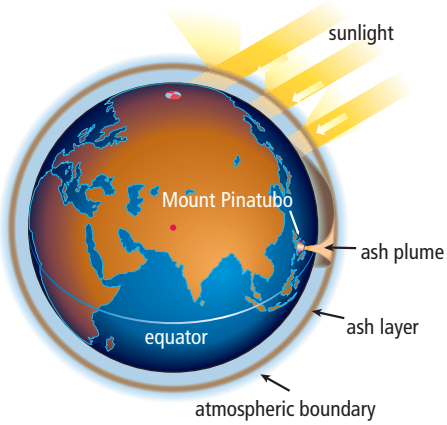


Figure 11.22B Mount Pinatubo erupted in the Philippines in 1991. The huge amount of ash blown out of the volcano formed an ash layer within the atmosphere. The ash layer circled the globe and cooled temperatures around the world.

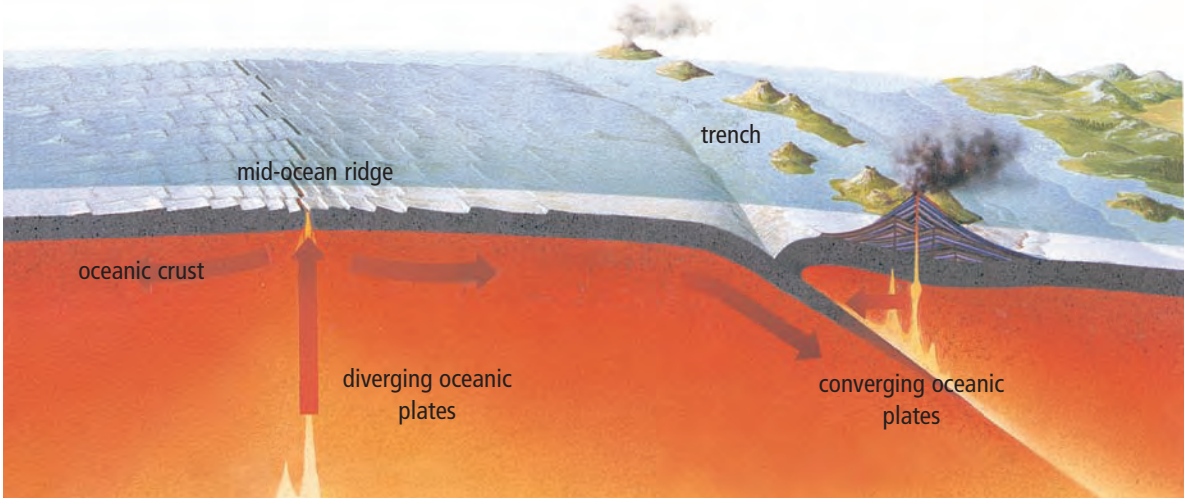


Figure 11.23 If the two converging plates are oceanic plates, either plate might subduct, forming volcanoes.

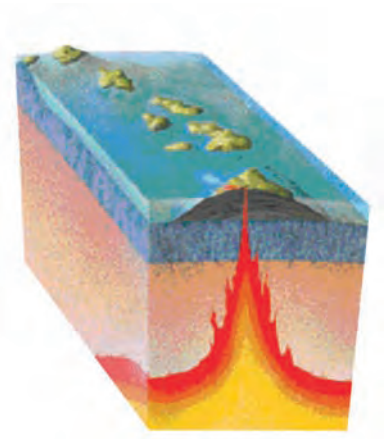


Figure 11.24 The northern islands in the Hawaiian Island chain no longer have any volcanic activity. Which islands in the chain do you think are the oldest?

Volcano Locations

Like earthquakes, volcanoes can be formed when rock surfaces beneath Earth's crust push against one another, and one layer is forced below the other. In a subduction zone, the descending rock moves deeper and deeper until it melts into magma. The magma rises up through cracks in the rock until it exerts enough pressure to cause the volcano to erupt (Figure 11.23).

Most volcanoes are found along plate boundaries. Volcanoes can be found in the following environments:

- *Where plates collide at convergent boundaries,* the part of the crust that is pushed downward reaches very hot areas where it melts and becomes magma. Eventually there is so much magma, it is forced up through openings, and erupts. An example is where the Pacific plate is being forced under Japan.
- *Where plates separate at divergent boundaries,* magma flows up to the surface. An example is the Mid-Atlantic Ridge.
- *In areas where plates are thin,* magma can be forced up through the cracks to the surface. Hot spots are places where the temperature under the crust is much higher than elsewhere. Hot spots are found below the Hawaiian Island chain in the Pacific Ocean (Figure 11.24).

Did You Know?

A new volcano is forming under the ocean, right beside the main island of Hawaii. It has been named Loihi. It will continue to grow until it is another island in the middle of the Pacific Ocean. Perhaps your descendents will visit Loihi in the future!

Volcanoes of the World

A famous eruption occurred in 1980 in Washington state. The rock on the side of Mount St. Helens began to bulge. Scientists knew that an eruption would happen soon, so they had time to warn people to stay away from the area. Figure 11.25 shows how magma built up inside the volcano to cause the eruption.

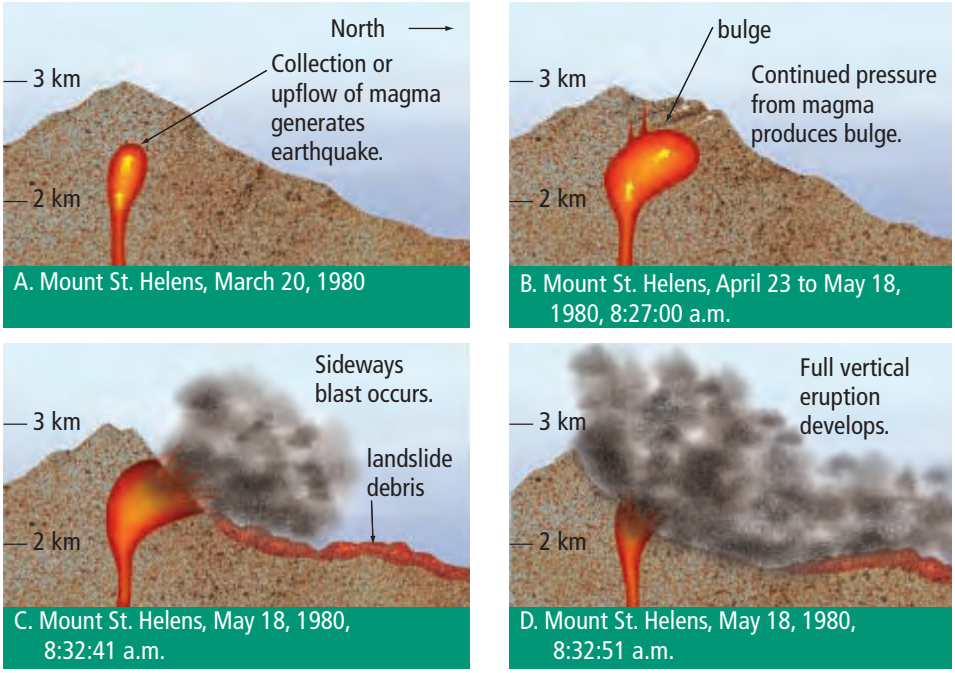


Figure 11.25 Volcanoes erupt in stages, over a period of several weeks, months, or even years.

One of the worst eruptions in history happened on August 27, 1883, when the volcanic island of Krakatau in Indonesia literally blew up. The blast was heard 4800 km away. At least 32 000 people died when tsunamis reaching 30 m in height were triggered by the eruption.

Many scientists believe that Mount Vesuvius, in southern Italy, is due for a large eruption. Mount Vesuvius is considered one of the most dangerous volcanoes in the world because it has a history of violent eruptions (Figure 11.26) and because almost three million people live close to the volcano. Its last eruption was in 1944, and since then a huge area beneath the peak has been filling with magma. The situation is even more dangerous because the opening at the peak is sealed by a rock "plug." Scientists have produced computer simulations to show that, when pressure forces the rock plug out, a cloud of molten rock, ash, and gas will blast about 1.5 km upwards. Plans are being made for emergency measures if such an event occurs.

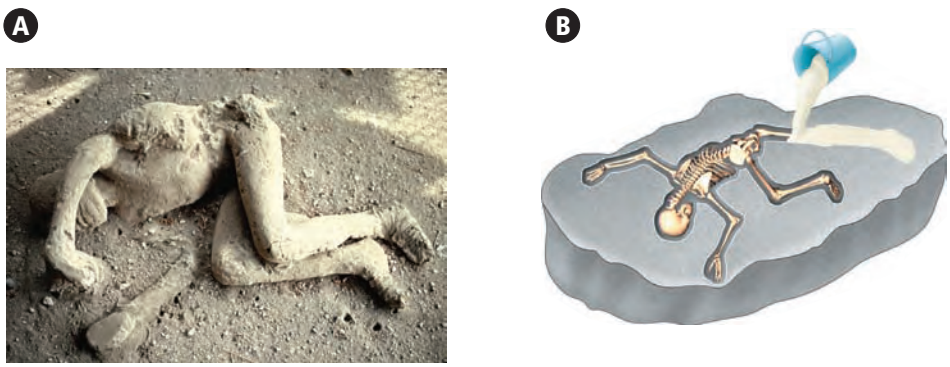


Figure 11.26 Photograph (A) shows a plaster cast of a body buried in the eruption of Mount Vesuvius in 79 C.E. After the body decayed, plaster was poured into the cavity it left. When the plaster cast hardened, the surrounding ash was removed (B).

Suggested Activity

Think About It 11-2E on page 386

Did You Know?

Some volcanoes have flat tops because they erupted beneath a glacier or in a glacial lake. Hyalo Ridge in British Columbia is a typical, flat-topped, steep-sided, sub-glacial volcano.

The volcanoes encircling the Pacific Ocean are called the **Ring of Fire** (Figure 11.27). Krakatau, Mount St. Helens, and Mount Pinatubo are part of this Ring of Fire.

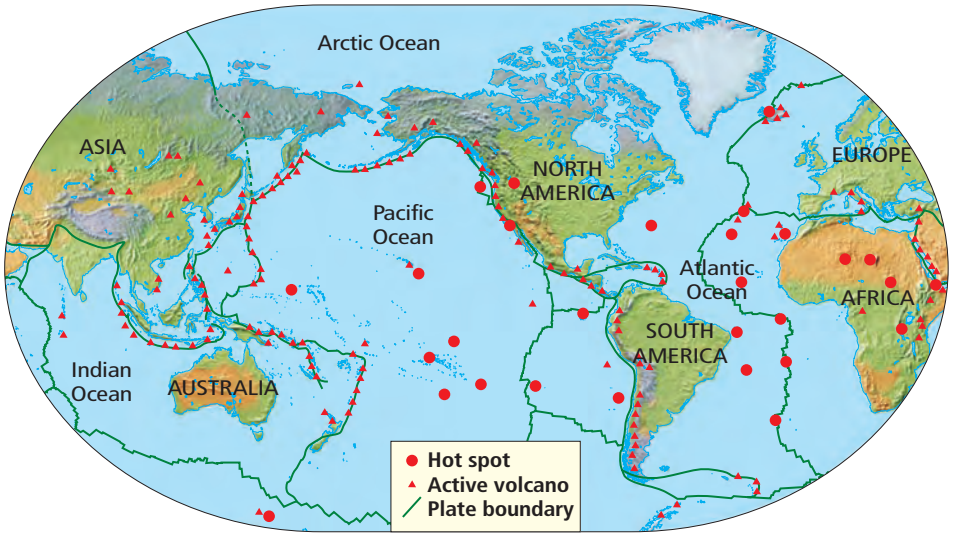


Figure 11.27 The Ring of Fire is a belt of active volcanoes that circles the Pacific Ocean.

Explore More

In November of 1963 the crew of a trawler noticed smoke from the ocean off the coast of Iceland. When they went to investigate, they discovered it was an underwater volcanic eruption. Within a few days the eruption had created an island. With continued eruptions, the island grew for the next four years. Find out more about the island of Surtsey. Visit **www.discoveringscience.ca.**

Reading Check

1. What are three benefits of volcanic eruptions?
2. What are three risks of volcanic eruptions?
3. What are three environments where volcanoes occur?

11-2C Seismic Stories

Think About It

Different cultures throughout history have had ideas and theories about the origins and causes of volcanic and earthquake activity. Anaxagoras, who lived in ancient times in Greece, believed that volcanic eruptions were caused by great winds within Earth. Hawaiian mythology tells of the Fire Goddess Pele, who lived inside the volcano Kilauea. When she was angry, the volcano erupted. North American Aboriginal people also have explanations for the movements of Earth. In this activity, you will investigate how people of various cultures, times, and traditions have explained volcanoes and earthquakes.

What to Do

1. Choose a culture to research. Find a story or explanation about the cause of volcanoes or earthquakes.
2. Learn the story and prepare a way to share it. You might tell it in your own words, create an illustrated book, or prepare a recording or short dramatization. Or you might make a class mural of ancient stories.

11-2D Shake It!

Design an INVESTIGATION

Inquiry Focus

Skill Check

- Measuring
- Modelling
- Evaluating information
- Working co-operatively

Materials

Suggested list:

- marbles or small rocks
- masking tape
- modelling clay
- paper (sheets of paper or adding machine paper)
- paper clips
- paper plates and cups
- pencils
- pieces of wood
- rubber bands
- shoebox
- soup can or oatmeal cylinder
- springs
- string
- washers
- water

Science Skills

For help in designing an investigation, turn to Science Skill 2.

In this activity, you will design and build a seismograph.

Question

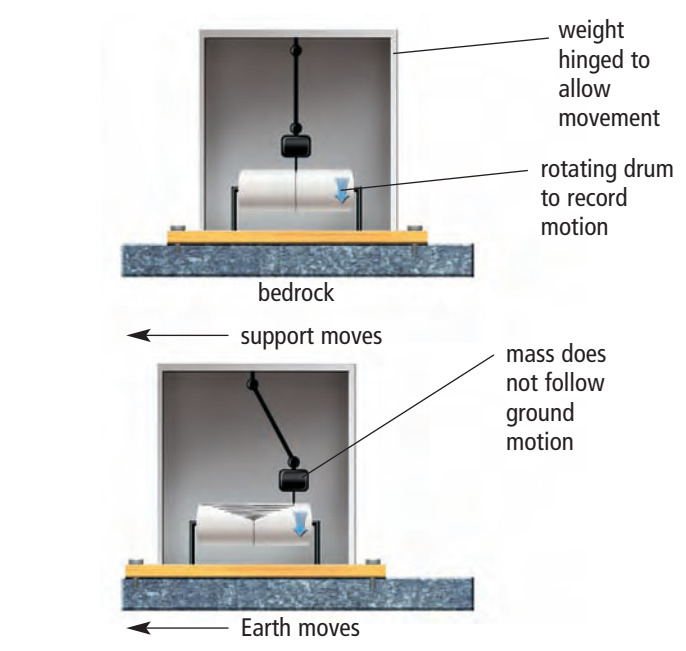
How can you design a device to detect movement?

Procedure

1. Work with your partner to design a seismograph.
2. You can use any combination of the materials listed or other materials approved by your teacher.
3. Draw and label your design. Have your teacher approve your design, and then build your seismograph.
4. Test your seismograph. Make any refinements or improvements you can think of. Record the changes you made to the design and why you made them.
5. Demonstrate your seismograph for other students. Compare it with those designed by your classmates.
6. Discuss your comparisons with your partner, and write down what you noticed.

Conclude and Apply

1. How well did your seismograph work?
2. What improvements could you make to your seismograph based on other groups' designs?
3. What was the most challenging part of designing a seismograph?



11-2E Patterns in Earthquake and Volcano Locations

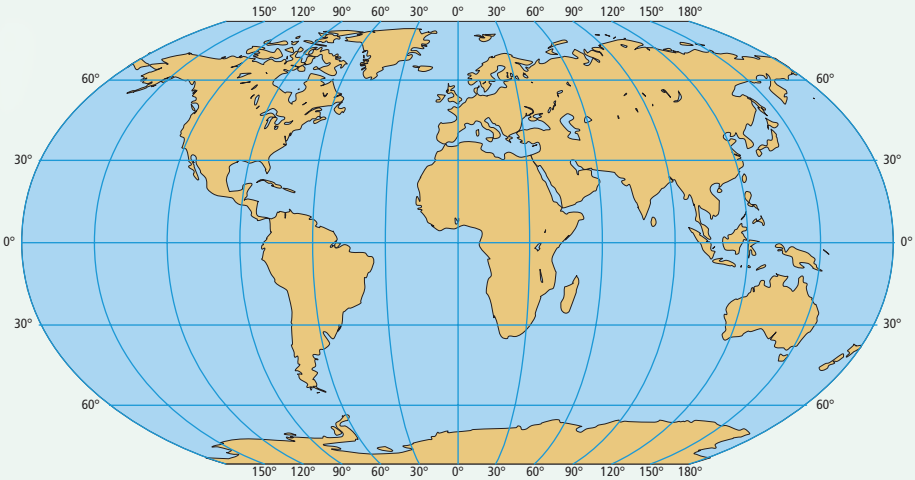
Skill Check

- Graphing
- Communicating
- Explaining systems
- Evaluating information

Materials

- world map with latitude and longitude lines
- blue, red, and green coloured pencils or markers

In this activity, you will plot earthquake, volcano, and plate boundary locations on a map using lines of latitude and longitude. You will look for patterns in the occurrence of earthquakes and volcanoes, and the locations of plate boundaries.



Procedure

1. Use the tables in this investigation, or obtain your own list of earthquake and volcano locations from the Internet.
2. Mark the locations of earthquakes with blue dots on the map provided by your teacher.
3. Mark the locations of volcanoes on your map with red dots.
4. Mark the locations of the plate boundaries on your map in green.
5. Create a legend on your map to show what each symbol represents.

Analyze

1. Are most of the earthquakes located near volcanoes? Explain.
2. Describe the pattern earthquakes, volcanoes, and plate boundaries in or around the Pacific Ocean.
3. Does the pattern around the Atlantic Ocean look similar to or different from the pattern around the Pacific Ocean? Explain.
4. Where do most earthquakes occur in North America?
5. Describe any other places in the world that appear to have a large number of earthquakes.

Earthquakes Around the World

Longitude	Latitude	Location
72°W	33°S	Valparaiso, Chile
78°E	44°N	Tien Shan, China
105°E	36°N	Kansu, China
140°E	36°N	Tokyo, Japan
102°E	37°N	Nan Shan, China
85°E	28°N	Bihar, India
39°E	35°N	Erzincan, Turkey
136°E	36°N	Fukui, Japan
133°W	54°N	Queen Charlotte Islands
97°E	29°N	Assam, India
3°E	35°N	Agadir, Morocco
48°E	38°N	Northwestern Iran
147°W	61°N	Seward Alaska
57°E	30°N	Southern Iran
87°W	12°N	Managua, Nicaragua
92°W	15°N	Central Guatemala
118°E	39°N	Tangshan, China
40°E	40°N	Eastern Turkey
68°W	25°S	Northwestern Argentina
78°W	1°N	Ecuador-Colombia border
137°W	37°N	Honshu, Japan
102°W	18°N	Western Mexico
45°E	41°N	Northwestern Armenia
122°W	37°N	San Francisco, California
135°E	35°N	Kobe, Japan
122°E	47°N	Nisqually, Washington
58°E	29°N	Bam, Iran
95°E	3°N	Sumatra, Indonesia

Volcanoes Around the World

Longitude	Latitude	Location
122° W	46°N	Mount St. Helens, Washington
123°W	50°N	Garibaldi, British Columbia
130°E	32°N	Unzen, Japan
25°W	39°N	Fayal, Azores
29°E	1°S	Nyiragongo, Zaire
152°W	60°N	Redoubt, Alaska
102°W	19°N	Parícutin, Mexico
156°W	19°N	Mauna Loa, Hawaii
140°E	36°S	Tarwera, Australia
20°W	63°N	Heimaey, Iceland
14°E	41°N	Vesuvius, Italy
78°W	1°S	Cotopaxi, Ecuador
25°E	36°N	Santorini, Greece
123°E	13°N	Mayon, Philippines
93°W	17°N	Fuego, Mexico
105°E	6°S	Krakatoa, Indonesia
132°W	57°N	Edziza, British Columbia
74°W	41°S	Osorno, Chile
138°E	35°N	Fujiyama, Japan
15°E	38°N	Etna, Sicily
168°W	54°N	Bogoslov, Alaska
121°W	40°N	Lassen Peak, California
60°W	15°N	Mount Pelée, Martinique
70°W	16°S	El Misti, Peru
90°W	12°N	Coseguina, Nicaragua
122°W	49°N	Mount Baker, Washington
121°E	15°N	Mount Pinatubo, Philippines

Conclude and Apply

1. What conclusions can you make about earthquake and volcano locations, based on your observations?
2. If you were a scientist, what might you hypothesize about the areas of Earth's crust where volcanoes and earthquakes are found?

Science Watch

Exploring the Big Deep

Picture the bottom of the sea floor, hundreds of metres below the surface. It is cold and dark and there is enormous pressure from all the layers of water. How can we gather evidence from the oceanic crust when it is such a dangerous place for us to visit?

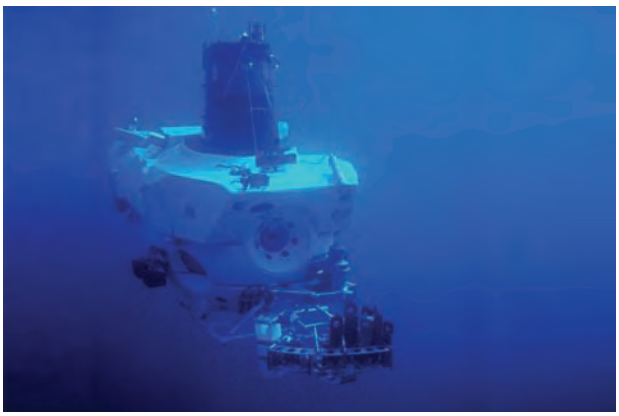
Luckily, a Canadian invention reduces the danger of exploring the sea floor. ROPOS (Remotely Operated Platform for Ocean Science) is a Canadian-owned and operated ROV (remotely operated vehicle) that can dive as deep as 5000 m below the ocean's surface. About the size of a small car, ROPOS is tethered to a mother ship and launched into the ocean inside a large cage. The cage releases ROPOS once it approaches the sea floor.

From the comfort of their control room inside the mother ship, the ROPOS team of pilots and technicians can carry out a wide variety of scientific explorations at the flick of a switch or swivel of a joystick. Live footage of the sea floor is transmitted from video cameras mounted on ROPOS via electrical-optical cable onto video monitors inside the control room. By manipulating two robotic arms on the vehicle, the ROPOS team can collect specimens of deep-sea organisms and geological samples from the sea floor. They can measure surrounding temperatures with temperature probes.

The team navigates ROPOS and its cage with the help of a sonar tracking system and Global Positioning System (GPS) satellites. This precise navigation system allows the ROPOS team to survey and map unexplored areas of the sea floor.

ROPOS and other deep sea vehicles have been used in exploring, filming, and gathering samples from hydrothermal vents in the sea floor. Data gathered by the vehicles has helped scientists better understand undersea volcanoes, seafloor spreading, and plate tectonics—all without having to dip a toe in the ocean!

ROPOS is lowered into the ocean in a metal cage.



The submersible *Alvin* was used to explore the wreck of *RMS Titanic*.

Questions

1. Why is the sea floor a dangerous area for humans to visit?
2. What are three activities ROPOS can perform?
3. How is ROPOS navigated?

Check Your Understanding

Checking Concepts

1. Define *earthquake*.
2. Explain how earthquakes are measured.
3. Explain how rock moves
   (a) in a normal fault
   (b) in a reverse fault
   (c) in a transform fault
4. Describe the difference between the focus and the epicentre of an earthquake.
5. Define *volcano*.
6. What are three environments where volcanoes can occur?
7. Where do most volcanoes occur?
8. Where is the Ring of Fire?
9. The buildings in this photograph were many kilometres from the epicentre of an earthquake near San Francisco. What caused the damage?

Understanding Key Ideas

10. Why does Newfoundland and Labrador experience far fewer earthquakes than British Columbia?
11. An earthquake, with a magnitude of 5.4 on the Richter scale, occurs in Alaska at the same time as an earthquake in California, measuring 5.3. Which earthquake was stronger: the one in Alaska or the one in California?
12. Copy this table into your notebook and complete it.

	How Are They Similar?	How Are They Different?
Locations of earthquakes and volcanoes		
Causes of earthquakes and volcanoes		

13. Why is it easier to predict *where* an earthquake will occur than *when* an earthquake will occur?
14. How do volcanoes support the theory of plate tectonics?

Pause and Reflect

An unusually low tide can be an indication that a tsunami is about to occur. Why do you think this is?

11.3 Mountain Building and Geologic Time

The movement along plate boundaries creates great heat and pressure. The pressure can cause the rock to fold and fault, forming mountains. Sometimes the heat can melt rock and cause it to rise to form volcanoes. Three different land masses were pushed together millions of years ago to form Newfoundland. The geologic times scale divides Earth's history into smaller units, based on when certain life forms appear. Fossils are the remains of living things.

Key Terms

fold
fossil
geologic time scale

"You're really growing, aren't you?" How many times has someone made a comment like this to you? Have you ever thought the same kind of comment could be applied to a mountain? How do mountains form? Which ones are still growing? Why do they stop growing? These are the kinds of questions that scientists ask as they try to solve some of the mysteries related to Earth's crust.

Mountain building takes many years, and it creates some of the most beautiful scenery in the world (Figure 11.28). Each mountain range has a distinctive and fascinating geological history due to plate tectonics.

Did You Know?

Mountains that are jagged at the top are young; mountains that are more rounded are older. The top of Mount Everest in the Himalayas, like you, is still growing taller. The Appalachians are an older mountain range that is in the process of being worn down.

Figure 11.28 Western Brook Pond is a popular destination in the Long Range Mountains on the island of Newfoundland.

11-3A Make a Mountain

Find Out ACTIVITY

In this activity, you will model how layers of sedimentary rock form into mountains.

Materials

- 3 sheets of flexible, spongy Styrofoam™ of different colours

What to Do

1. Pile the Styrofoam™ sheets on top of each other.
2. Put your hands on each side of the stacks and push together.

What Did You Find Out?

1. What happened to the Styrofoam™ as you pushed the sides together?
2. What happens to bendable objects when they are squeezed?
3. (a) Infer: Can rocks bend?
   (b) On what evidence do you base your answer?
4. Suppose you had cut a fault (crack) through the layers before you squeezed them. How might your results be different?

Rocks under Pressure

Most mountains are large areas that have been uplifted due to the movement or heating of plates. Sedimentary rocks that are placed under slow, gradual pressure can either fold or fault. A **fold** is a bend in rock layers. A fault is a break in rock layers.

Fold mountains: When plates collide at convergent boundaries, the rock is placed under great heat and pressure (Figure 11.29). Rocks can fold if they are hot enough to act like bendable plastic. Some of the sedimentary rock can be changed to metamorphic rock during the process of folding. The Himalayan mountains are being built this way as the Indo-Australian Plate collides with the Eurasian Plate. The Appalachian Mountains are another example of fold mountains.

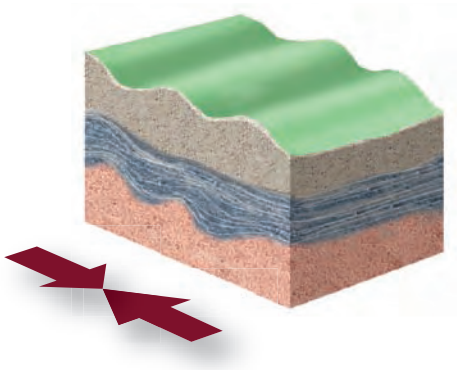


Figure 11.29A Fold mountain

Figure 11.29B Trace the sedimentary layers of Mount Kidd in Alberta with your finger. Which forces can bend and fold a mountain?

Fault block mountains: Sometimes the rocks in Earth's crust are too brittle to fold. When pressure is exerted on the rocks, they break, forming a fault. A fault can be the result of squeezing or stretching of Earth's crust. When sedimentary rock is squeezed from the sides, it can form into slabs that move up and over each other like shingles on a roof. This process is called *thrust faulting*. When Earth's crust is streched, fault blocks can tilt or slide down. The older rock may end up on top of the younger rock. These huge chunks of rock form mountains called fault block mountains (Figure 11.30).

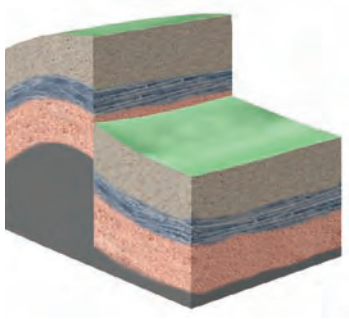


Figure 11.30A Fault block mountain

Figure 11.30B The Andes Mountains in South America are examples of fault block mountains.

Volcanic eruptions: Mountains can be formed by the convergence of continental plates and oceanic plates (Figure 11.31A). The continental plate is lighter and rides over the oceanic plate. Melted rock wells up under the edge of the overriding plate, pushing up mountains. When magma is forced up by pressure from deep within Earth, it can uplift the rock and create features on Earth's crust. The melted rock can break through the surface and erupt as volcanoes. Domed mountains are broad, circular mountains formed when layers of rock are uplifted. (Figure 11.31B on the next page).

Figure 11.31A If converging plates are both continental, their leading edges crumple, forming mountains (A). If an oceanic plate slides under a continental plate, melting occurs, forming volcanoes and mountain ranges (B).

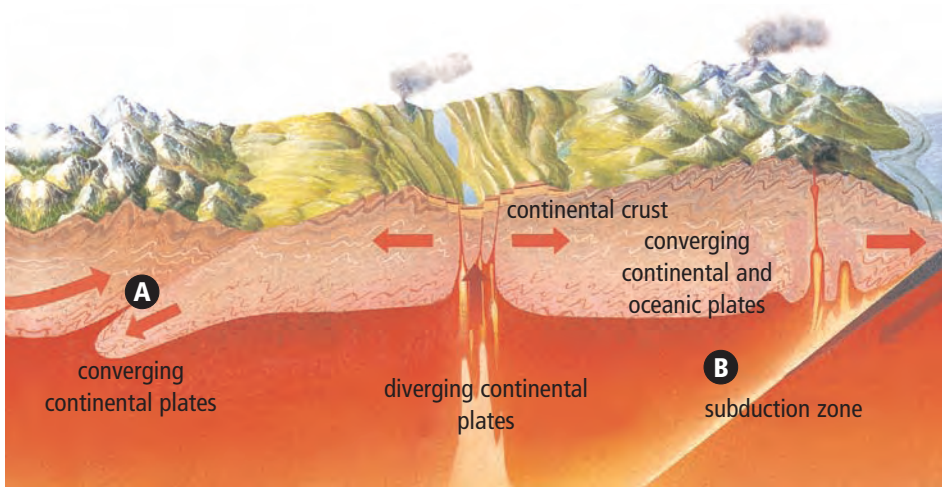


Figure 11.31B Mount St. Helens (foreground) and Mount Adams (background) are examples of domed mountains.

In Figure 11.32 you can review the locations of major mountain ranges. You can turn back to Figure 11.11 to view the locations of mountain ranges on the sea floor.

Mountain Ranges

1. Great Dividing Range
2. Rockies
3. Andes
4. Appalachians
5. Alps
6. Carpathians
7. Urals
8. Himalayas

Figure 11.32 Major mountain ranges

Reading Check

1. How are fold mountains formed?
2. How are fault block mountains formed?
3. Where are mountains and volcanoes found together?

Putting Newfoundland Together

You may recall that the continents were once joined in a super continent called Pangaea. It is likely that the land that eventually became the island of Newfoundland was once near the centre of the ancient continent. The moving continents may have converged, forcing up a huge mountain chain that included what we now call the Appalachians, of which the Long Range Mountains are a part. When Pangaea separated, part of the mountain chain became the eastern edge of North America, and part became the northern and western edges of Britain and Norway.

Evidence of continental collisions and movements can be found in many parts of Newfoundland and Labrador today. For example, in Gros Morne National Park huge slabs of ancient sea floor have been uplifted to form Table Mountain (Figure 11.33).

Three types of rock were pushed together to form the island of Newfoundland as shown in Figure 11.34. The oldest rock is in the Western Zone, which is over 1 billion years old. The rocks of the Central Zone are the remains of volcanic islands that were crushed and forced into the Long Range and Topsail mountains. The rock in the Eastern Zone is related to the rock of Africa and Europe, a reminder of 200 million years ago when Africa and North America began to separate.

internet connect

In Gros Morne National Park, geological features that usually lie deep underground are exposed at the surface. The park was declared a UNESCO World Heritage site to preserve its unique geological landscape. Find out more about Gros Morne National Park. Visit **www.discoveringscience.ca.**

Figure 11.33 Table Mountain

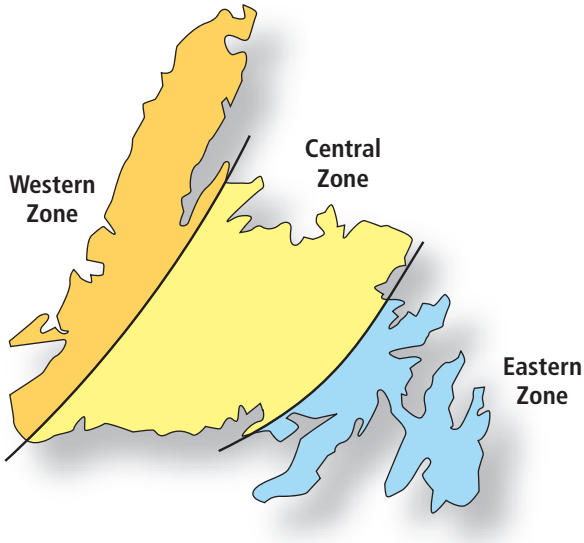


Figure 11.34 Newfoundland can be divided into three zones based on the origin of the rock.

Fossils

Newfoundland and Labrador rock provides clues about Earth's evolution, and scientists come from all over the globe to study it. Our province of has some of the oldest rock and oldest fossils found anywhere in the world. **Fossils** are the remains of organisms that lived long ago. Some fossils are preserved as films on rock, some are petrified (turned to stone), some are the actual remains preserved in ice, and some are traces such as footprints in mud that hardened into rock.

Figure 11.35 This species of trilobite, *Paradoxides davidis*, is from the Manuels River Gorge on the Avalon Peninsula. Our modern spiders and insects are relatives of the ancient trilobites.

One common fossil found worldwide is the trilobite, an extinct arthropod (Figure 11.35). Trilobites found in Western Newfoundland are from species that lived in warm, shallow waters. Trilobites found on the Avalon Peninsula are from a species that lived in cool, deep water. These fossils provide evidence that rock from several areas joined together long ago to form the island of Newfoundland.

Geologic Time Scale

How old are the fossils of Newfoundland and Labrador? How old is Earth? Figure 11.36 on the next page shows the major divisions of the geologic time scale. The **geologic time scale** divides Earth's history into smaller units, based on the appearances of different kinds of life forms in the fossil record, such as simple life forms, dinosaurs, and mammals.

It is estimated that our planet formed almost 4.6 billion years ago. Notice in Figure 11.36 that human existence on Earth represents a very small proportion of that geological time. It can be very difficult to imagine how long 4.6 billion years is. If we compare this period of time to a 24 h day, for example, humans have only been here for the last second.

Did You Know?

Students have made important fossil discoveries in Canada. A 12-year-old girl found the first dinosaur skeleton in British Columbia in 1988. In 2000, two boys, age 8 and 11, playing along a creek discovered dinosaur footprints near Tumbler Ridge. In 1967, S.B. Misra, a student at Memorial University in Newfoundland discovered Ediacaran fossils at Mistaken Point.

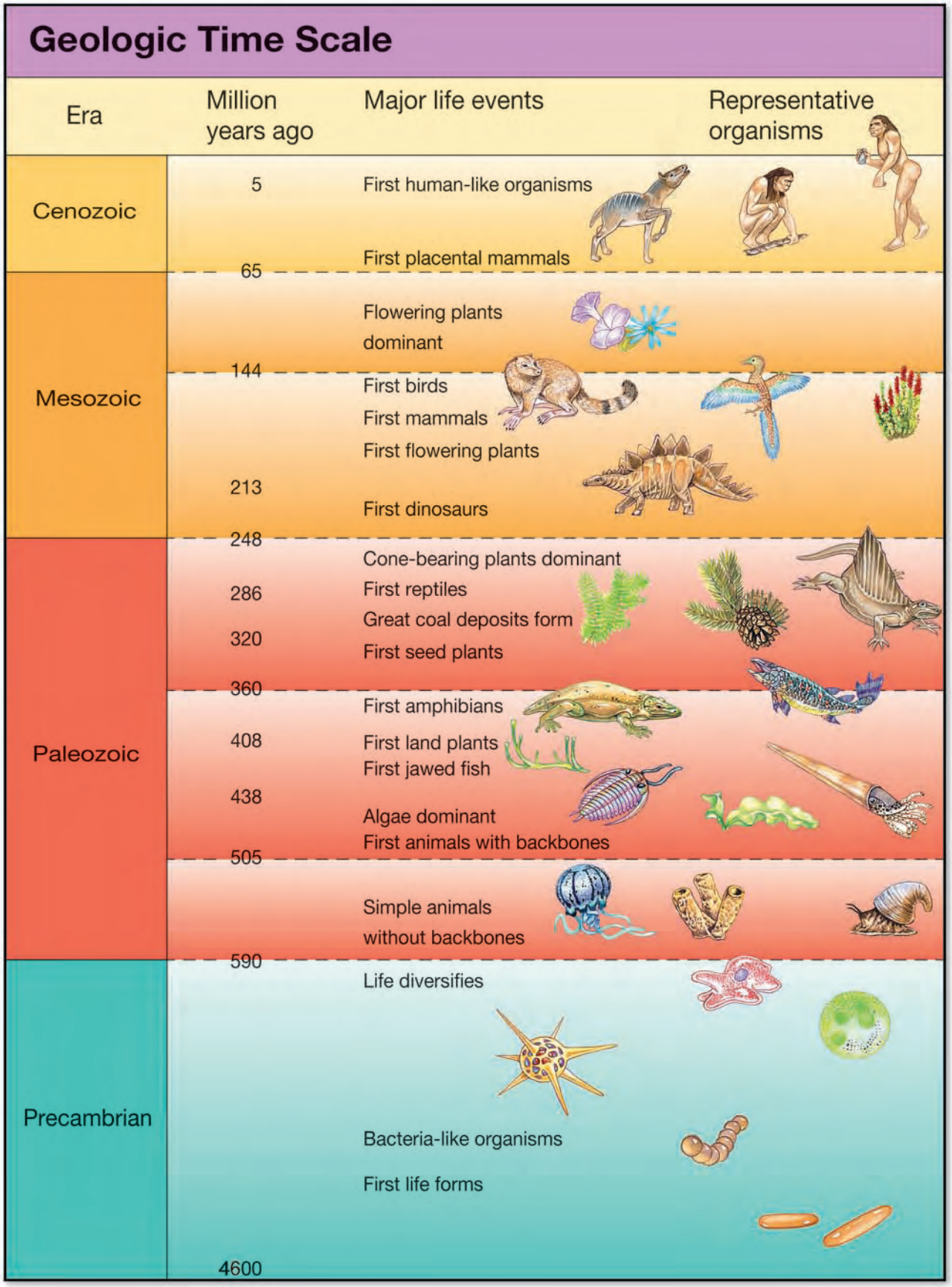


Figure 11.36 Notice the following main events of each era. (i) Precambrian—formation of Earth and appearance of simple life forms; (ii) Palaeozoic—appearance of more complex life forms; (iii) Mesozoic—appearance and extinction of dinosaurs; and (iv) Cenozoic—appearance of humans.

The Fossil Record

The largest era is the Precambrian era, lasting approximately 4 billion years. During most of the Precambrian era, life was microscopic. However, during the late Precambrian, more complex animal organisms called Ediacarans appeared in the fossil record. Some of the best and oldest fossil evidence of life on Earth can be found in the Ediacaran fossils at Mistaken Point, on the Avalon Peninsula (Figure 11.37). The fossils have been preserved under beds of volcanic ash. The local community at Mistaken Point helps protect the fossils and assists scientists in making new discoveries.

The appearance of fossils in rock layers has provided important clues for scientists about Earth's age and evolution. For example, the disappearance of dinosaurs from the fossil record marks the end of the Mesozoic era and the beginning of the Cenozoic era about 65 million years ago.

Fossils also provide evidence for the theory of plate tectonics. In 1884, 24-year-old Joseph Burr Tyrrell noticed a brown object sticking out of the banks of the Red Deer River in Alberta (Figure 11.38). With his hands and his geologist's hammer he began to clear the dirt from the object and gradually uncovered a dinosaur skeleton. He had just discovered the world's richest collection of dinosaur fossils, and proof that the climate of the land in Alberta had once been much warmer.

Figure 11.37 An Ediacaran fossil from Mistaken Point

internet connect

The recent discoveries of Ediacaran fossils and other evidence of Precambrian life have led to some proposed changes to the geologic time scale. Find out more about the revised geologic time scale. Start your search at **www.discoveringscience.ca.**

Figure 11.38A Joseph Burr Tyrrell (1858-1957)

Figure 11.38B The Albertosaurus was one of Tyrrell's many discoveries.

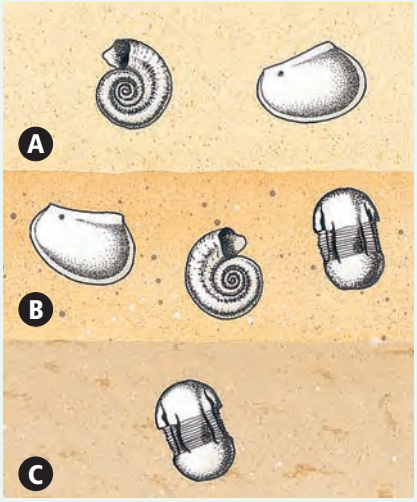
11-3B Tell-Tale Layers

Think About It

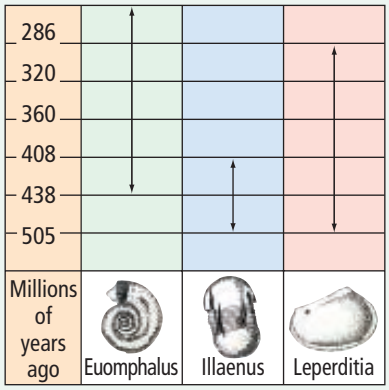
In this activity, you will investigate how fossils can be used to determine the age of rock layers.

What to Do

1. Examine the cross-section below. It shows three layers of sedimentary rock and the fossils found in each rock layer.



2. The chart below identifies each fossil. The vertical arrows show the time span in which the animal lived.



3. Identify the time range in which each rock layer might have been formed.

What Did You Find Out?

1. When might rock layer A have formed?
2. When might rock layer B have formed?
3. When might rock layer C have formed?

Explore More

Find out more about the fossils of Newfoundland and Labrador. Visit **www.discoveringscience.ca.**

Reading Check

1. What is a fossil?
2. What are divisions in the geologic time scale based on?
3. How do fossils contribute to our understanding of Earth?
4. Approximately how old is Earth?

11-3C Canada—Past, Present, and Future

Think About It

Imagine you are a time traveller suddenly transported to millions of years in the past or millions of years in the future. Do you think you would recognize the area where you now live? In this activity, you will describe how a region of Canada has changed and might change in the future.

What to Do

1. Your teacher will assign your group one of the four eras of the geologic time scale and a region of Canada.
2. Choose the format you will use to present your information, such as a mural or timeline.
3. Decide group roles for researching, preparing, and presenting your information.
4. Research to find out what the land, plants, and animals (if any) might have been like in your region in your assigned era. Find out what your region is like today. Predict what it will be like millions of years from now.
5. Create and share your presentation.

What Did You Find Out?

1. What was the most difficult part about representing your region in the past?
2. How has your present-day region changed from how it was in your assigned era?
3. What factors did you need to consider in predicting how your region might look in the future?

11-3D Rock Stars

Think About It

Earth scientists investigate how rocks got to where they are today. It is a journey that has taken place over millions of years. There are many Canadian earth scientists who are rock stars—they have contributed important discoveries to our understanding of Earth's crust. In this activity, you will research the contributions of a Canadian earth scientist and share your information with your classmates.

What to Do

1. Choose a Canadian earth scientist from your own research or from the following list.
2. Research the contributions your scientist has made to our understanding of Earth's crust.

Frank Dawson Adams	William Logan
Helen Belyea	Albert Peter Low
Steve Blasco	Lawrence Whitaker Morley
George Dawson	Alexander Murray
J. William Dawson	Guy Narbonne
Herb Dragert	F. Fitz Osbourne
Catherine Hickson	Ann Sabina
James P. Howley	Alice Wilson

3. Choose a format to share your information. For example, you could make a poster, write a poem, create a slide show presentation, or design a booklet. Or your class could prepare a time line that illustrates the evolution of our understanding of Earth's structure.

11-3E Model Mountains of Moving Magma

Find Out ACTIVITY

In this activity, you can model the formation of domed mountains and other features caused by the movement of magma.

Safety

- Be careful not to poke yourself with the scissors.

Materials

- scissors
- clear plastic disposable glass
- 125 mL soil
- tube of toothpaste

What to Do

1. Work with a partner.
2. Use the scissors to cut a hole in the centre of the bottom of the plastic glass. Make the hole large enough to insert the mouth of the toothpaste tube.
3. Cover the bottom of the hole with your finger while you pour the soil into the glass.
4. Remove the cap from the toothpaste. Insert the mouth of the toothpaste tube into the hole from below the glass.
5. Have your partner hold the glass while you press against the tube to force the toothpaste into the soil.
6. Observe the surface of the soil.

What Did You Find Out?

1. How was this activity similar to the formation of domed mountains?
2. (a) What do you think would happen if you added rocks on top of the soil before squeezing the tube?

   (b) How might those results be similar to features found on Earth's crust?
3. What features in addition to domed mountains do you think moving magma might make?
4. Chapter 10 describes the difference between intrusive and extrusive rock. If the toothpaste hardened in your model, which type of rock would it represent? Why?

11-3F Building a Mountain–Building Theory

Inquiry Focus

Skill Check

- Classifying
- Modelling
- Explaining systems
- Evaluating information

Materials

- world map provided by your teacher
- 3 colours of coloured pencils or makers
- atlas or other source of mountain locations

What is a mountain? The term *mountain* has no simple definition because there are so many different ways mountains can be built. In this activity, you will investigate the location of many of Earth's mountain ranges. You will create a legend to distinguish mountains from each other based on how they were formed.

Question

What has created the major mountain ranges on Earth's surface?

Procedure

1. Research the location of Earth's major mountain ranges. Be sure to include the mountain ranges on the sea floor.
2. Classify the mountains based on how they were formed.
3. Choose a separate colour for each type of mountain category.
4. Record the location of as many mountain ranges as you can on your map.
5. Add a legend to your map to explain your system of colouring.
6. You probably found mountains for which you could not explain the origin. Form an hypothesis about how these mountains might have developed.

Analyze

1. What categories did you create to classify your mountains? Why?
2. Where do most of the mountains on Earth's crust occur?
3. (a) Compare your map with the map of volcano locations in Figure 11.27. What similarities can you observe between the locations of mountain ranges and that of volcanoes?

   (b) How does volcanic activity contribute to mountain building?

Conclude and Apply

1. (a) How do the locations of mountain ranges compare with the locations of plate boundaries?

   (b) What are the exceptions?
2. Describe at least three different ways in which mountains can be created.
3. (a) Predict where new mountain ranges might occur in the next 3 to 4 million years.

   (b) On which facts do you base your prediction?
4. Write a definition of the word *mountain*.

Science

Math connect

Keeping Track of All Those Zeros

Geologic time measures a very, very long time. We measure our lives in terms of days, weeks, and years, but these are blips in time compared to Earth's 4 600 000 000 years. Numbers on the geologic time scale can be difficult to write out on a sheet of paper, let alone use in calculations. You can get dizzy just looking at all those zeros!

Scientists reduce the number of zeros in a large number while still keeping track of them by using scientific notation. With scientific notation, very large (and very small) numbers can be expressed in a shortened form, which makes it easier to make precise calculations and compare the size of different numbers.

Scientific notation consists of two parts: a *coefficient* and a *base.* The coefficient is a number between 1 and 10 and the base is a power of 10. The general format for scientific notation is:

$N \times 10^x$ Where N = a number greater than or equal to 1 and less than 10

^{x} = the exponent or "power of 10"

Using scientific notation, large numbers become much easier to work with because the zeros are tucked up into the exponent. So:

100 becomes 1.0×10^2

1000 becomes 1.0×10^3

1 000 000 becomes 1.0×10^6

How about writing out Earth's age using scientific notation?

4 600 000 000 years becomes 4.6×10^9 years

Notice there are eight zeros in the number, yet the exponent or power of 10 is 9. This is because the exponent represents the number of digits to the right of the first digit (in this case 4), whether they happen to be zeros or not.

Geologists, palaeontologists, and astronomers use the abbreviations "mya" and "bya" when discussing large numbers. The abbreviation mya means "million years ago," and like its counterpart bya ("billion years ago"), it is used as a unit to measure time. In scientific literature, the abbreviations Ma (mega-annum) and Ga (giga-annum) are often used instead of mya and bya and mean the same thing. Using these abbreviations, Earth's age is 4.6 bya or 4.6 Ga.

If you need to use even bigger numbers, consult the chart below.

Number of zeroes	Number
3	thousand
6	million
9	billion
12	trillion
15	quadrillion
18	quintillion
21	setillion
24	septillion
27	octillion
30	nonillion
33	decillion

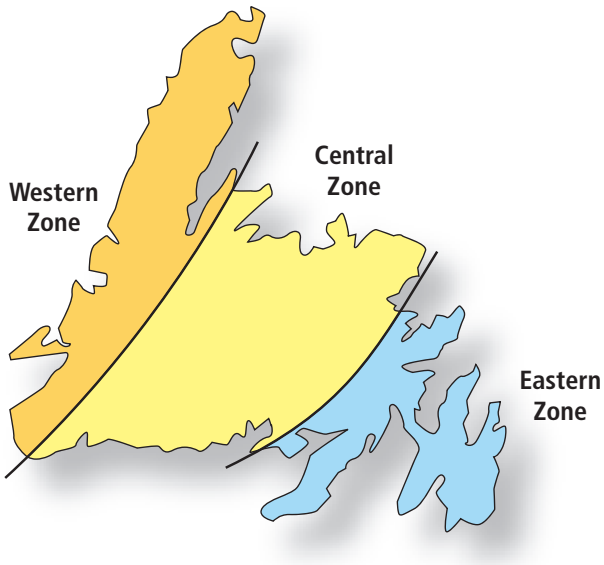
Questions

1. How would you write the number one trillion (1 000 000 000 000) using scientific notation?
2. Using either the abbreviation mya or bya, when did dinosaurs appear on Earth? (Refer to Figure 11.36, the geologic time scale in this section.)
3. When might you need to use very large numbers, such as trillions or quadrillions?

Check Your Understanding

Checking Concepts

1. Draw and label an example of a fold mountain showing how it was formed.
2. Draw and label an example of a fault block mountain showing how it was formed.
3. How does volcanic activity contribute to mountain forming?
4. In which directions can rock move along a fault?
5. Where has the rock come from in each of Newfoundland's three zones?



6. What are fossils?
7. What is the geologic time scale?
8. (a) Name the four major eras in Earth's history.
   (b) What is an example of a life form from each era?
9. What did Joseph Burr Tyrrell discover?

Understanding Key Ideas

10. Why do the Appalachian Mountains in eastern North America have a much lower elevation and a more rounded texture than the Rocky Mountains in Western Canada?
11. Why is there little fossil representation in the Precambrian rock record?
12. Why have dinosaur fossils been found in areas where they would not be able to live if they were alive today?
13. Make a circle graph of the geologic time scale. Show the four eras in their correct proportion.

Pause and Reflect

How do mountains become taller? How do mountains become smaller? Use a sketch to help explain your answers.

Chapter Review

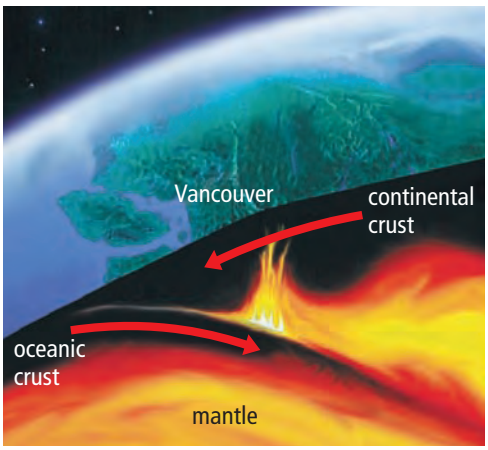
Prepare Your Own Summary

In this chapter, you investigated how and why Earth's crust moves and some of the ways it has changed over the course of geologic time. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help using graphic organizers.) Use the following headings to organize your notes.

1. Plate Tectonics
2. Earthquakes
3. Volcanoes
4. Mountains
5. Geologic Time

Checking Concepts

1. Make a labelled diagram of the four layers of Earth.
2. (a) Describe Pangaea.
   (b) Why does Pangaea no longer exist?
3. What are three types of evidence for continental drift?
3. What are three types of evidence of moving crust from the sea floor?
4. How do convection currents help explain plate movement?
5. How does the Richter scale help geologists describe earthquakes?
6. Draw and label three types of faults.
7. (a) Where do most of the world's earthquakes happen?
   (b) Why?
8. (a) Where are most of the world's volcanoes found?
   (b) Why?
9. Describe three ways that mountains can be formed.
10. (a) Where are most of the world's mountain ranges found?
    (b) Why?
11. What is the difference between a fold and a fault?
12. How were life forms in the Mesozoic era different from life forms in the Cenozoic era?
13. (a) What type of zone is shown in the photograph below?
    (b) What features or events occur at this zone?
    (c) Why do the features or events occur there?



Understanding Key Ideas

14. Read the newspaper article below, and answer the following questions:

(a) What inaccuracy does this article contain?

(b) An earthquake in the city of Kobe, Japan in 1995 killed thousands of people and cost many billions of dollars in property damage. Aside from its greater strength, why do you think the Kobe earthquake killed thousands of people, while the earthquake described in this article only killed 60 people?

> About 60 people were killed, many as they slept, during an earthquake in central Bolivia yesterday. A 5.9 magnitude earthquake struck, followed by a second one, 13 min later, with a magnitude of 6.8. The epicentre was 89 km below Earth's surface. Repeated aftershocks—up to 150 in the first 12 h alone—sent panicked residents fleeing any buildings left standing. About 30 000 people, mostly farmers, live in the area hit by the earthquakes. Eighty percent of houses in the community where the earthquakes struck were destroyed, the hospital roof caved in, and a landslide blocked access to the town. Reports indicate that the town was almost wiped out. People gathered in main plazas after the jolts, fearing the aftershocks would bring down more buildings. Streets were cleared of rubble by tractors so that workers could assist the injured and homeless.

Adapted from *Winnipeg Free Press*, May 23, 1998

15. Explain why we do not have fossil evidence of all the species that once lived.

16. Here are answers to three different questions. Write a question for each answer:

(a) Alfred Wegener

(b) J. Tuzo Wilson

(c) Joseph Burr Tyrrell

17. Some volcanoes erupt quietly and other eruptions are violent. What do you think causes the difference?

18. Trilobites discovered along Manuels River on the Avalon Peninsula are directly related to trilobites found across the Atlantic in Wales. How does this support the theory of continental drift?

19. How could you demonstrate convection currents?

20. Describe how convection currents have changed the surface of Earth.

21. Prepare a time line that illustrates the evolution of our understanding of plate tectonic theory.

Pause and Reflect

Sea floor spreading along the Mid-Atlantic Ridge averages about 2.5 cm per year, or 25 km in a million years. This may seem like a slow rate, but over the past several hundred million years, it has caused a tiny inlet of water between the continents to grow into the vast Atlantic Ocean. What do you think the continents will look like 135 million years from now? Sketch your ideas in your science notebook.

Chapter 12

Soil is the living component of Earth's crust.

What do you hold when you hold a handful of healthy soil? You have in your hands a combination of minerals, organic matter, water, air, and organisms such as bacteria and earthworms. These five basic components work together to provide nutrition to plants to keep you—and other organisms—healthy. The soil in your hands can take thousands of years to form but can be easily lost. You hold a handful of valuable possibilities for your community and for the world.

What You Will Learn

In this chapter, you will

- **investigate** how rocks are affected by weathering
- **explore** how sediment is moved from location to location
- **identify** effects of enriching soils
- **research** current issues related to agriculture
- **investigate** how organic matter affects soil moisture

Why It Is Important

Soil is created from sediment, which in turn is produced through the processes of weathering and erosion. The health of the soil is directly related to our own health. We need to safeguard our soil. The misuse or loss of soil has an impact on us.

Skills You Will Use

In this chapter, you will

- **observe** evidence of weathering in your community
- **predict** which rocks will be most affected by weathering
- **classify** a soil sample based on its characteristics

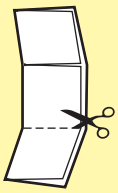
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 12.

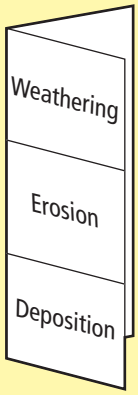
STEP 1 **Fold** an 8.5 × 11″ sheet of paper in half along the long axis.

STEP 2 **Fold** the paper in thirds along its length.

STEP 3 **Unfold** the sheet and **cut** the bottom tab along the fold lines as shown.



STEP 4 **Label** the tabs as "Weathering", "Erosion", and "Deposition".



Organize Define each term on the front of the tabs. Take notes and explain the cause and effect of each term under the tabs.

12.1 Weathering, Erosion, and Soil Formation

Weathering is the process that breaks rock down into sediments. In mechanical weathering, the rock is simply broken into smaller pieces. In chemical weathering, chemical reactions with the rock produce new substances. Weathered rocks may be loosened and transported to other locations through the process of erosion. They are deposited in their new locations by the process of deposition. Weathered rocks and minerals can be combined with organic matter, water, and air to form soil.

Key Terms

chemical weathering
deposition
erosion
mechanical weathering
soil
weathering

Figure 12.1 You might have noticed a pile of rocks at the bottom of a rocky cliff. Why did the rocks break off from the side of the cliff? What force caused the rocks to fall?

Earth's crust is constantly being changed. Some changes, such as earthquakes and volcanoes, are sudden. Other changes, such as mountain building, are very slow processes. Rocks on the sea floor and the continents have many forces acting on them and wearing them down. Animals and plants can weaken and break apart rocks at Earth's surface. Water and ice can also break rocks into smaller pieces. Even tiny moss plants, burrowing shrews, and the oxygen in the air are part of the processes that wear down rocks. **Weathering** is the mechanical and/or chemical breakdown of rock. Rocks that are created by magma or lava, sedimentation, or metamorphic processes are all exposed to the forces of weathering when they are at or near Earth's surface.

Over millions of years, weathering has changed Earth's surface. The weathering process continues today. Weathering affects rocks, caves, mountains, and even buildings and streets.

Two types of weathering—mechanical weathering and chemical weathering—work together to shape Earth's surface and create sediments.

Did You Know?

Over hundreds of thousands of years, weathering can transform mountains into rolling hills.

12-1A Use the Force

Find Out ACTIVITY

Which forces in nature can move sediment? In this activity, you will use a model to explore how sediment is moved from location to location.

Safety Precautions

- Wash your hands thoroughly after completing this activity.
- Clean all surfaces.

Materials

- a mixture of sand and gravel
- a stream table or metal pan

What to Do

1. Place a small pile of sand and gravel in one end of a stream table or metal pan.
2. Your task is to move the sediment to the other end of the pan without touching the particles with your hands. You can touch and move the outside of the pan, but you cannot touch the sediment. You can use forces or objects approved by your teacher.
3. Try to move the mixture in a number of different ways. Each time, record your method. Record and draw what happens to the sand and gravel.
4. Pile up the sand and gravel in the centre of the pan. Slowly drip water onto the pile, and watch how the sand and the gravel move as the water flows down. Record and draw your observations.
5. Add a total of one half cup of water. Record and draw where the sand and gravel end up.

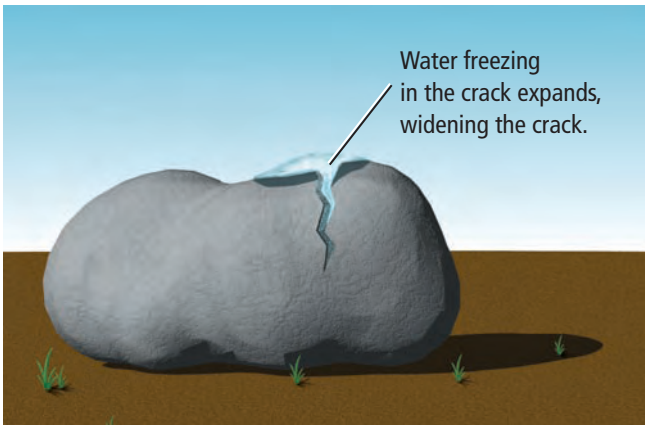
What Did You Find Out?

1. Describe the methods you used to move the sediment.
2. Which method was most effective?
3. Explain how your methods compare with forces of nature that move sediment.
4. Which human activities affect the movement of sediment in nature?
5. Describe a local example where grass is used to prevent the movement of sediment.

Mechanical Weathering

During **mechanical weathering**, rocks are simply broken into smaller pieces. The overall chemical make-up of the rocks stays the same, so each piece of rock is similar to the original rock. Gravity causes these broken rocks to fall down a cliff and they may land with enough force to break into smaller pieces. Three common causes of mechanical weathering are described below.

- The most common type of mechanical weathering is *frost wedging*. Recall from your earlier studies and observations that water expands when it freezes. When water enters the cracks in a rock and freezes, it expands. The cracks enlarge and the rock breaks apart (see Figure 12.2). Then, more water can enter the cracks, freeze, and expand, causing the cracks to grow even bigger. The cycle of freezing and thawing that breaks up rocks can also break up roads. When water enters cracks in the pavement and freezes, ice forces the pavement apart and causes potholes in roads.



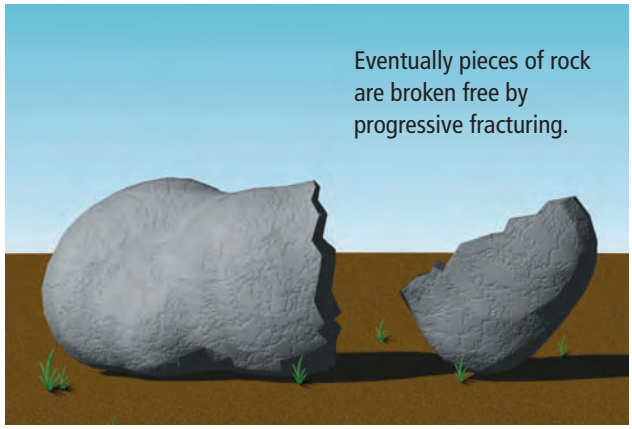


Figure 12.2 Frost wedging occurs when water entering cracks in rocks repeatedly freezes and thaws.

- Mechanical weathering can also occur when a plant wedges its way into a crack in a rock, just as frost does. Water and nutrients that collect in the cracks of a rock allow plants to grow. As the roots of the plants grow, so does the crack. The rock is pushed apart until it eventually crumbles and breaks (Figure 12.3).

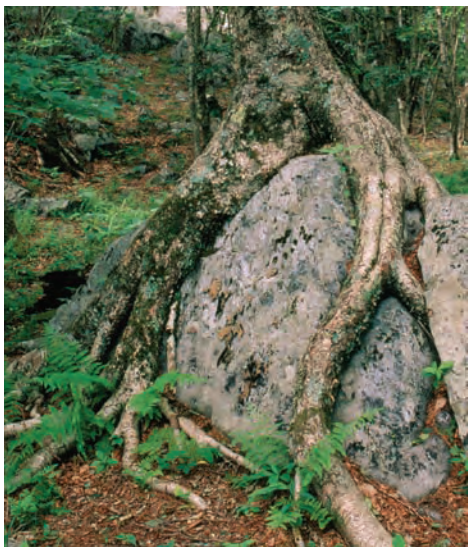


Figure 12.3 The roots of a tree can break a rock apart.

- Mechanical weathering can be caused by animals, such as earthworms, rodents, and ants. As the animals move through the soil, they loosen sediments and push the sediments to the surface. Once the sediments are at the surface, other weathering processes can act on them.

Did You Know?

Humans can influence mechanical weathering by mining, quarrying, and excavating foundations for buildings.

Chemical Weathering

In **chemical weathering,** chemical reactions occur with rocks to create new substances. The larger the surface area of rock, the faster the rate of chemical weathering. Some rocks, such as salt, gypsum, and limestone, may be dissolved. Other rocks may be weakened.

Rocks can react with water, with chemicals dissolved in water, or with gases in the air. For example, hydrogen in water can react with minerals such as feldspars, and chemically alter them to become clays. When oxygen combines with the iron in a rock, iron oxide (rust) can form. This chemical change weakens the rock's structure, making it easier for the rock to break apart. Chemical weathering occurs more quickly in areas where the climate is warm and humid. Common causes of chemical weathering include the following.

Suggested Activity

Conduct an Investigation 12-1B on page 416

Figure 12.4 Chemical weathering of limestone can create underground caves and caverns. If the caves collapse they can form a sinkhole, like the one in Codroy Valley shown here.

- Acidic groundwater can dissolve minerals such as calcite. Calcite is the main mineral that makes up limestone. When acidic groundwater flows through layers of limestone, rock is dissolved and caves are produced (Figure 12.4).
- Acidic rainwater reacts with some rocks, such as limestone and dolomite. The rock material dissolves easily in the acidic water and washes away (Figure 12.5).

Figure 12.5 Many old headstones, statues, and buildings have been chemically weathered by acid rain.

Figure 12.6 What signs of weathering can you see in the rock in this photograph?

- The acidic action of some organisms that live on rocks, such as lichens, can cause chemical weathering (Figure 12.6). As well, chemical reactions can take place between rock material and acidic fluids that are produced by plant roots, bacteria, fungi, and some insects and other small animals. As the rock slowly dissolves and flows away with rainwater, cracks and crevices increase in size until the rock finally breaks apart.

Mechanical and chemical weathering work together to break down rock. For example, mechanical weathering can crack a rock, exposing more surface area for chemical weathering to dissolve. In a cold, harsh climate, mechanical weathering may be more common. In a hot, humid climate, chemical weathering may be more common. However, both types of weathering are always working to change the landscape.

Reading Check

1. What is weathering?
2. What are two types of weathering?
3. What are three causes of mechanical weathering?
4. What are three causes of chemical weathering?

Erosion

For millions of years, nature has been weathering rocks into sediment, breaking down softer materials, and exposing more resistant rock. The work of water, ice, and gravity has changed the surface of rocks. Sometimes plants and animals have helped in the process.

Have you ever been by a river or stream after a heavy rain? The water looks muddy because it is carrying a lot of sediment (Figure 12.7). Some of the sediment comes from the riverbank. The rest of the sediment comes from more distant sources and is carried by wind, water, and ice. Muddy water is a product of erosion. **Erosion** is the process that loosens and moves weathered rock particles (sediment) over Earth's surface. Some types of erosion are gradual, and happen over many thousands of years. Other types of erosion, such as flash floods and landslides, happen suddenly.

Figure 12.7 A stream carries away sediment after a heavy rain.

Agents of Erosion

Water in motion is the most powerful agent of erosion (Figure 12.8). Bodies of water erode their shorelines. When waves hit cliffs and shores, rocks are broken down and eroded. In some places, erosion happens quickly. A coastline can lose several metres every year to erosion by seawater. Rivers can cut straight into rock to form canyons or gorges and steep v-shaped valleys. Streams and rivers carry rock fragments along in the water. The faster the water flows, the bigger and denser are the sediments it can carry.

internet connect

Find out why the province of Newfoundland and Labrador is sometimes called "Earth's Geological Showcase." Start your search at **www.discoveringscience.ca.**

Figure 12.8 When powerful waves break against a shoreline, they help to break up rocks (weathering) and carry them away (erosion).

- *Meteorological processes,* such as rain and wind, can cause erosion. In addition to causing flooding, heavy rain can disturb the stability of a slope, causing landslides (Figure 12.9). Wind can pick up fine particles, like clay and sand, which act like sandpaper on Earth's surface. The faster the wind is, the larger the particles it can carry.
- *Geological processes,* such as gravity and glaciers, can also cause erosion. An example of gravity's force occurs when weathering breaks down rock on mountainsides and hillsides. The force of gravity pulls the rock and sediment down from higher places to lower places. The rock and sediment can move quickly after a heavy rain or an earthquake, when it is no longer being supported by the material beneath it.

Figure 12.9 Heavy rains at the top of the cliffs and erosion at the bottom of the cliffs caused landslides in Daniel's Harbour on Newfoundland's west coast in 2006 and 2007.

Figure 12.10 This huge rock near Conception Bay South was left behind by a glacier thousands of years ago.

Glacial Erosion

As recently as 10 000 years ago, glaciers covered Newfoundland and other northern lands. Remnants of these glaciers are found today in Greenland. Glaciers are large bodies of ice that move like slow bulldozers. Glaciers flow across Earth's surface, carving and scraping, pushing loose rocks and soil out of their path, and dragging rocks and sediment far away. When glaciers melt and retreat, they deposit the rocks and sediment in new locations (Figure 12.10). Materials deposited by glaciers, sometimes called ice age sediments, provide excellent drainage and important building materials for roads and concrete buildings. Ice age sediments include sand, gravel, silt, and clay.

Did You Know?

Glacial ice layers are a record of global climate change over millions of years. Scientists use long drills to remove cores of ice from glaciers. Each layer of ice in a core corresponds to a single year or season. The layers include wind-blown dust, ash, and atmospheric gases.

Deposition

Gravity, ice, wind, and water all wear away materials and carry them off. However, agents of erosion erode materials only when they have enough energy to do so. All agents of erosion deposit the sediment they are carrying when their energy decreases. For example, a river *erodes* materials where it is flowing fastest and has the most energy. A river *deposits* these materials along its route when it slows down and loses energy. The dropping of sediment is called **deposition.** Deposition is the final stage of erosion.

Erosion is generally considered to be a destructive process because it wears down land features and carries them away. Deposition is considered to be a constructive process because land features are produced and built up.

Erosion and deposition work together. Earth's materials are picked up from one place and are dropped off somewhere else. Sediments are deposited every day in Newfoundland and Labrador, changing the surface of the land (Figure 12.11). Mountains are gradually worn down from steep peaks to rolling hills. Valleys are gradually widened and filled with rock and soil. The same sediment may be eroded again and again over millions of years.

Figure 12.11 These photographs were taken before and after a series of storms along Conception Bay. What evidence of erosion and deposition can you see in the photograph on the right?

Formation of Soil

Sediments are an in-between stage in the rock cycle. Eventually, these eroded materials will be recycled to form new rocks. The slow process of rock formation takes thousands of years to occur. What happens to these materials in the meantime? They may become part of the soil. **Soil** is a combination of eroded rocks and minerals, water, air, and organic matter such as decaying plant and animal materials.

Reading Check

1. What is erosion?
2. What is the most powerful agent of erosion?
3. What is deposition?
4. What are the main components of soil?

Explore More

Billions of dollars worth of oil is trapped in sedimentary rock that was once eroded and deposited on the continental shelf off the shores of Newfoundland and Labrador. Learn more about the resources of the continental shelf by visiting **www.discoveringscience.ca.**

12-1B Rocks that Fizz

Skill Check

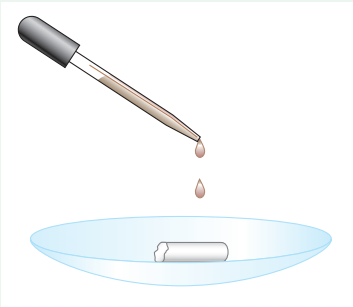
- Observing
- Predicting
- Measuring
- Classifying

Safety

- If acid gets on your skin, immediately wash the area with lots of cool water.

Materials

- small pieces of identified rock
- two unidentified rock samples from your geographic area
- watch glass
- tongs or tweezers
- medicine dropper
- 1% hydrochloric acid



In this activity, you will investigate which types of rocks are affected by chemical weathering.

Question

When acids react with certain rocks, some minerals dissolve, and carbon dioxide gas is formed. Which rocks do acids affect?

Hypothesis

Formulate an hypothesis about which rocks are affected by acid rain and acid groundwater.

What to Do

1. Make a table of observations like the one below. Give your table a title.

Name	General Observations	Amount of Fizz
granite		
chalk		
sandstone		
shale		
marble		
limestone		
unknown rock A		
unknown rock B		

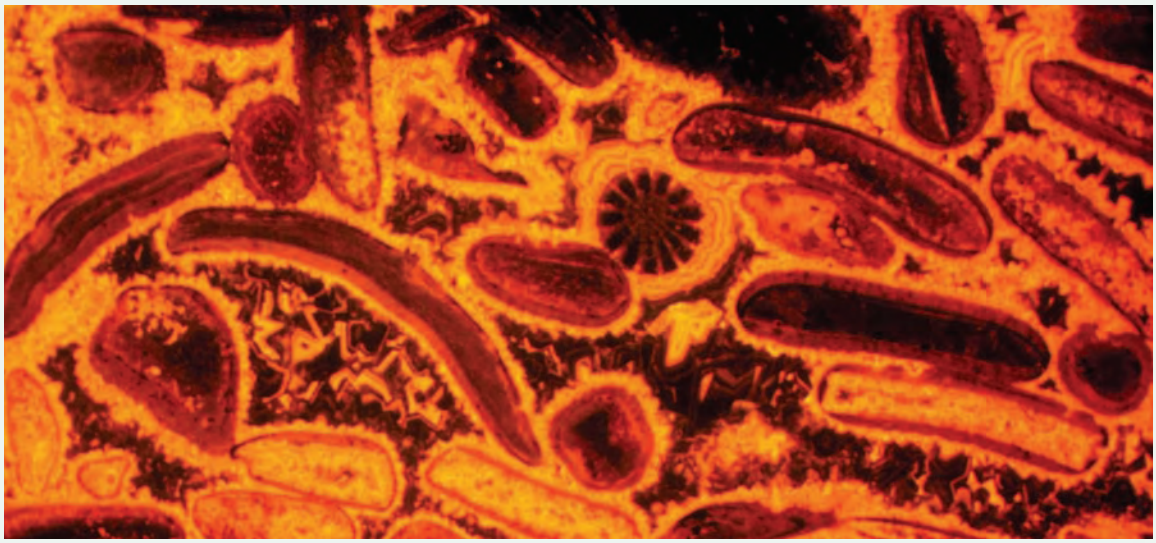
2. Observe the physical characteristics (such as colour and texture) of one of the specimens. Record your observations under "General Observations."
3. Put a specimen on a watch glass.
4. Put on your safety glasses. Use the medicine dropper to place a few drops of acid on the specimen. Observe what happens. Record the amount of fizz in your table.
5. Rinse the specimen with water. Dry the specimen. Return the specimen to the proper place.
6. Repeat steps 2 to 5 for each of the other specimens.

Analyze

1. (a) What was the manipulated variable (the feature that you changed)?
   (b) What was the responding variable (the feature that you observed changing)?
2. (a) Which rocks were affected by chemical weathering?
   (b) How could you tell?
3. Could you formulate a reasonable prediction about whether a rock would fizz or not just by looking at it? Explain why or why not.

Conclude and Apply

1. What is happening to the rock when the acid makes it fizz?
2. (a) Which unknown rock was affected by chemical weathering?
   (b) Based on the information collected in your table, which other rock specimen does this unknown rock most closely resemble?
3. How could chemical weathering make it easier for a rock to undergo mechanical weathering?



This is a photograph of a very thin slice of limestone. Over 200 million years ago, these sea shell fragments were compacted together and then cemented with calcite.

12-1C Crystals in a Cave

Find Out ACTIVITY

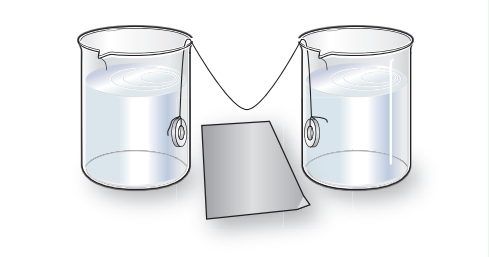
Chemical weathering can result in interesting formations in a cave or cavern. Stalactites are crystals that form on the roof of a cave. Stalagmites are crystals that form on the floor of the cave. In this activity, you will model the formation of stalactites and stalagmites.

Safety Precautions

- Never eat or drink anything in the science room.

Materials

- 2 small beakers or jars (such as baby food jars)
- Epsom salts or baking soda
- tap water
- spoon
- 2 washers
- 30 cm cotton string or yarn
- sheet of dark construction paper



Setup as described in step 4

What to Do

1. Fill the jars about three-quarters full of tap water. Add a spoonful of Epsom salts or baking soda to the water in each jar. Stir until it is dissolved. Continue adding Epsom salts or baking soda to the water and stirring until no more can dissolve.
2. Tie a washer to each end of the string or yarn.
3. Place the sheet of dark construction paper between the jars.
4. Place one washer in each of the jars. Position the jars so that the string hangs between them. The lowest part of the string should be a few centimetres above the paper.
5. Leave the jars in an area where they will be undisturbed and out of any drafts.
6. Allow the jars to stand undisturbed for one week or longer. Observe the results.

What Did You Find Out?

1. How does this activity model chemical weathering in caves?
2. Would the crystal formation likely be faster in a cool, dry classroom, or in a warm, humid classroom? Explain your answer.

Chemical weathering can form stalactites and stalagmites in caves.

12-1D Weathered Lettering

Find Out ACTIVITY

In this activity, you will observe evidence of weathering in your community cemetery, either on a field trip, or by viewing photographs of headstones. By examining changes to the surface of headstones, you can gather evidence about how much weathering has taken place.

Amount of Weathering		
1	No obvious weathering	Lettering is sharp and clear
2	Little weathering	Lettering easy to read but shows some signs of weathering
3	Some weathering	Most letters still legible but all clean edges removed
4	Quite a bit of weathering	Difficult to distinguish lettering
5	Very weathered	Unable to read any of lettering

Materials

- photographs of headstones

What to Do

1. Make a table of observations like the following one. Give your table a title.

Headstone Name	Date on Headstone	Age of Headstone	Type of Rock	Amount of Weathering

2. Record your prediction of which type(s) of rock will weather the fastest.
3. Observe the headstones as instructed by your teacher. If you are in the cemetery, be respectful. Be careful not to disturb any plants growing nearby.
4. Record your observations in your table. Assign each headstone a value for its amount of weathering using the Amount of Weathering chart at the top of the page.

What Did You Find Out?

1. (a) What evidence of mechanical weathering did you observe?
   (b) What evidence of chemical weathering did you observe?
2. (a) Do all headstones of the same age have the same amount of weathering?
   (b) Explain why or why not.
3. What type or types of rock were the headstones made of?
4. Have headstones that are the same rock type and approximately the same age weathered differently? Explain.
5. What other factors besides age, type of rock, and position in the cemetery might play a role in how much a headstone has weathered?
6. Are headstones of the distant past made from the same materials as more recent headstones? Why?

Wild, Weird, Wonderful

www Science

Sails Made of Stone

They rise up 500 m or more from a flat plain in central Newfoundland. We call them "tolts," but elsewhere in the world they are known as inselbergs, monadnocks, tors, and bornhardts.

We also call three of them the Topsails. They have the names of sails, the Main, the Gaff, and the Mizzen, because at a distance they look like the upper sails on a three-masted ship.

They might look like sails, but woe betide any ship's captain who tries to hoist one of them up a mast! The Topsails are huge rocky knobs surrounded by smaller rocky debris on Buchans Plateau east of Grand Lake. They are relics, all that is left over from a former higher landscape level that has all but disappeared due to erosion.

How were the tolts formed? For the past 200 million years, erosion has been the main event in the geological history of Newfoundland and Labrador. During this time, glaciers repeatedly advanced and retreated across our province, carving up the land and polishing it smooth. Rivers eroded the ground, stripping rock and soil from the land's surface and carrying it to the ocean. River erosion, also known as fluvial erosion, led to the development of the plains and plateaus that make up parts of our province.

The combined effect of glacial and fluvial erosion wore the land that used to be level with the tolts down to a featureless plateau. The plateau is a windswept highland area much of which is over 400 m above sea level.

In addition to the towering granite tolts that managed to resist the erosion that went on around them, the plateau is also littered with glacial till and erratics. Erratics are large boulders left behind long ago by retreating glaciers.

Although they withstood earlier glacial and fluvial erosion, the tolts themselves cannot escape erosion altogether. They are slowly being worn down as wind and rain remove weathered debris from their slopes. With time, the tolts will slowly be reduced. As mighty and impenetrable as they look, eventually even the Topsails will surrender to the slow but powerful forces of erosion.

Main Topsail, Central Newfoundland

Check Your Understanding

Checking Concepts

1. Make a series of drawings with captions and labels showing how frost wedging occurs.
2. How is chemical weathering different from mechanical weathering?
3. How do plants contribute to
   (a) mechanical weathering?
   (b) chemical weathering?
4. Explain how both chemical weathering and mechanical weathering can wear down a marble headstone in a cemetery.
5. What is the process called that loosens and moves weathered sediments over Earth's surface?
6. Describe two processes that cause erosion.
7. Describe two ways that glaciers move sediments.
8. What is the final stage of erosion?
9. (a) Why is erosion considered to be a destructive process?
   (b) Why is deposition considered to be a constructive process?
10. What is the name of the in-between stage in the rock cycle between a parent rock and a sedimentary rock?

Understanding Key Ideas

11. A hard candy dissolves much faster in your mouth if you first break it into pieces. How is this process like
    (a) mechanical weathering?
    (b) chemical weathering?

12. What evidence of weathering have you observed in your community?
13. Use the example of a rock falling off a cliff to explain the difference between weathering and erosion. Draw a labelled illustration as part of your answer.

Pause and Reflect

Imagine you are a writer for a scientific magazine. Write a short article describing how a mountain can be weathered and eroded into a rolling hill and what happens to the sediments.

12.2 Soil Types and Characteristics

Soil can take thousands of years to form. Soil gradually develops into three layers, called a soil profile. The topsoil is the most fertile part of the soil, and includes humus and living organisms, as well as air, water, and weathered rock fragments. Soils are different depending on the parent material, climate, vegetation, landscape, and amount of time they have been forming. Different soils have different textures. Sandy, gravelly soils are gritty and have large particles. Clay soils are greasy and have small particles. Loam can be both gritty and greasy and has a variety of particle sizes.

Key Terms

humus
leaching
permeability
porosity
soil profile
subsoil
texture
topsoil

Why is the rock cycle so important to our daily lives? We need plants to survive. Plants need soil containing the right balance of air, nutrients, and water to survive.

Soil is created as part of the rock cycle. Rocks are weathered and eroded by water, wind, ice, and gravity and other factors. The end result of weathering is fine sediment or dirt. Dirt is mainly weathered minerals with little organic matter. How does dirt become fertile soil like the soil found in Codroy Valley (Figure 12.12)?

Figure 12.12 The fertile soil of Codroy Valley is some of the best farmland in Newfoundland. The soft sedimentary rocks of the valley, such as sandstone, limestone, and shale, erode easily and help form excellent soil.

12-2A Comparing Dirt and Soil

Find Out ACTIVITY

In this activity, you will compare and contrast a sample of soil with a sample of dirt.

Materials

- 250 mL dirt/ground rocks
- paper
- 250 mL rich garden soil
- hand lens
- stir stick
- optional: goose-neck camera to magnify and view specimens

What to Do

1. Place a sample of dirt on a piece of paper. Examine the dirt using the hand lens. Use the stir stick to separate the particles. Make as many observations as you can. Record your observations.
2. Place a sample of soil on a piece of paper. Examine the soil using the hand lens or goose-neck camera. Use the stir stick to separate the particles. Make as many observations as you can. Record your observations.
3. Clean up and put away the equipment you have used. Wash your hands thoroughly.

What Did You Find Out?

1. Create a Venn diagram to compare and contrast dirt and soil.
2. What components (parts) of the soil could you identify?
3. What type of processes do you think soil has undergone that dirt has not?
4. Why do you think soil is a better medium for growing most plants than dirt?

Humus

Soil is a mixture of weathered and eroded rock, humus, air, water, and living things, such as fungi, mould, bacteria, and earthworms. **Humus** (HYEW-muhs) is material produced by breaking down plant and animal remains. Decayed plant and animal remains are the main source of nutrients for plant growth. Humus is rich in nutrients, such as nitrogen, phosphorus, potassium, and sulphur. These nutrients dissolve in water in the soil.

Plants absorb the nutrient-rich water through their roots. Humus also promotes good soil structure and helps keep the water in the soil. As worms, insects, and rodents burrow throughout the soil, they mix the humus with the fragments of rock. Figure 12.13 on the next page illustrates how humus and weathered rock fragments can become soil.

A *fertile* soil is soil that can supply nutrients for plant growth. Soils that develop near rivers are generally fertile. Some soils may be nutrient-poor and have low fertility, such as the eroded, rocky soil of steep cliffs and roadsides.

Did You Know?

About one half the volume of good soil is air and water. The other half is about 90% rock and mineral sediments and 10% organic matter, including living organisms as well as decaying plant and animal remains.

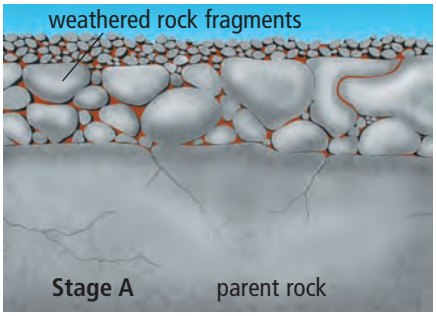


Figure 12.13A These weathered rock fragments contain many cracks and spaces, providing areas that air and water can fill.

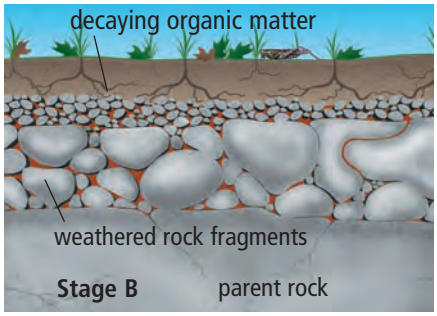


Figure 12.13B Immature soil can support small hardy plants that attract insects and other small animals. Over time, dead plant and animal material build up, and bacteria and fungi cause them to decay. The decaying organic matter forms a layer of humus on top of the weathered rock.

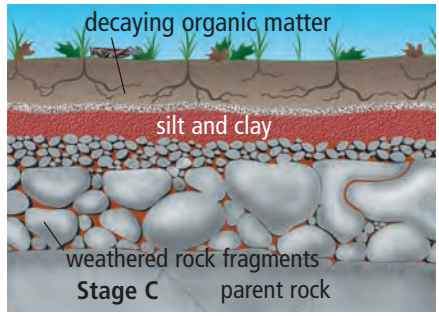


Figure 12.13C Mature soil contains mineral-rich clay on top of weathered rock. The clay forms when water carries the minerals away from the decaying organic matter above. Above the clay, the topsoil extends to the surface and contains humus, plant roots, and living organisms.

Soil Profiles

Soils can take thousands of years to form. They can range in thickness from more than 60 m in some areas to just a few centimetres in others. Soil varies in structure and appearance, depending on its depth. As the soil forms, it slowly develops layers with clear differences in appearance and composition. A **soil profile** is the series of layers in soil from the surface down to bedrock. The soil profile in Figure 12.14 on the next page shows how the layers are divided. The layers show different degrees of soil evolution.

The top layer (A) is called the **topsoil.** The topsoil is the most fertile part of the soil and can range in depth from a few centimetres to one metre or more. Topsoil consists of dark-coloured, rich, crumbly soil that contains humus and small grains of rock. As well as supporting plants, this layer is home to insects, earthworms, rodents, and microorganisms.

The next layer (B) is the **subsoil.** Subsoil is more tightly packed and generally lighter in colour than topsoil because there is little or no humus, and because it contains minerals that have leached from the top layer. **Leaching** is the removal of soil materials dissolved in water. Water reacts with humus to form an acid. This acid can dissolve elements and minerals from upper layers and carry them through the spaces in the soil to lower layers. Subsoil may be brownish or red because of the clay and iron oxides (rust) washed down from the top layer. Subsoil is less productive than topsoil because the subsoil contains less water and organic nutrients.

Did You Know?

There can be billions of microorganisms in every gram of healthy topsoil.

Figure 12.14 You can often see soil profiles along roadsides and riverbeds. If you notice a soil profile, try to identify the different layers.

The bottom layer (C) is weathered bedrock. This layer contains partly weathered rock and minerals leached from above. The bottom layer most closely resembles the bedrock below and is at the beginning of the long, slow process of rock evolving into soil. The bedrock is the parent rock from which the overlying soil was made.

Mature soils have all three layers. Some plants grow better on rocks or dirt or early soils. Other plants grow better on mature soils. A newly developing soil does not yet have a subsoil layer. It has a thin layer of topsoil over a layer of bedrock. As the soil continues to develop, a subsoil layer forms and over time becomes more distinct.

How Do Soils Develop?

Weathered and eroded rocks form the parent material of soils. Organic material provides the nutrient base for a variety of soil ecosystems. The type of soil that forms depends on the type of rock that is being weathered. For example, when shale is weathered, clay-type soil results.

Five major factors affect the rate at which soil forms as well as soil texture and composition: parent material, climate, vegetation, landscape, and time (see Table 12.1 on the next page). Wildlife and human populations also affect soil development. Animals help to recycle nutrients as they dig and burrow in the soil. Humans plough, irrigate, and fertilize soil, change drainage patterns, and use soil for non-agricultural developments and disposal of wastes.

Table 12.1 Major Factors that Determine how Soil Develops

Factor	What It Does	Examples
Parent material	– determines physical and chemical properties of soil	– red soils indicate parent rock is rich in iron – limestone bedrock helps make soil less acidic
Climate	– determines what kinds of plants will grow, and how fast they decompose – affects weathering and causes erosion, carrying nutrients from the soil – determines severity of erosion, the rate and amount of water entering the soil, and the rate of chemical reactions and biological activity	– moisture is required for soil organisms to change organic matter into humus – high rainfall leaches mineral nutrients from topsoil – spring run-off helps create rich river-bottom land – wind can blow away sediment before soil has a chance to form – coastal sand dunes contain wind-blown sand
Vegetation	– determines the amount and type of organic matter in and on the soil – protects the soil from erosion	– decaying plants add nutrients and organic matter to the soil – leaf litter in pine forests increases soil acidity – plant roots help hold the soil in place
Landscape	– affects drainage, warmth, and protection from weather – movement of glaciers exposes bedrock, moves parent materials, and deposits sediments	– soil may be eroded from slopes and deposited in lowlands – glaciers deposit sand and gravel; unusually rocky fields; sediment with a wide variety of particle size, from fine clay to coarse gravel
Time	– influences the availability of minerals and the extent of humus development	– young soils do not yet have much humus

Reading Check

1. What is dissolved from upper soil layers in leaching?
2. What are the three layers in a soil horizon?
3. What are five factors that determine how soils develop?

Particle Size, Porosity, and Permeability

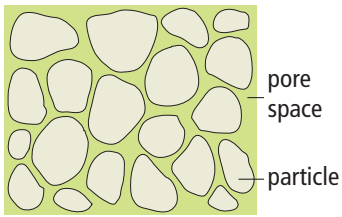


Figure 12.15 Particle size helps determines how much space in the soil will be available for air and water.

Rock particles in soil are the result of weathering and erosion, so the particles vary depending on the parent material from which they formed, such as sandstone or granite. The formation of topsoil depends largely on the particle size of the rock fragments (see Table 12.2 on the next page). The particle size determines how large the spaces will be in the soil. The amount of empty space in a soil or rock is called **porosity.**

The particle size, texture, and porosity affect how quickly water will drain through, or permeate, the soil. **Permeability** is a measure of how easily liquids and gases pass through a soil or a rock.

Table 12.2 Average Particle Size

Name of rock sediment	Average particle diameter
Gravel	over 2.0 mm
Sand	0.05 mm to 2.0 mm
Silt	0.002 mm to 0.05 mm
Clay	less than 0.002 mm

Suggested Activitiy

Conduct an Investigation 12-2B on page 428.

Types of Soil

There are many types of soil possible because there are so many different types and amounts of components that make up soil (Figure 12.16). One way to classify soil is to determine its texture. **Texture** relates to how soil feels when it is rubbed between two fingers. Texture can tell us much about the soil: what is in it and what it can do.

- *Sandy/gravelly soil:* This kind of soil has a high permeability. The relatively big spaces between the particles mean that there is a lot of air in the soil. Sandy/gravelly soil tends to be dry and well-drained most of the time. The particles feel gritty when you roll them between your fingers.
- *Clay soil:* Clay particles are so small that they fill up most of the spaces in soil, leaving little room for air, water, or plant roots. Rainwater often sits on top of the soil in puddles and soaks in very slowly. Clay-rich soil feels sticky or greasy, like toothpaste. These soils have very little texture, especially when wet.
- *Loam:* To grow most plants, topsoil should allow water to permeate at a moderate rate. Farmers and gardeners prefer a type of soil referred to as *loam*. A loamy soil is composed of sand, silt, and clay in nearly equal proportions. Loam is medium-textured and may feel gritty and sticky at the same time.

Soils may also be classified according to the climate and area where they occur. Different types of vegetation can be found in different soil types.

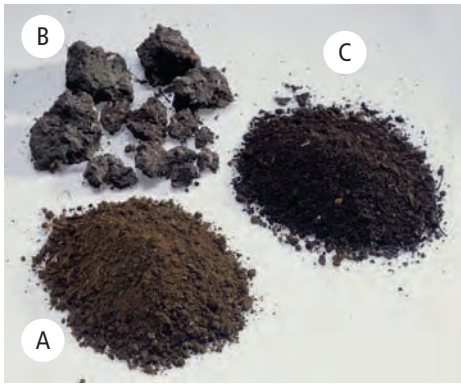


Figure 12.16 Three types of soil: sand (A), clay (B), and loam (C).

Reading Check

1. What is porosity?
2. What is permeability?
3. Which rock sediment has the smallest particle size?
4. What are three main types of soil?

Explore More

What kinds of soil are in deserts, rain forests, prairies, and mountains? Find out more about different types of soil. Start your search at **www.discoveringscience.ca.**

12-2B Be a Soil Sleuth

Core Lab

Skill Check

- Observing
- Measuring
- Classifying
- Evaluating information

Safety Precaution

- Be careful when using objects with sharp points or edges.

Materials

- soil sample, sand, gravel, clay
- paper
- hand lens
- ruler
- 4 large plastic cups
- thumbtack or pushpin
- cheesecloth
- rubber bands
- scissors
- 4 plastic coffee-can lids
- 4 glasses or beakers (250 mL)
- measuring cup or graduated cylinder
- water
- watch

What is the difference between clay, sand, and gravel? In this activity, you will use tests to determine the characteristics of a soil sample by comparing it to samples of clay, sand, and gravel.

Question

What are the characteristics of a soil sample?

Procedure

1. Make a table of observations like the one below.

Soil Sample				
	Your Soil Sample	Clay	Sand	Gravel
Colour				
Average particle size				
Texture when wet				
Texture when dry				
Time to drain 25 mL				

2. Spread your soil sample on a sheet of paper.
   (a) Record the colour of the soil.
   (b) Measure the diameter of an average particle while looking through the hand lens. If there is a variety in the size of particles, measure the diameter of a group of particles. Divide the diameter by the number of particles you estimate are present along the diameter. This will give you an estimate of the size of one particle.
3. Repeat step 2 with the sand, gravel, and clay samples.

4. Rub a small amount of your soil sample between your fingers to evaluate its texture. How does it feel? Press the soil sample together. Does it stick together or crumble? Wet the sample and try again. Record your observations in the table.

5. Repeat step 4 with the sand, gravel, and clay samples.
6. Test for water drainage.
   (a) Label the plastic cups "sand," "clay," "gravel (with sand and clay)," and "area soil sample." Using the thumbtack, punch an equal number of holes around the bottom of each cup.
   (b) Cover the area of holes on each cup with a cheesecloth square. Secure the cheesecloth with a rubber band.
7. To hold each cup over the glass or beaker, cut a hole in a coffee-can lid so that the cup will just fit inside the hole. Place a cup and lid over each glass or beaker.
8. Half-fill the appropriate cups with dry sand, clay, and your soil sample. Make a mixture of equal parts gravel, sand, and clay, and half-fill the last cup with this mixture.
9. Use the measuring cup (or graduated cylinder) to pour 100 mL of water into each cup. Record the time for 25 mL of water to drain through the sample.
10. Wash your hands thoroughly after completing this investigation. Clean up and put away the equipment you have used.

Analyze

1. Compare the feel and stickiness (texture) of the sand, gravel, and clay samples.
   (a) Which one is the grittiest?
   (b) Which one is the stickiest?
   (c) How does your soil sample compare to these? Is it more like one than another?
2. (a) Compare the drainage of the sand, clay, and gravel mixture. Which drained the most quickly? Which drained the least quickly?
   (b) How did the drainage rate of the gravel mixture compare with the drainage rate of the others?
   (c) Which one did your soil sample resemble the most in drainage?

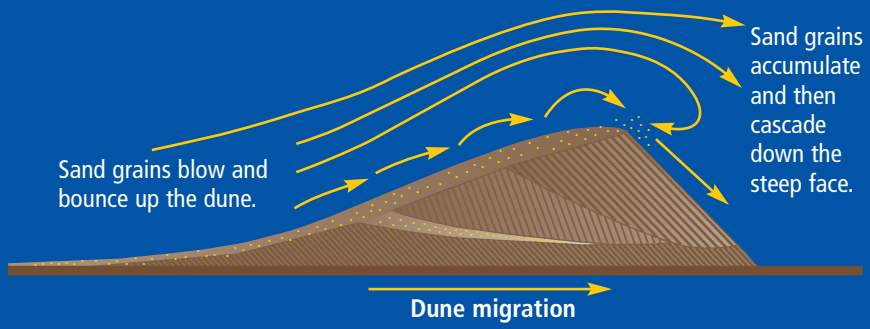
Conclude and Apply

1. How does the addition of gravel and sand affect the speed at which water drains through the clay?
2. What would you do to increase the speed at which water drains through your soil? What would you do to decrease its speed? Why would this be useful to know?
3. (a) Describe three characteristics of soil.
   (b) Which characteristics do you think most affect how quickly water drains through the soil?
4. Rank the size of the soil particles from largest to smallest in clay, sand, and gravel.
5. Which types of soil would be the best to grow vegetables in your garden? Why?

NATIONAL GEOGRAPHIC

VISUALIZING HOW DUNES FORM AND MIGRATE

Sand blown loose from dry desert soil often builds up into dunes. A dune may begin to form when windblown sand is deposited in the sheltered area behind an obstacle, such as a rock outcrop. The sand pile grows as more grains accumulate. As shown in the diagram to the right, dunes are mobile, gradually moved along by wind.



▲ A dune migrates as sand blows up its sloping side and then cascades down the steeper side. Gradually, a dune moves forward—in the same direction that the wind is blowing—as sand, lost from one side, piles up on the other side.

▲ Dunes are made of sediments eroded from local materials. Although many dunes are composed of quartz and feldspar, the brilliant white dunes in White Sands National Park, New Mexico, are made of gypsum.

▲ Deserts may expand when humans move into the transition zone between habitable land and desert. Here, villagers in Mauritania in northwestern Africa shovel the sand that encroaches on their schoolhouse daily.

◀ The dunes to the left are coastal dunes from the Laguna Madre region of South Texas on the Gulf of Mexico. Note the vegetation in the photo, which has served as an obstacle to trap sand.

(tl)Stephen J. Krasemann/Photo Researchers, (tr)Steve McCurry, (b)Wyman P. Meinzer, (bkgd)Breck P. Kent/Earth Scenes

Check Your Understanding

Checking Concepts

1. What are the main components of soil?
2. What is the role of humus in the soil?
3. (a) Draw a diagram of a soil profile.
   (b) Label each layer.
   (c) Describe what is happening in each layer.
4. What are the five major factors that determine how soils develop?
5. Put the following sediments in order from smallest particle size to largest: clay, gravel, and sand.
6. What is the difference between porosity and permeability?
7. (a) What are the three basic types of soil?
   (b) Describe the basic characteristics of each type of soil.

Understanding Key Ideas

8. How does the amount of weathered rock material change as you go deeper into a soil profile?
9. Is leaching a helpful process or a harmful process in soil development? Explain your answer.
10. (a) What kinds of organisms live in the soil?
    (b) What role do they play?
11. A sample of soil is greasy, sticky when wet, and does not let water drain very quickly.
    (a) What particle type do you think this soil is made from?
    (b) What could you do to turn it into good gardening soil?
12. How would the soil profile in a rain forest be different from the soil profile in a desert?
13. Give three examples of how the type of soil determines the type of plants present.
14. Why do you think there is relatively little farmland in Newfoundland and Labrador?
15. Copy and complete the following chart in your notebook. Place a checkmark in each of the columns that describes each factor that influences soil development.

	Factor	Meteorological	Geological	Biological	Chemical
(a)	Acidic action				
(b)	Glaciers				
(c)	Gravity				
(d)	Plants				
(e)	Rain				
(f)	Wind				

Pause and Reflect

Make a hypothesis about how to change the permeability of a soil sample. Design an investigation to test your hypothesis. What will be your manipulated and responding variables? What factors will you need to control?

12.3 Sustaining Fertile Soils

Fertile, healthy soil is the nutrient-rich, but delicate basis of healthy plants and animals. Soil can be easily lost to erosion, resulting in desertification. Modern farming methods can reduce productivity and affect other parts of the ecosystem. Ecological farming practices aim at preventing soil erosion. Composting is a method of producing humus. Forestry conservation practices include covering the soil and planting trees.

Key Terms

algal blooms
composting
desertification
fertilizers
no-till farming

Soil is an amazing natural system with billions of residents per cubic metre. To lose the soil, or its ability to grow plants, would be a disaster. Without healthy topsoil, life on our planet would be in danger.

It takes hundreds of years to form a few centimetres of soil, but it takes only a short time to lose the soil to erosion. In the 1930s, farmers in Canada and the United States learned a hard lesson about the importance of conserving topsoil. For years, they had overplanted their fields without adding any nutrients to replace those that were lost. Eventually, there was no humus left, so the soil could not use what little moisture was available during times of drought. The soil turned to dust and was carried away by the wind as shown in Figure 12.17.

Did You Know?

The health of all animals, including humans, is directly related to the health of the soil.

Figure 12.17 Uncovered soil can be blown away.

12-3A Save the Soil

Find Out ACTIVITY

If some topsoil is lost to erosion, how much does it matter? In this activity, you will use a model to represent the amount of topsoil on Earth.

What You Need

- cutting board
- knife
- apple

Safety Precautions

- The knife is sharp and may cause cuts if not handled properly.
- Never eat anything in the science room.

What to Do

1. Carefully cut the apple into quarters.
2. Set aside three quarters. Cut the fourth quarter lengthwise into two equal pieces (each piece is one eighth of the apple).
3. Set aside a one-eighth piece. Carefully cut the other one-eighth piece into four equal pieces. (Each piece is one-thirty-second of the apple.)
4. Set aside three thirty-second pieces. Carefully peel the skin from the last thirty-second piece.
5. Each piece of apple represents the following:
   - The three quarters represent the part of Earth covered by oceans.
   - The one-eighth piece represents land that is unsuitable for human life.
   - The three thirty-second pieces represent land that is unsuitable for food crops.
   - The peel from the last piece represents the layer of topsoil that can support life.

What Did You Find Out?

1. Suppose a crop of food that could only grow in fairly limited regions was affected by loss of topsoil.
   (a) What might be the effect on this food supply?
   (b) What might be the effect on other species?
2. Aside from the loss of food crops, what other long-term effects can be caused by loss of topsoil?

Desertification

Soil is an important resource in Canada and throughout the world. When vegetation is removed by harvesting crops, the soil is exposed to the direct action of rain and wind. Topsoil, which contains the nutrient-rich humus, can be eroded and carried away. Also, without plants, soil development slows and sometimes stops because humus is no longer being produced. When natural vegetation is removed from land that receives little rain, plants do not return. All of these conditions can contribute to the destruction of the natural ecosystem and lead to desert formation. **Desertification** is the process in which nutrient depleted soils are formed through erosion of fertile soil. Desertification is currently happening the world over.

internet connect

Desertification is happening in Canada as well as in other countries of the world. Find out more about desertification in Canada. Start your search at **www.discoveringscience.ca.**

Figure 12.18 This topsoil is exposed to wind and water erosion.

Farming, Soil Loss, and the Environment

Modern farming methods are capable of feeding billions of people on Earth. However, these methods can contribute to the destruction of the very environment that is needed for such large-scale farming. Large equipment requires that farmers plough long straight lines (Figure 12.18). This can contribute to loss of topsoil due to water erosion. Trees that are used as windbreaks often have to be cut down to make larger fields, which can expose the fields to a loss of topsoil due to wind erosion. In many cases, marshes have been drained and fields ploughed right to the edge of rivers or streams. This can contribute to the elimination of different species of wildlife. The machinery used in large-scale agricultural operations relies on the combustion of fossil fuels, which adds to air pollution.

When farmland is cultivated to grow field crops, vegetation is removed. Water enters the soil since there are no plants to absorb water. Irrigation brings even more water into the soil, adding to the groundwater. The excess groundwater leaches minerals (salts) from the soil. Eventually, when the water evaporates the salts are left behind. Every year that salt collects in soil, the soil becomes less and less able to grow crops. In some areas, growing crops is no longer possible (Figure 12.19).

Figure 12.19 A white crust on the soil is evidence of too much salt. Two factors lead to salty soil: too little vegetation and too much water.

Suggested Activity

Find Out Activity 12-3C on page 439

Enriching the Soil

Like you, crops need minerals to survive and stay healthy. Healthy, growing plants require large amounts of three nutrients: nitrogen (N), phosphorus (P), and potassium (K). Different parts of plants use different amounts of each of these nutrients. For example, nitrogen helps make leaves green. Phosphorus is required for the development of roots and new seedlings. Flower and fruit production is stimulated by potassium. Farmers must find ways to replace minerals in the soil that crops have used.

One method of preserving or returning minerals to the soil is crop rotation. Farmers plant a different crop in each field each year. This ensures that the minerals used by one crop are replaced the following year by a different crop (Figure 12.20). For example, a crop of soybeans will replace nitrogen that has been used by a previous crop of corn.

Figure 12.20 Many farmers use forages (legumes and grasses) in a crop rotation to add organic matter and provide protection from wind and water erosion.

Fertilizers

The most common method of enriching the soil is to apply fertilizers. **Fertilizers** are substances that provide nutrients for plants. You may have seen fertilizers being applied in your community, in your garden or greenhouse, or on a local farm. Organic fertilizers are made from plant and animal remains and waste. Inorganic fertilizers are made from essential elements and minerals. Types of fertilizers include compost, manure, and natural and synthetic chemical fertilizers.

- **Composting** is the breakdown of plant material (decomposition). Various organic materials, such as dry leaves, manure, and vegetable peelings are piled together in the right conditions to be transformed into humus. You might have a compost pile or bin at home for food scraps and yard clippings (Figure 12.21).
- Manure from livestock is often used to add organic matter, improve soil structure, and increase nutrients and biological activity. Farmers have added animal manure and bedding to soil for centuries. Manure from herbivores (plant eating animals) such as cows, sheep, goats, and horses is high in nitrogen.
- Chemical fertilizers may be natural or synthetic (human made). Some chemical fertilizers include decomposed animal or plant material, such as bone meal, fish emulsion, and seaweed. Other chemical fertilizers include minerals from Earth's crust, such as volcanic ash and rock dust (crushed basalt, granite, and other rocks).

Figure 12.21 A compost bin

Effects of Using Fertilizers

There are both positive and negative effects of using fertilizers. The *intended* positive effect of using fertilizers is enhanced plant growth. Enhanced plant growth means decreased erosion, more food, and better looking plants and crops.

The *unintended* negative effect of fertilization is increased pollution in run-off. When phosphates from fertilizers run off into nearby ponds or lakes, the result may be **algal blooms**, which are huge increases in the amount of algae in the water. Algal blooms remove dissolved oxygen from the water, which makes it impossible for fish and other aquatic creatures to live there (Figure 12.22).

Nitrogen compounds and other substances in fertilizers and manure, as well as chemicals in pesticides and herbicides, dissolve in water and find their way into the rivers, streams, and groundwater systems. The result is the pollution of human drinking water. How can farmers minimize the damage?

Did You Know?

Run-off from fertilizer was probably the cause of E. coli bacteria entering the water supply of Walkerton, Ontario in 2000. Hundreds of people became ill and within a few days seven people had died as a result of drinking the water.

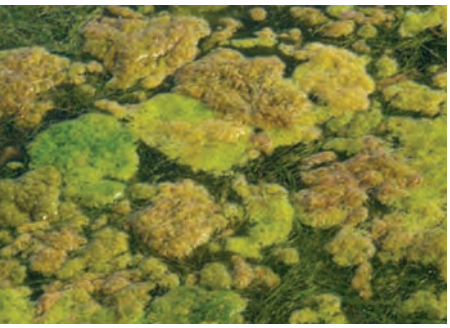


Figure 12.22 An algal bloom caused by run-off from fertilized fields removes oxygen from the water.

Reading Check

1. What is desertification?
2. What are three types of plant nutrients?
3. What is the intended positive effect of using fertilizers?
4. What is the unintended negative effect of using fertilizers?

12-3B Agriculture in the News

Think About It

In this activity, you will research current issues related to agriculture.

What to Do

1. Research current information on agriculture issues in your community or region. You could search local newspapers, news magazines, and the Internet, and talk with local farmers and gardeners.
2. Post the information you find, or summaries of your conversations with experts, on a bulletin board.

What Did You Find Out?

1. Read the information collected by the class, and then, answer the following questions:
   (a) Which issues seem to be receiving the most attention in the media?
   (b) Why do you think they are receiving so much attention?

Ecological Farming Practices

Most farmers try to prevent soil erosion and to minimize the environmental impact of their farming practices. Many of the problems associated with our use of soils, including desertification, can be solved using more ecological farming practices. An *ecological* approach considers the relationship of living things to their environment and to each other. Ecological farming practices include the following.

Suggested Activities

Find Out Activity 12-3D on page 439

Conduct an Investigation 12-3E on page 440

Reducing reliance on chemical fertilizers

Chemical fertilizers can inhibit or kill soil microorganisms that are needed to provide a balanced diet to crops. Ecological soil management aims at helping all parts of the soil ecosystem.

Limiting run-off

Soil erosion can be solved by planting a cover of vegetation on the surface of the ground to slow the flow of water. This gives the soil more time to absorb the water. When more water soaks in to the soil, less water will flow along the surface and cause erosion. Less water will seep into the groundwater and cause salty soils. Vegetation covers also protect soil from the wind. Even covering bare soils with decaying plants helps to hold soil particles in place. In dry areas, instead of ploughing the natural vegetation under the soil to plant crops, farmers graze animals on the natural vegetation. Proper grazing management can retain plants and reduce soil erosion.

No-till farming

Some farmers till or plough their fields two or three times a year, exposing the topsoil to dangerous wind erosion each time. In recent years, many farmers have switched to the practice of no-till farming. In **no-till farming,** plant stalks are left in the field (Figure 12.23). At the next planting, farmers use seed drills to push seed right through the stubble of the previous crop into the undisturbed soil.

Figure 12.23 No-till farming provides cover for the soil all year round and reduces soil erosion.

Planting windbreaks

Farmers plant windbreaks (rows of trees) along edges of fields (Figure 12.24). Windbreaks reduce wind damage to crops, trap snow to increase soil moisture, and provide habitat for wildlife.

Figure 12.24 Rows of trees can reduce soil erosion and damage from wind.

Saving Soil in Forests

Forestry also has an impact on soils. When trees are cut and removed from an area, wind and water can erode the soil. To minimize damage, some trees and debris such as logs and stumps are left on cut areas. As the debris decays, it adds organic matter to the soil. Forests are also replanted with new trees shortly after they are harvested (Figure 12.25). As well, trees and shrubs are usually left around streams to minimize soil loss.

Figure 12.25 Forestry erosion control methods slow the flow of water and the loss of soil to erosion.

Explore More

What are other alternative farming practices that reduce erosion and safeguard the precious topsoil? You can find out by visiting **www.discoveringscience.ca.**

Reading Check

1. What does "ecological" mean?
2. What are four ecological farming practices?
3. Why are trees and shrubs left near streams in forestry conservation practices?

12-3C Maintaining Moisture

Find Out ACTIVITY

In this activity, you will investigate how organic matter affects soil moisture.

Materials

- 3 metal baking pans or similar pans
- garden soil or potting soil
- organic material, such as wood shavings, grass clippings, or leaves
- water
- fan (optional)
- grow light or heat lamp (optional)
- paper towel
- soil moisture metre (optional)

What to Do

1. Add equal amounts of soil to each tray.
2. Cover the soil in one tray with organic matter. Mix the same amount of organic matter in with the soil in the second tray. Do not add organic matter to the third tray.
3. Dampen the soil in the trays using equal amounts of water. Do not saturate the soil.
4. Leave the trays in a warm area, under grow lights, or place them in front of a fan.
5. After several hours, press a sheet of paper towel onto the soil in each tray. Compare the amount of moisture on each paper towel. You can also use a soil moisture metre for this step.

What Did You Find Out?

1. Which tray had the highest soil moisture?
2. How was the amount of soil moisture affected by placing the organic matter on top of the soil or mixing it?
3. What is another way you could measure soil moisture?

12-3D Fertilizer Formulations

Find Out ACTIVITY

A container of fertilizer usually has three numbers that indicate the percentage of each of the three major nutrients of nitrogen, phosphorus, and potassium. For example, a bag of fertilizer marked 12-14-18 contains 12 percent nitrogen, 14 percent phosphorus, and 18 percent potassium. In this activity, you will research fertilizer formulations.

What to Do

Arrange to visit a garden store or nursery or speak with a knowledgeable person. Find answers to the following questions:

- What formulations of fertilizer are available locally?
- How is each formulation used?
- Which fertilizer is used most commonly?
- What other forms of fertilizer are popular, and how are they used?

What Did You Find Out?

1. Organize your findings in a table to present to your class.
2. (a) What amount of fertilizer is best for a plant?
   (b) Can plants have too much fertilizer?
   (c) Rewrite questions (a) and (b) as hypotheses that you could test.

12-3E Decomposing Dinner

Skill Check

- Observing
- Classifying
- Controlling variables
- Evaluating information

Safety Precautions

- Never eat anything in the science classroom.

Materials

- 4 identical plastic pots with drainage holes
- saucers to go under pots
- pieces of window screen or similar material
- magnifying glass
- small stones
- labels for pots
- garden soil (not sterilized)
- water
- Approximately 250 mL of 2 items from List A and 2 items from List B

List A: banana peels, cabbage leaves, grass clippings, potato peels, carrot peels, egg shells
List B: aluminum foil, small pieces of plastic, shredded wax paper, shredded paper

Imagine cooking dinner at your home. You may peel potatoes, chop lettuce, and crack an egg. Each of these actions leaves you with waste material to throw away. Kitchen "waste" does not need to be garbage, however. Under the right conditions, it can be composted. When waste is composted, it is broken down so that the nutrients can be released. The composted material can be recycled, for example, as fertilizer in your garden. In this activity, you will explore the process of composting.

Question

What kinds of materials decompose?

Procedure

Part 1

1. Before starting this investigation, formulate a hypothesis about the kinds of materials that can decompose. Choose four materials to test: two from List A and two from List B. Based on your hypothesis, predict what will happen to each of the materials you are going to test.
2. Set each pot on a saucer.
   (a) Put a few small stones over the drainage hole in each pot.
   (b) Add garden soil to each pot until the pot is about half full.
3. Put one test material in each pot. Label the pots to show what material is in it.
   (a) Cover the materials in the pots with equal amounts of soil.
   (b) Estimate the amount of water that you can add to each pot so that a little water will come out of the bottom of the pot into the saucer. Add the same amount of water to each pot. If no water drains out of the bottom of the pots, add small but equal amounts of water to each pot until some water drains out.
   (c) Cover the open top of each pot with a piece of window screen.
   (d) Put the pots in a sheltered location. Moisten the soil every few days. Be sure to add the same amount of water to each pot.

Part 2

4. After a week, remove the uppermost layer of soil. Check that the soil underneath is moist. Use a hand lens to observe the amount of decomposition of your materials. Record your observations.
5. Replace the soil, and continue to check the decomposition each week until you can see a difference in the condition of the test materials.
6. Clean up your work area as your teacher directs. Wash your hands thoroughly after completing each part of this investigation.

Analyze

1. (a) Which test materials decomposed rapidly?
   (b) Why do you think these test materials decompose rapidly?
2. (a) Which test materials decomposed slowly?
   (b) Why do you think these test materials decompose slowly?
3. (a) Which materials did not decompose over the course of the investigation?
   (b) Why do you think these materials did not decompose?
4. Did your results support your hypothesis? Explain.

Conclude and Apply

1. (a) What factors might speed up the decomposition of the materials you listed in your answer to Analyze question 2?
   (b) Design an investigation to test one of the factors.

Earthworms are an important part of composting and creating healthy soil. As they burrow through the soil, earthworms create channels for air and drainage. They pull down organic matter from the soil surface into their burrows where they partially digest it and mix it with mineral particles to help form humus.

Science Watch

Putting a Stop to Desertification

Desertification is a global problem that currently threatens about 30 percent of the land on Earth. The United Nations declared 2006 to be the International Year of Deserts and Desertification. In doing so, the United Nations was not celebrating desertification. It was making the point that desertification is a serious problem facing the entire world and that we can all help to prevent it. More than 110 countries around the world, including Canada, have land that is at risk of desertification.

The term "desertification" refers to what happens when people overuse or misuse lands. The main culprits behind desertification are overcultivation, overgrazing by livestock, deforestation, and poor irrigation practices. All of these human activities eventually lead to the erosion of topsoil making the land almost useless.

Earth's landmasses are losing as much as 24 billion tons of topsoil each year. Projects in Canada to prevent desertification started in the 1930s are still underway today, including planting windbreaks and developing community pastures. Canada is also active in supporting countries around the world in reclaiming land and preventing desertification.

What are people in other countries doing to combat desertification? In many countries, farmers use different materials to build multi-level terraces on the land to prevent soil erosion. In the African country of Burkina Faso, farmers use rocks to build terraces. In Thailand and the Philippines, farmers plant tall hedges of vetiver grass to terrace land along sloped fields. In South America and Africa, farming techniques such as no-till farming are used to keep soil moist and fertile.

Planting trees is another way to combat desertification. In Niger's Majjia Valley, farmers plant trees to act as windbreaks to reduce wind erosion. Planting trees also helps bind soil and nutrients in the soil together. In the Sahel region of North Africa, trees are planted and grow among crops and pastures, providing shade, moisture, and nutrients to the soil.

Projects to stop desertification can be small and involve a handful of farmers, or they can be projects on a grand scale, like the Great Green Wall project in China, which is named after the Great Wall of China. The Chinese government plans to plant a 4480-km windbreak of trees across the northwest rim of the country along the Gobi Desert. Once the planting is completed in approximately 2074, the Great Green Wall will be longer than the Great Wall itself!

In Niger in West Africa, a girl helps plant drought-resistant plants to hold the topsoil in place.

Questions

1. How do humans cause desertification?
2. Why is desertification such a serious problem?
3. How does planting trees help combat desertification?

Check Your Understanding

Checking Concepts

1. Why is topsoil valuable?
2. (a) What is desertification?
   (b) When does it happen?
   (c) Where is it happening?
3. What are five modern farming practices that contribute to soil loss or destruction of the environment?
4. (a) Define fertilizers.
   (b) What are three types of fertilizers?
5. Explain the process of composting.
6. Draw a flow chart showing the unintended negative effect of using fertilizers.
7. Name five farming or forestry practices that help prevent soil erosion or improve soil health.

Understanding Key Ideas

8. What impact does loss of soil have on humans?
9. Why might you choose not to use chemicals to help your lawn grow?
10. Why is it important to limit run-off on farms?
11. What are the benefits of limiting reliance on chemical fertilizers?
12. Draw a labelled illustration that explains the process of no-till farming. Include and label a windbreak in your drawing.
13. (a) Forests are often cut down to provide space for homes to be built. How do the conditions shown in the photograph below increase erosion of soil?
    (b) How could this erosion be reduced?

Pause and Reflect

"Feed the soil, not the plant," is one way of expressing an ecological approach to enhancing soil. What does this expression mean? How could you put this expression into practice if you were a farmer or a gardener?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the processes of weathering, erosion, and soil formation as well as the importance of topsoil. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help using graphic organizers.) Use the following headings to organize your notes.

1. Weathering
2. Erosion
3. Soil Formation
4. Soil Loss
5. Soil Enrichment

Checking Concepts

1. How do animals that dig in the soil help weather rocks?
2. Where do acids used in chemical weathering come from?
3. In what type of climate is chemical weathering more rapid? Why?
4. What is the most powerful agent of erosion on the surface of Earth?
5. Explain the difference between
   (a) weathering and erosion
   (b) erosion and deposition
6. (a) List three agents of erosion.
   (b) Describe one affect that each agent might cause.
7. (a) What is humus?
   (b) Why is humus important to soil development?
8. Explain what process is occurring in the top, middle, and bottom layers of a soil profile.
9. (a) Define porosity.
   (b) Define permeability.
   (c) Relate porosity and permeability to soil types.
10. (a) What are the three main soil types?
    (b) How is each soil type different in terms of texture?
11. What are two problems that can be caused by overuse of chemical fertilizers?

Understanding Key Ideas

12. (a) How are weathering and erosion harmful to life on Earth?
    (b) How are weathering and erosion helpful to life on Earth?
13. In what ways can humans cause erosion? Make a list and record your ideas of how humans can prevent each cause.
14. The rock formation below is called a sea stack.
    (a) What process has carved and shaped the sea stack?
    (b) Draw what these rocks might have looked like thousands of years ago.
    (c) Draw how these rocks might look thousands of years in the future.

15. Discuss an example of human action in your community that has been taken to prevent damage from one of the environmental changes described in this chapter.

16. (a) Explain how soils that develop under grassland might be different from those that develop under forest vegetation.
    (b) What causes the soils to develop differently?

17. Imagine that you are an experienced field crop farmer. You are thinking about buying a particular parcel of land and want to check the soil. Answer the following questions:
    (a) How could you test the soil for organic matter?
    (b) Why would you be concerned about organic matter?
    (c) If the soil is low in organic matter, how could you improve it?

18. (a) Explain ways in which farming practices can actually damage the soil.
    (b) Why is it in a farmer's best interest to take steps to reduce the impact that large-scale farming can have on the environment? Use specific examples in your answer.

19. What can be done to slow erosion? Record your ideas for each of these landforms: a steep slope, the plains, and an ocean shoreline.

Pause and Reflect

Sediment from weathered and eroded rock is necessary for forming soil. Could it be possible to have too much sediment in an area? Explain your ideas with examples.

Unit Summary

10 Earth's crust is made up of rocks and minerals.

- A mineral is a pure, naturally occurring, inorganic solid substance, such as quartz, hematite, mica, and magnetite. (10.1)
- Minerals can be identified by their properties, such as lustre, colour, streak, hardness, cleavage, and fracture. Lustre can be dull, glassy, or metallic. The Mohs Hardness Scale is used to rank the hardness of minerals. (10.1)
- A rock is a mixture of two or more minerals. Rocks are grouped into three families based on how they were formed: igneous, sedimentary, and metamorphic. (10.2)
- Igneous rocks result from the cooling of magma below Earth's surface (intrusive) or the cooling of lava at Earth's surface (extrusive). (10.2)
- Sedimentary rocks are formed through the processes of compaction and cementation and are composed of sediment from rocks, minerals, and decaying plants and animals. (10.2)
- Metamorphic rocks are made when heat, pressure, and/or hot fluids change one type of rock into another type. (10.2)
- Rocks change from one family to another as they are heated up, cooled down, worn away, and placed under pressure in the ongoing processes of the rock cycle. (10.3)
- Rocks and minerals have many uses. Many rock and mineral resources are found in Newfoundland and Labrador. (10.3)

11 Earth's crust is constantly changing.

- Earth is made of four layers: crust, mantle, outer core, and inner core. (11.1)
- Evidence from the shape of continents, fossils, rocks, and climate change indicates that Earth's crust is broken into pieces. Evidence has also been gathered from the sea floor by sonar, magnetometers, and deep sea drilling. (11.1)
- The theory of plate tectonics replaced the continental drift theory and suggests that convection currents in the mantle may be the reason for the movement of the crust. (11.1)
- Earthquakes can occur where plates push together, pull apart, or move sideways past each other. (11.2)
- Where plates meet on convergent boundaries, mountains can form. When one plate subducts under another plate, melting occurs, forming volcanoes and mountain ranges. (11.3)
- The geologic time scale divides Earth's history into eras based on the appearance of life forms in the fossil record. (11.3)

12 Soil is the living component of Earth's crust.

- Weathering, erosion, and deposition work together to break rock down and transport the sediments to other locations. (12.1)
- Eroded minerals, organic matter such as decaying plant and animal materials (humus), water, and air can combine to form soil that can support the life of plants. (12.2)
- Soils are considered to be sandy/gravelly, clay, or loam depending on their particle size. Five factors that determine the type of soil formed are parent rock, climate, vegetation, landscape, and time. (12.2)
- Topsoil is a precious and valuable resource that can easily be lost due to misuse. There are ecological farming and forestry practices that can reduce erosion and help improve the quality of the soil. (12.3)

Key Terms

- beds
- cementation
- cleavage
- compaction
- extrusive rock
- fracture
- gems
- hardness
- igneous
- intrusive rock
- lava
- lustre
- magma
- metamorphic
- mineral
- parent rock
- resource
- rock
- rock cycle
- sedimentary
- streak

Key Terms

- bedrock
- continental drift
- convection currents
- convergent boundary
- crust
- divergent boundary
- earthquake
- epicenter
- fault
- focus
- fold
- fossil
- geologic time scale
- inner core
- magnetometer
- mantle
- outer core
- pangaea
- plate tectonics
- Richter scale
- Ring of Fire
- seismic waves
- seismograph
- sonar
- subduction zones
- transform boundary
- volcano

Key Terms

- algal blooms
- chemical weathering
- composting
- deposition
- desertification
- erosion
- fertilizers
- humus
- leaching
- mechanical weathering
- no-till farming
- permeability
- porosity
- soil
- soil profile
- subsoil
- texture
- topsoil
- weathering

Modelling Geological Processes in Your Community

There are many examples of geological processes at work in your community and across the province of Newfoundland and Labrador. Scientists and researchers from all around the world have come to our province to investigate the stories written in our rock about the effects of the rock cycle, the movement of Earth's crust over time, evidence from the fossil record and geologic time, and the development of soils.

Now it is your turn to research the geology of our province. You can investigate evidence of a geological process at work in your community or elsewhere in our province and share your findings with your classmates. Your teacher might assign your group a topic, or you might choose your own.

Problem

What evidence of geological processes in your local community or elsewhere in our province can you identify and model?

Criteria

- You should research your geological process by visiting the site and making direct observations, by researching using the library and Internet, and/or by speaking with local experts.
- You should represent the evidence or process visually, either with detailed photographs, drawings, a mural, a 3-D model, a computer slide show, or through a skit or dance.
- Your presentation should be accompanied by a summary explaining the site you researched, the evidence you have found, and the conclusions you have made based on the evidence.

Procedure

1. After you have chosen or been assigned a topic, meet with your group to brainstorm information you already know about your topic. Make a list of questions you would like to answer about your topic.
2. Assign group roles for gathering information and preparing the presentation. Decide on which format you will use to present your information.
3. Research to answer your questions and to create illustrations, photographs, scenery, and so on, as needed. You can start your research at www.discoveringscience.ca.
4. Make an outline of your presentation. Discuss improvements and refinements to the outline. Try to encourage ideas from all group members.
5. Create your presentation and practise sharing it. Make refinements to improve the presentation.
6. Create the written summary to accompany the presentation.
7. Be prepared to answer questions about your presentation.

Report Out

Share your presentation with members of your class, school, and/or community. Answer questions from your audience.

Soil Super Stars

Introduction

Adding leaves to compost

Soil super stars are students who know how to compost. Students in schools across Canada are discovering that it is easy and fun to compost. They are setting up composting programs in their schools and communities, indoors as well as outdoors, and using the compost to help beautify the school property or to add to the school garden. You can start a program in your school. All you need to start is a little bit of research, a suitable space or container, yard trimmings, and fruit and vegetable scraps.

Background

Adding compost to soil is an effective way of improving the fertility of the soil and the health of plants that grow in it. Compost releases its nutrients to the soil gradually, in small doses over long periods of time. It improves soil structure and texture, loosens clay soils and helps sandy soils hold water. Compost also helps soils control soil erosion and stimulates healthy root development in plants.

Find Out More

Find out more about how other schools have set up their compost programs. Create a list of questions to guide your research. You might want to ask questions such as the following:

- How does compost benefit the soil?
- What kind of container did they use?
- Where did they place their compost container or pile?
- What does ready-to-use compost look like?
- Is there a smell?
- How long does it take to produce compost?
- What role does moisture content play in decomposition?

If you are researching indoor composting, you might want to know:

- What are red wrigglers? What are their habitat requirements? How can they be used to help recycle waste?

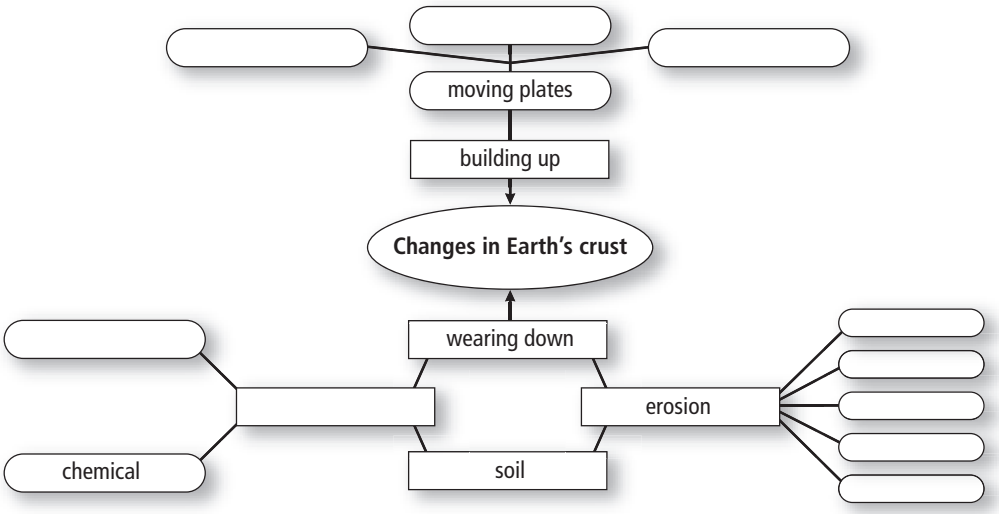
Start your research at www.discoveringscience.ca

Report Out

1. Write an article for a school web site or webcast explaining how to set up a compost program.
2. Create a flow chart of instructions that other classes or schools could use to set up a compost program.

Visualizing Key Ideas

1. Copy the following concept map about Earth's crust into your notebook. Complete the map.



Using Key Terms

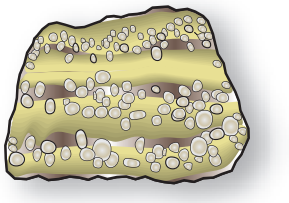
2. In your notebook, state whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) If a mineral has cleavage, it splits along smooth, flat planes.
   (b) Metamorphic rocks form through the processes of compaction and cementation.
   (c) The processes in the rock cycle do not occur in a set order.
   (d) Two plates pull apart at a subduction zone.
   (e) Seismic waves spread out like ripples on a pond.
   (f) Earth is estimated to be 4600 million years old.
   (g) Weathering affects only natural features such as rocks, caves, and mountains.
   (h) Leaching is the removal of soil dissolved in water.

Checking Concepts

10

3. (a) What six properties would you use to identify minerals?
   (b) Explain how you would use each property.
4. What is the difference between a rock and a mineral?
5. Where do rocks come from?
6. How can sediment change into sedimentary rock?
7. If igneous rocks and metamorphic rocks both form from heat, why are these two kinds of rock different?

8. (a) Place the rock below in its correct family.



(b) How did you decide?

9. Draw and label an illustration of the rock cycle.

11

10. How can two coastlines be separated by an ocean and have matching shapes?
11. What are mid-ocean ridges?
12. What is happening to the crust at mid-ocean ridges?
13. How is Earth's crust recycled through the mantle?
14. "An earthquake starts at the epicentre." Is this statement true or false? Explain your answer.
15. What effects does a volcano have on the surrounding environment?
16. (a) What is the relationship between the locations of earthquakes, volcanoes, and mountain ranges?
    (b) Which parts of the world have all three?
17. What is the difference between a mountain formed by folding and a mountain formed by faulting?
18. Many fossils of trilobites are found in Newfoundland. What does this tell you about Newfoundland's past?

12

19. What property of water makes frost wedging possible?
20. (a) How can wind change Earth's surface?
    (b) How can gravity change Earth's surface?
21. (a) What is soil?
    (b) How does it form differently in different places?
22. What is the difference between topsoil and subsoil?
23. What is the main property used to classify a soil?
24. (a) Compare compost and humus.
    (b) Explain their importance in the formation of soils.
25. Explain how procedures such as clear cutting, overgrazing, and farming can lead to desertification.
26. Imagine you are a farmer. What could you do to help reduce soil erosion on your land?

Understanding Key Ideas

27. Imagine yourself in one part of the rock cycle. For instance you could be "magma man" or "weathered woman." Write a story of your voyage through one complete cycle of the rock cycle. Be creative!

28. Is a rock a permanent thing? Explain your answer.

29. (a) Why do you think some igneous rocks have holes or air spaces?
(b) Do you think such rocks are likely to be intrusive or extrusive? Explain why.

30. These layers of sedimentary rock in Gros Morne National Park were once horizontal. How did they become tilted?

31. Prepare a poem or a song in which you compare and contrast volcanoes and earthquakes.

32. Why do you think the Precambrian era was so much longer than the other eras?

33. Imagine that you are designing a display showing dinosaurs in their environment. Would you include any models of humans in the display? Explain why or why not.

34. How does water contribute to
(a) mechanical weathering?
(b) chemical weathering?
(c) erosion?
(d) soil fertility?

35. Use diagrams to describe the processes involved in moving material from a mountain to the bottom of a river over time.

36. Explain the importance of glaciers to the mineral resource industry.

37. (a) How do organisms help soils to develop?
(b) Is their activity an example of mechanical weathering or chemical weathering? Explain.

38. (a) Name three processes that build up Earth's surface.
(b) Is Earth's crust getting thicker? Why or why not?

39. (a) Give two examples of gradual change in Earth's crust.
(b) Explain their causes.

40. (a) Give two examples of sudden change in Earth's crust.
(b) Explain their causes.

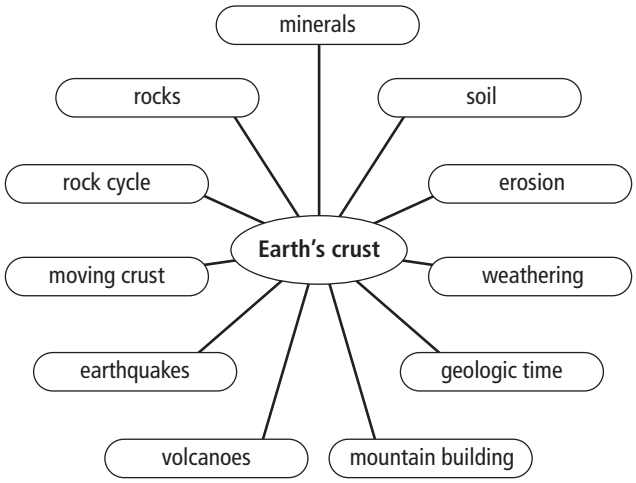
Thinking Critically

41. A core sample was taken from the bottom of a lake. The sample contained first a layer of sandstone, then a layer of shale, and finally a layer of conglomerate on top.
(a) Why could these sediments not have settled at the same time?
(b) Explain what you think happened.

42. Suppose you were given two rocks to classify. Rock A was formed deep underground and was found at the surface. Rock B was found in an underground mine but was formed at the surface. Write a paragraph about each rock in which you predict how each might have been formed and moved to its new location.
43. Imagine returning to your community 100 years from now. How might weathering and erosion have changed the landscape? Use specific examples from your community.

Developing Skills

44. Copy this chart into your notebook. For each topic, choose one question that you would like to investigate. Write each question next to its topic.



45. Research in newspapers and magazines, or on the Internet to find an article about an earthquake or volcano. Write a summary of the article to share with the class. Identify three questions that the article did not answer.
46. Design a fair test to investigate the effectiveness of using natural fertilizers as compared to human-made fertilizers.

Pause and Reflect

Suppose you are trying to find out what geological processes have taken place where you live. What kinds of clues would you look for? Where would you look?

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Organizing and Communicating Scientific Data

Drawing a Data Table

To learn how to set up a data table, read the paragraph below that contains data. Then compare the data in the paragraph to the data in the table below.

White rats have an average mass of 0.15 kg and a resting heart rate of about 350 beats per minute. An average 12.0 kg dog has a resting heart rate of about 100 beats per minute. Adult humans have an average mass of about 70 kg and a heart rate of about 72 beats per minute. An elephant with a mass of 4000 kg has a heart rate of about 30 beats per minute.

Table 1 Heart Rates and Masses of Four Animals

Type of Animal	Mass (kg)	Heart Rate (beats per min)
white rat	0.15	350
dog	12.0	100
human	70.0	72
elephant	4000	30

Notice that the data contain three categories:

- type of animal
- mass of animal
- heart rate of animal.

The number of categories tells you how many columns you need in your table.

There is a complete set of data for each of four animals. The number of sets of data tells you how many rows you will need in your table. You need one row for each set of data and one row for headings for each column. As well, you should always give your table a title.

Tips for Drawing Data Tables

1. Use a ruler to draw your table.
2. Print all letters and words so they will be easy to read.
3. Express numbers in your data as numerals (for example, 1, 2, 3) not as words (one, two, three).
4. Give the table a title. If there are small numbers in the title, you can express them in words. The variables in the observations or experiments can become the title of your data table. For example, "The Effects of Light on Plant Growth."
5. Your table has the shape of a box. Place the title outside the box.
6. Print headings neatly at the top of each column. Include units for the data with the headings, not in the columns.
7. Draw a line separating the headings from the data.
8. Record the data in the columns below the headings.
9. Separate the columns of data with lines.

Instant Practice

Draw a table from the data in the following paragraph.

A serving of cooked pasta has about 15 g of carbohydrate, 3 g of protein, and no fat. A serving of beef has no carbohydrate, 7 g of protein, and about 5 g of fat. A serving of bananas has 15 g of carbohydrate, no protein, and no fat. A serving of milk has 12 g of carbohydrate, 8 g of protein, and 3 g of fat. A serving of tomatoes has 5 g of carbohydrate, 2 g of protein, and no fat.

Graphing

A **graph** is often a line or curve that shows how one quantity depends on changes in another quantity. A graph is a good way to display data so that you can see patterns and relationships among variables.

Graphing Terms to Know

x- and y- axes: The *x*-axis is the horizontal line on a graph. The independent/manipulated variable is placed on the *x*-axis. The *y*-axis is the vertical line on a graph. The dependent/responding variable is placed on the *y*-axis.

Origin: The point at which the x and y axes meet. The origin is often, but not always, the point on a graph at which x and y are equal to zero.

Plotting: Drawing a point or line on a graph that represents data.

Scale of numbers: Equal divisions marked on the x and y axes so that they can be used for measuring. The magnitude (size) of the numbers on a scale must increase as you move away from the origin. As you go to the right or upward, the numbers become increasingly positive. As you go left or downward, the numbers become increasingly negative.

Interval: The value of the divisions between units marked on a scale (for example, 0, 1, 2, 3, … or 0, 5, 10, 15, …). The interval between the numbers on the scale must be equal in size.

Range: The difference between the largest and smallest of a series of numbers.

Key: (Legend): A small table that explains or identifies symbols on a graph. The legend should be placed close to the graph.

Example

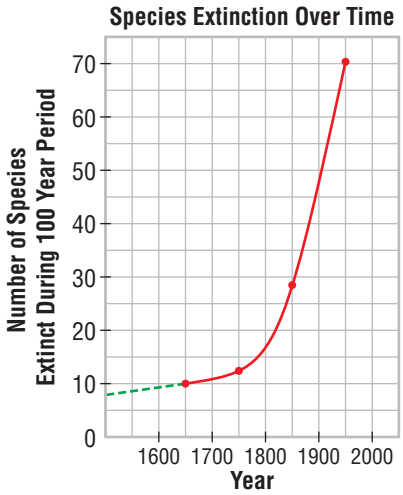
The following data table gives the number of species that became extinct during each 100 year period between 1600 and 1900. To learn how to draw a line graph from the data, examine the graph as you read the steps.

Table 2 Species Extinction Over Time

Year	Species Extinct During Century
1600 – 1700	10
1700 – 1800	11
1800 – 1900	28
1900 – 2000	70

Drawing a Line Graph

You can use a line graph whenever the data you collect depend on each other. Line graphs make it easy to see relationships between two quantities. You can use a line graph to predict values that are not even on the graph.



1. With a ruler and pencil, draw an x-axis and a y-axis on a piece of graph paper.
2. Label the axes. Write the years along the x-axis and "Number of Species Extinct During 100 Year Period" along the y-axis.
3. Decide on a number scale to use. Your x-axis will have four intervals of 100 years each. Your y-axis will go from 10 to 70. You can start at zero and end at a number above 70. Use a tick mark at major intervals on your scale.
4. Go to the point representing the middle of the century 1600 to 1700. Now move up until you are at a point that represents 10 species. Make a dot at this point. Repeat this procedure for all data points on the table.
5. Do not simply connect the data points when you draw a line graph. Experimental data points usually have some error. If the points are almost in a straight line, draw a straight line as close to most of the points as possible. There should be about as many points above the line as there are below the line. This line is called a **line of best fit.** If the data points do not appear to follow a straight line, then draw a smooth curve that comes as close to the points as possible. A line of best fit shows the trend of the data. It can be extended beyond the first and last points.
6. Give your graph a title.

Interpolation and Extrapolation

Often, scientists need to know the value of a variable at a point that was not measured. For example, you can use the shape of the graph to predict the number of species that were extinct in the year 1550. Notice that this year is not in the range of the measurements that were taken. It is beyond the range of the data.

Extrapolation is a way to approximate values that are beyond (outside of) the range of the data. Look at the graph again. The part of the line that is in green is an extrapolation of the data. Based on this extrapolation, predict how many species were extinct in the year 1550. What about the year 1500? How accurate do you think your predictions are?

What if, on the other hand, you wanted to predict the number of species that were extinct in the year 1700. This year is inside the range of the data.

Interpolation is a way to approximate values that are between points of a graph (inside the range of values). Predict how many species were extinct in the year 1700. What about the year 1800? How does the accuracy of your interpolated predictions compare with the accuracy of your extrapolated predictions?

Drawing a Bar Graph

A bar graph helps you to compare the number of items in one category with the number of items in other categories. The height of the bar represents the number of items in the category. Study the example in the next column, and then make your own bar graph.

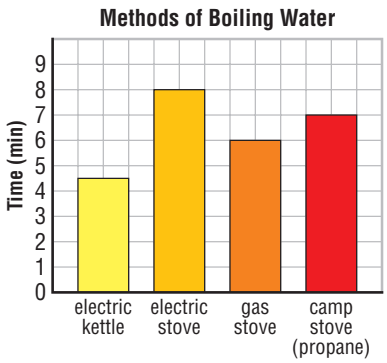
Example

Make a bar graph from the data in the table at the top of the next column. Use only the data on time in the second column. Do not graph the data (Cost) in the third column. As you read the steps, examine the completed graph on the right to see how the steps were followed.

Table 3 Time and Cost to Boil 900 mL of Water

Method	Time (min)	Cost (cents)
electric kettle	4.5	0.71
electric stove	8.0	1.25
gas stove	6.0	0.32
camp stove	7.0	11.1

1. Draw an *x*-axis and a *y*-axis on a sheet of graph paper. Label the *x*-axis with the names of the heating methods. Label the *y*-axis with the title "Time (min)." (See the bar graph below.)
2. Look at the data carefully in order to select an appropriate scale. The range of the data is between 4.5 min and 7.0 min. You can number the scale from 0 to 9. Write the numbers on your *y*-axis scale.
3. Decide on a width for the bars in the graph. They should be large and easy to read.
4. Mark the width of the bars on the *x*-axis. Leave the same amount of space between each bar.
5. To draw the bar for the electric kettle, go to the centre of the bar on the *x*-axis, then go up until you are halfway between 4 and 5. Make a mark to represent 4.5 min. Use a pencil and a ruler to draw in the first bar.
6. Repeat the procedure for the other heating methods.
7. When you have drawn all the bars, colour them so that each one is different. If you are comparing two or more independent/manipulated variables that you have plotted on the *x*-axis, you will need to make a legend or key to explain the meanings of each bar.
8. Give your graph a title.



Instant Practice

A science teacher asked her students what kind of pet they had or would like to have. She planned to have her students research the proper care and feeding of each pet. The responses are shown in the following table. Make a bar graph using the data.

Table 4 Pets Chosen by Students

Pet	Number of students choosing pet
cat	16
gerbil	11
hamster	13
goldfish	3
mouse	7
guinea pig	10
dog	14
hedgehog	10

Constructing a Histogram

The graph on the right is called a histogram. It is another type of bar graph. Notice that there is no space between the bars in a histogram but there is space between the bars in a bar graph. The reason for the space is that each bar represents a different item.

In a histogram, the *x*-axis represents one continuous item, divided into size categories. In the histogram, notice that the *x*-axis represents temperature, divided into two-degree categories. Thus, the *x*-axis is quantitative, meaning that it contains numerical values. In a typical bar graph, the *x*-axis is qualitative and cannot be described with numbers.

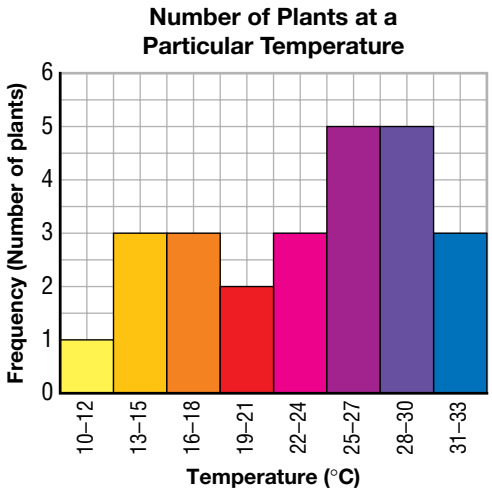
Example

A group of students conducted a test on plant growth. They placed plants in rooms with different temperature ranges and observed the effects on the plants. Table 5, called a frequency table, shows how many plants were placed in each location. As you read the steps, examine the completed histogram below.

Table 5 Temperature of Rooms

Temperature (°C)	Frequency (number of plants)
10–12	1
13–15	3
16–18	3
19–21	2
22–24	3
25–27	5
28–30	5
31–33	3

1. On a piece of graph paper, draw an *x*-axis and a *y*-axis. Label the *x*-axis "Temperature (°C)" and the *y*-axis, "Frequency (number of plants)."
2. Separate the *x*-axis into eight equal segments. Label the segments using the temperatures listed in the frequency table.
3. Make a scale on the *y*-axis that goes to 6.
4. Move your pencil up the *y*-axis to 1, and make a light mark. Then, using a ruler, make a bar that is the width of the 10–12°C temperature range.
5. Repeat this procedure for each temperature range and corresponding number of plants.



Designing and Conducting Experiments

A useful experiment usually starts with an observation. The observation might be as simple as watching a child on a playground swing such as the one shown below.

A swing has a rhythmic motion.

Observing and Inferring

If your observation can lead to the development of an experiment, you must be able to ask a question that can be answered by a scientific investigation. You might ask, "What features of a playground swing or any other swinging object determine the rhythm of the swinging motion?" To answer the question, you might think back to when you were younger. You knew that you could make a swing go higher, but it always seemed to swing back and forth at the same rate. You have narrowed the question down to what determines the rate at which a swinging object goes back and forth. You have *inferred* that some characteristic of a swinging object determines the rhythm. You could compare a child on a swing to some other previous experience. Maybe you bumped into a hanging planter at home and watched it swing. It seemed to swing faster than the child on the swing. The hanging planter is a shorter system than the child on the swing. You might infer that the length of the rope influences the rate of swinging. This is an idea that you can test by creating a model of a child on a swing. You can model a child on a swing by building a simple pendulum (see the photograph below).

Hypothesizing and Predicting

When you have developed a model, you can use it to formulate a hypothesis. You might think about the size of the mass at the end of the string on your pendulum. You might hypothesize that a heavier mass would swing faster. If this is the case, you could predict that a larger mass would cause the time for one complete swing to be shorter. The term that describes the length of time for the pendulum to swing from one end to the other and back again is the *period*. You are nearly ready to carry out your experiment. First, you must identify all of the variables involved when a pendulum swings.

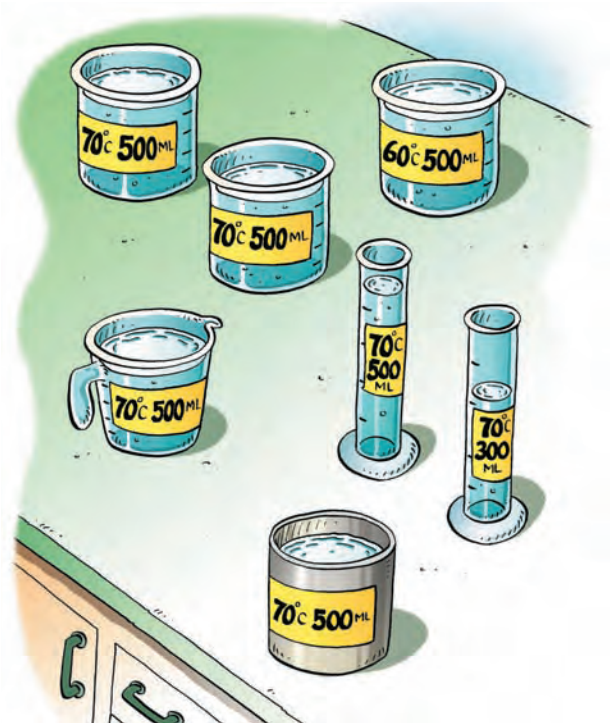
These students are modelling a child on a swing by setting up a pendulum.

Variables

A variable is anything that might affect the outcome of the experiment. The period of the pendulum is a variable. All of the other variables that might affect the period are:

- the mass of the pendulum bob (the object at the end of the string),
- the length of the string, and
- how far you pull the pendulum bob to one side before letting it go.

In order to carry out a fair test, you must test the effect of only one specific variable at a time. You must ensure that all the other variables do not change. Scientists say that you *control* the other variables. This is important because, if you changed both the mass of the bob and the length of the string and you observed a change in the period, you would not know whether the change in the mass or in the length of the string caused the period to change. Study the figure below and see if you can identify the variables in another experiment.

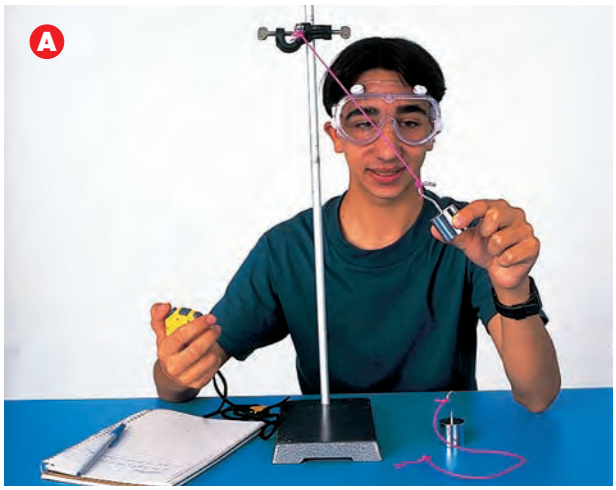


Examine the containers of water. Assume that you want to know what factors affect the length of time it takes for water to evaporate. How many variables can you find in the figure? What are those variables? How would you test each variable individually?

Independent, Dependent, and Controlled Variables

The variable that you choose to test is called the manipulated or **independent variable.** You can remember which variable is the independent variable by remembering, "**I** choose to test the **I**ndependent variable." You can select which independent variable that you will test. The responding or **dependent variable** is the one that you observe to see if it has been affected by the changes to the independent variable. All of the other variables that you are not testing are **controlled variables.** They remain the same while you change the conditions of the independent variable. These concepts will become clear as you study the pictures of the student in the photographs.

In part (A) of the pendulum experiment, the length of the string is the independent/manipulated variable.

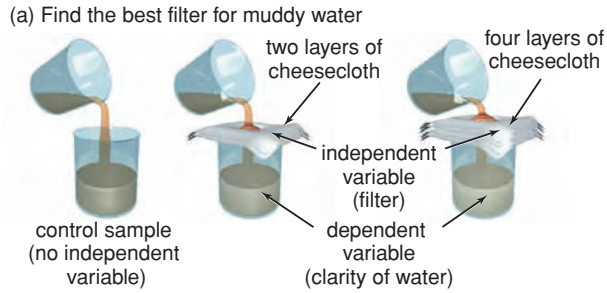


The student is testing two different lengths to see how they affect the period of the pendulum. He will start the stopwatch when he releases the pendulum bob and measure the time for one period. In this case, time is the dependent/responding variable. Notice that the student is using the same mass and he is holding the mass the same distance from the central position. These are the controlled variables.

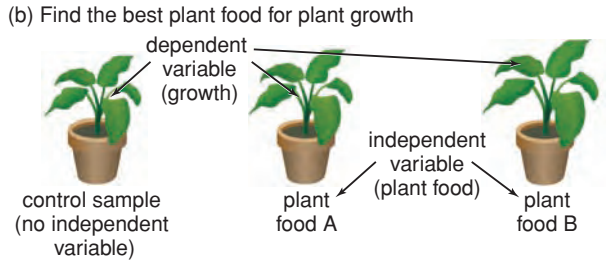
In part (B) of the pendulum experiment, the mass is the independent/manipulated variable. Notice that the length of the string is the same in both cases. The length of the string is now a controlled variable.

Control Sample

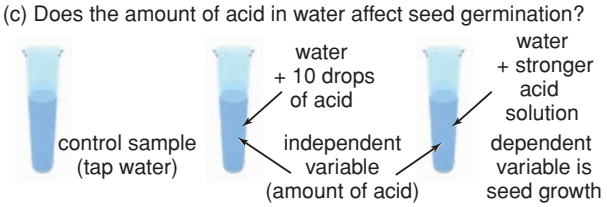
In many experiments, you need to have a control sample in which there is no independent/manipulated variable at all. Examine the figures below to understand when you need to have a control sample.



(a) If you compared only the two filters, you would not know whether the filters were doing anything at all. You need to compare both filters to the case in which there is no filter. The sample with no filter is the control sample.



(b) If you tested only the two plant foods and plant (B) grew taller than plant (A), you would not know if plant food A had any effect at all. You need to compare both plants with plant food to a third plant that received no plant food.



(c) To fully understand the effect of acid on seed germination, you have to compare the effect of two acid strengths to a control sample with water only and no acid.

Recording Data

Before you conduct an experiment, be sure that you know what tests you are going to perform and what measurements you will take. Prepare tables for your data before you start your experiment. Also, list values of the controlled variables with each data table. If you were going to do the pendulum experiment, you might make a table such as the one on the right. Note that the controlled variables are listed on the bottom row. Now you are ready to conduct your experiment.

Mass of Pendulum Bob		Length of string		Angle between string and vertical support	
Mass (g)	Average Period (s)	Length (cm)	Average Period (s)	Angle (˚)	Average Period (s)
25		50		5	
50		100		10	
75		150		15	
100		200		20	
Values of Controlled Variables					
Length constant at 100 cm Angle constant at 10˚		Mass constant at 50 g Angle constant at 10˚		Length constant at 100 cm Mass constant at 50 g	

After you have set up your apparatus and received your teacher's permission, you can begin to collect data. Taking one measurement is never enough. It is too easy to make an error in measurements. You need to take at least four measurements for each value of the independent/manipulated variable. You can then calculate an average value. Write your average value in the table.

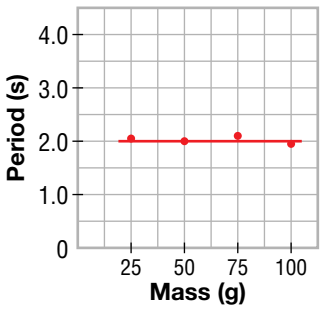
Often, it is easier to interpret your results if you graph your data. Your pendulum results might look like those in the table and graphs below. Because there is always some error in the data, the points will not lie on a smooth line. Therefore, draw a smooth line or curve close to the points.

Mass of Pendulum Bob	
Mass (g)	Average Period (s)
25	2.1
50	2.0
75	2.2
100	1.9
Length constant at 100 cm Angle constant at 10˚	

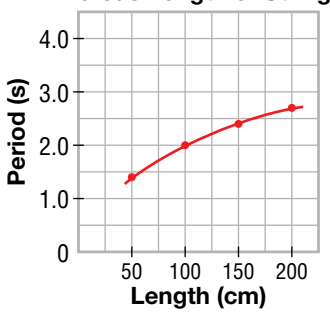
Length of string	
Length (cm)	Average Period (s)
50	1.4
100	2.0
150	2.4
200	2.7
Mass constant at 50 g Angle constant at 10˚	

Angle between string and vertical support	
Angle (˚)	Average Period (s)
5	2.1
10	1.9
15	2.2
20	2.0
Length constant at 100 cm Mass constant at 50 g	

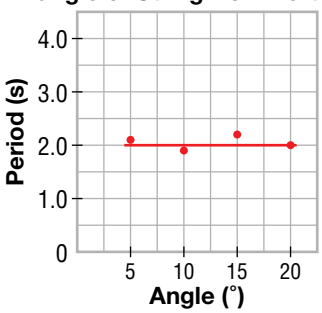
Period of Pendulum versus Mass of Pendulum Bob



Period of Pendulum versus Length of String



Period of Pendulum versus angle of String from Vertical



Summarize Results

Always write a summary of your results in a descriptive paragraph. Your summary of the pendulum experiment might be similar to this.

> When the mass of the pendulum bob was changed, the period stayed the same. When the length of the string was changed, the period changed. When the string was made longer, the period became longer. When the angle between the string and the vertical support stand was changed, the period stayed the same.

Conclusion

Finally, you will write a conclusion statement. Your conclusion will explain the meaning of the results. If your experiment was based on a hypothesis, your conclusion should state whether the results supported your hypothesis. Imagine that your hypothesis for the pendulum experiment had been:

> "A larger mass will make the pendulum swing faster than a smaller mass will make it swing. Therefore, the period of the pendulum will be shorter for larger masses."

Your conclusion statement would have to say that the results did not support your hypothesis. Your conclusion statement might read like this:

> "The results did not support the hypothesis that a large mass will produce a shorter period than will a small mass. Mass had no effect on the period of the pendulum. The angle between the string and the vertical support stand also had no effect on the period. The length of the string was the only variable that affected the period of the pendulum. As the string was made longer, the period of the pendulum swing also became longer."

Should you consider an experiment to be a failure if the results did not support your hypothesis? No! Your recorded data is valid. You demonstrated that the mass of the pendulum bob and the angle between the string and the support stand had no effect on the period. That information is just as important as the conclusion that the length of the string *did* determine the period of the pendulum.

Instant Practice

How could you design an experiment to test the question, "What effect does the size of the hole in tubing have on the rate at which water flows through the tube?" or "What factors affect the amount of sugar that will completely dissolve in water?" When you design your experiment, be sure to answer the following questions.

1. What are all of the possible variables that could affect your results?
2. What is your independent/manipulated variable?
3. What is your dependent/responding variable?
4. What are the controlled variables for this experiment?
5. How are you going to ensure that all of the controlled variables are held constant?
6. Do you need a control sample? If so, what will your control sample be?
7. What will be the form of the data that you are recording?
8. What will you need to put in your data table?
9. Will you need to graph the data? If so, what type of graph will you choose?

Plan your experiment and obtain your teacher's approval before conducting your experiment. **Note:** Be sure to include all necessary safety precautions.

Metric Conversion and SI Units

Throughout history, groups of people have developed their own units of measurement. When different groups of people began to communicate, they became confused because they did not understand each other's units of measurement. For example, imagine trying to report your weight in scruples or buying a "hogshead" of strawberries! For consistency, scientists throughout the world have agreed to use the metric system of units of measurement.

The Metric System

The **metric system** is based on multiples of ten. The basic unit of length is the metre. All larger units of length are expressed in units based on metres multiplied by 10, 100, 1000, or more. Smaller units of length are expressed in units based on metres divided by 10, 100, 1000, or more. A prefix (a part of a word joined to the beginning of another word) tells you what number to use when you multiply or divide. For example, *kilo-* means "multiplied by 1000." One kilometre is one metre multiplied by 1000. You can write this relationship mathematically as shown here.

$$1 \text{ km} = 1000 \text{ m}$$

The prefix *centi-* means "divided by 100." As shown below, one centimetre is one metre divided by 100.

$$1 \text{ cm} = \frac{1}{100} \text{ m} \quad \text{or} \quad 1 \text{ cm} = 0.01 \text{ m}$$

In the metric system, the same prefixes are used with nearly all units of measurement such as units of mass, weight, distance, and energy. The table on this page lists the most commonly used metric prefixes.

Commonly Used Metric Prefixes

Prefixes	Symbol	Relationship to the base unit
giga-	G	$10^9 = 1\,000\,000\,000$
mega-	M	$10^6 = 1\,000\,000$
kilo-	k	$10^3 = 1\,000$
hecto-	h	$10^2 = 100$
deca-	da	$10^1 = 10$
–	–	$10^0 = 1$
deci-	d	$10^{-1} = 0.1$
centi-	c	$10^{-2} = 0.01$
milli-	m	$10^{-3} = 0.001$
micro-	μ	$10^{-6} = 0.000\,001$
nano-	n	$10^{-9} = 0.000\,000\,001$

(**Note:** Time does not have a metric form of measure. Time is measured in seconds, minutes, and hours. There are 60 s in 1 min, 60 min in 1 h, and 24 h in 1 d.)

The following examples show you how to convert from one metric unit to another.

Problem Tip

When you are solving problems and you have the same unit in the numerator and in the denominator, you can cancel the units. Notice how the units are cancelled in the following examples.

Example 1

The length of Canada's longest river, the Mackenzie River, is 4241 km. Convert the length of the river from kilometres to metres.

Solution

$$4241 \text{ km} = ____ \text{ m}$$

$$1 \text{ km} = 1000 \text{ m}$$

$$(4241\ \cancel{\text{km}})\left(\frac{1000 \text{ m}}{\cancel{\text{km}}}\right) = \frac{4241\ \cancel{\text{km}} \times 1000 \text{ m}}{\cancel{\text{km}}}$$

$$4241 \text{ km} = 4\,241\,000 \text{ m}$$

Example 2

There are 250 g of rice in a package. Express this mass in kilograms.

Solution

$$250\ \text{g} = \square\ \text{kg}$$

$$1000\ \text{g} = 1\ \text{kg}$$

$$(250\ \cancel{\text{g}})\left(\frac{1\ \text{kg}}{1000\ \cancel{\text{g}}}\right) = \frac{250\ \cancel{\text{g}} \times 1\ \text{kg}}{1000\ \cancel{\text{g}}}$$

$$250\ \text{g} = 0.250\ \text{kg}$$

Quantities Described by More Than One Term

Mass

One quantity for which you will need to learn more than one unit of measurement is mass. To report an amount of mass, you would usually use the unit of grams with a prefix. For example, one thousand grams is a kilogram (kg). A special unit has been given to one thousand kilograms. That unit is the tonne (t). A tonne is defined as one thousand kilograms. When working with very large amounts of mass, many people prefer to use units of tonnes instead of grams. The relationships are summarized here.

$$1\ 000\ 000\ \text{g} = 1000\ \text{kg} = 1\ \text{t}$$

Area

You can also express large areas in two different units of measurement. The basic unit of area is the square metre (m^2). For example, a square with sides of 1 m has an area of 1 m × 1 m = 1 m^2. Ten thousand square metres is given the unit hectare (ha). You usually use the hectare to describe areas of land. You can write the relationship between square metres and hectares as shown here.

$$10\ 000\ \text{m}^2 = 1\ \text{ha}$$

Volume

You can express volume in cubic metres (m^3). For example, a cube that is 1 m long, 1 m wide, and 1 m high has a volume of 1 m × 1 m × 1 m = 1 m^3. When you are working with fluids, however, you usually express the volume in units of litres (L) or millilitres (mL). One millilitre has the same volume as one cubic centimetre (cm^3). One litre is one thousand millilitres.

Some important relationships are listed below. Notice that one litre is NOT equivalent to a cubic metre. There are one thousand litres in a cubic metre.

$$1\ \text{cm}^3 = 1\ \text{mL}$$

$$1000\ \text{mL} = 1\ \text{L}$$

$$1000\ \text{L} = 1\ \text{m}^3$$

Metric Unit Conversions Involving Squares or Cubes

When you are converting units of area and volume, you must be very careful when you determine the number of square or cubic units that are equal to each other. For example, one hundred square centimetres is not equal to one square metre. The following examples show you how to calculate the correct relationships.

Example 1

Convert 125 cm^2 into m^2.

Solution

$$125\ \text{cm}^2 = \square\ \text{m}^2$$

$$100\ \text{cm} = 1\ \text{m}$$

$$(100\ \text{cm})^2 = (1\ \text{m})^2$$

$$100^2\ \text{cm}^2 = 1^2\ \text{m}^2$$

$$10\ 000\ \text{cm}^2 = 1\ \text{m}^2$$

$$(125\ \cancel{\text{cm}^2})\left(\frac{1\ \text{m}^2}{10\ 000\ \cancel{\text{cm}^2}}\right) = \frac{125\ \cancel{\text{cm}^2} \times 1\ \text{m}^2}{10\ 000\ \cancel{\text{cm}^2}}$$

$$125\ \text{cm}^2 = 0.0125\ \text{m}^2$$

Example 2

Convert 3.5 m^3 into cm^3.

Solution

$$3.5\ \text{m}^3 = \square\ \text{cm}^3$$

$$1\ \text{m} = 100\ \text{cm}$$

$$(1\ \text{m})^3 = (100\ \text{cm})^3$$

$$1^3\ \text{m}^3 = 100^3\ \text{cm}^3$$

$$1\ \text{m}^3 = 1\ 000\ 000\ \text{cm}^3$$

$$(3.5\ \cancel{\text{m}^3})\left(\frac{1\ 000\ 000\ \text{cm}^3}{1\ \cancel{\text{m}^3}}\right) = \frac{3.5\ \cancel{\text{m}^3} \times 1\ 000\ 000\ \text{cm}^3}{1\ \cancel{\text{m}^3}}$$

$$3.5\ \text{m}^3 = 3\ 500\ 000\ \text{cm}^3$$

Use the table of prefixes on the previous page and the relationships discussed above to solve the following Instant Practice problems.

Instant Practice

1. A can contains 0.355 L of pop. How many millilitres does the can contain?
2. The height of a table is 0.75 m. How high is the table in centimetres?
3. A package of chocolate-chip cookies has a mass of 396 g. What is the mass of the cookies in milligrams?
4. One cup of water contains 250 mL. What is the volume of one cup of water in litres?
5. The distance from your kitchen to the front door is 6000 mm. How far is the front door in metres?
6. A student added 0.0025 L of lemon juice to water. How much lemon juice did the student add in millilitres?
7. A jug contains 1525 cm^3 of water. What is the volume of the water in units of m^3?

SI Units

Even when scientists began to use the metric system, some confusion still arose. Some scientists would report distance or length in centimetres while others used metres. As well, some scientists reported mass in grams while others reported it in kilograms. Finally, scientists gathered at an international conference in Paris and agreed upon a specific set of units for communicating with other scientists. In 1960, the SI system of units was accepted worldwide. The name SI is taken from the French name *Le Système International d'unités.*

There are seven base units in the SI system. Many other units consist of a combination of base units. These units are called *derived* units, which you will learn about in later science courses. You will use the following base units in this course.

Base Units:

- The SI unit of mass is the kilogram (kg).
- The SI unit of distance is the metre (m).
- The SI unit of time is the second (s).

(**Note:** There are no metric units for time. However, the second (s) is an SI unit.)

When solving problems, you should always report your answers in SI units unless the problem requires a different type of unit. Study the examples below. Then complete the Instant Practice problems that follow.

Example 1

Convert 426 cm to the SI unit for length.

Solution

$$\text{SI unit} = \text{m}$$
$$426\ \text{cm} = \boxed{}\ \text{m}$$
$$100\ \text{cm} = 1\ \text{m}$$
$$(426\ \cancel{\text{cm}})\left(\frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right) = \frac{426\ \cancel{\text{cm}} \times 1\ \text{m}}{100\ \cancel{\text{cm}}}$$
$$426\ \text{cm} = 4.26\ \text{m}$$

Example 2

Convert 1.7 h into SI units.

Solution

$$\text{SI unit} = \text{s}$$
$$1.7\ \text{h} = \boxed{}\ \text{s}$$
$$1\ \text{h} = 60\ \text{min}$$
$$1\ \text{min} = 60\ \text{s}$$
$$(1.7\ \cancel{\text{h}})\left(\frac{60\ \cancel{\text{min}}}{\cancel{\text{h}}}\right)\left(\frac{60\ \text{s}}{\cancel{\text{min}}}\right) = \frac{1.7\ \cancel{\text{h}} \times 60\ \cancel{\text{min}} \times 60\ \text{s}}{\cancel{\text{h}} \times \cancel{\text{min}}}$$
$$1.7\ \text{h} = 6120\ \text{s}$$

Instant Practice

Convert the following quantities to the SI base unit.

1. 7.02 g
2. 32 min
3. 8.13 km
4. 25 961 mm
5. 223 625 cm
6. 3.25 h

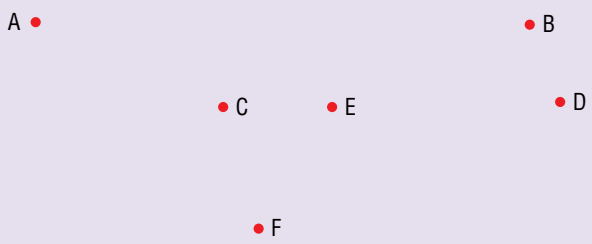
Measurement

Measuring Length

You can use a metre stick or a ruler to measure short distances. Metre sticks and rulers are usually marked off in millimetres and centimetres. To measure a distance, place the zero mark of the metre stick or ruler at one end of the distance to be measured and read the length at the other. Notice that the zero point is usually *not* at the end of the ruler.

Instant Practice

Use a ruler to measure the distance between the following pairs of points: A and D; C and E; B and F.



Measuring Area

Area is the amount of the surface of an object. You might want to determine the area of a piece of paper, a wall, or the surface area of a cube. If the area of an object is made up of common geometric shapes, you can measure the dimensions of the shape and use mathematical formulas to calculate the area. A piece of paper, for example, is often rectangular. You would measure the length and the width and then use this formula to calculate the area of the paper:

$A = l \times w$ (area = length × width)

Note: When you are making calculations, always be sure to use the same units of measurement. If you mix centimeters and metres, your calculations will be incorrect.

Instant Practice

Imagine that you are in charge of an art project that will transform one wall of your classroom into a large mural to show a variety of patterns. You may use as many different patterns and materials as you like. However, each piece must be a 30 cm × 30 cm square. How many squares will you need to make your mural?

1. Choose the unit of measurement that will be most practical for the area of the mural.
2. Measure the height and width of the wall you will cover.
3. Calculate the area of the wall in the unit you have chosen.
4. Calculate the number of 30 cm × 30 cm squares to fill one square unit. For example, if you chose metres, the square unit would be square metres (m^2).
5. Multiply this number by the area of the wall in the square unit that you chose.

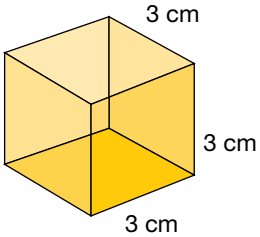
These students are using 10 cm × 10 cm squares. You are using 30 cm × 30 cm squares.

Measuring Volume

The **volume** of an object is the amount of space it occupies or the empty space in a hollow object. If an object is made up of common geometric shapes, you can measure the dimensions of the object and use mathematical formulas to calculate the volume:

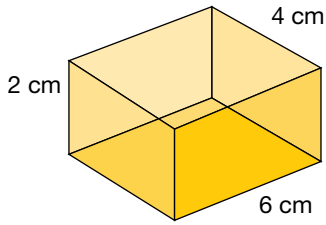
$V = l \times w \times h$

$V = 3\text{ cm} \times 3\text{ cm} \times 3\text{ cm}$
$= 27\text{ cm}^3$

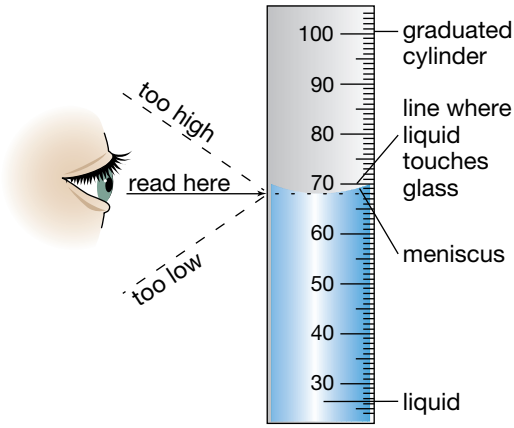


$V = l \times w \times h$

$V = 6\text{ cm} \times 4\text{ cm} \times 2\text{ cm}$
$= 48\text{ cm}^3$



The volume of fluids is usually expressed in litres or millilitres. You can measure the volume of a liquid directly by using a graduated cylinder as shown below. To measure accurately, be sure that your eye is level with the *bottom* of the meniscus. The meniscus is the curved surface of the liquid, as shown below.

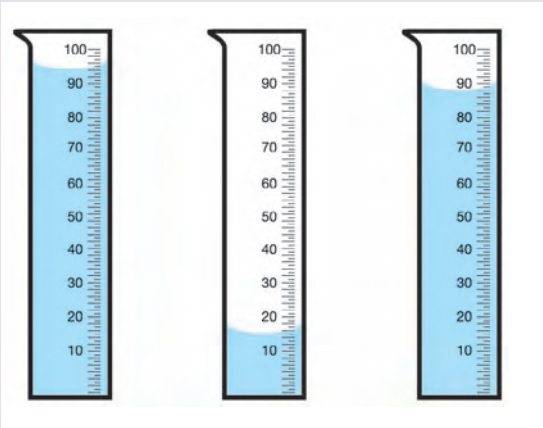


You can use liquids to help you measure the volume of an irregularly shaped solid. You would first measure a volume of a liquid such as water (Photo 1). Then, carefully slide the object into the water (Photo 2). Determine the total volume in the cylinder (Photo 3). The volume of the solid is equal to the difference between the volume before and after adding the solid.

$$\text{Volume of object} = \text{volume of water with solid} - \text{volume of water only}$$

Instant Practice

1. Read each volume shown below.



Measuring Mass

The **mass** of an object is the amount of matter that makes up the object. Mass is usually measured in milligrams, grams, kilograms, or tonnes. A balance is used for measuring mass. Your school might have triple beam balances like the one shown here. To measure the mass of a solid using a triple beam balance, follow these steps:

1. Set the balance to zero by sliding all three riders back to their zero points. Use the adjusting screw to be sure that the pointer rests at the zero point at the far end of the balance.

2. Place the object on the pan of the balance. The pointer will move up.
3. Slide the largest rider along until the pointer is just below zero. Then move the rider back one notch.
4. Repeat step 3 with the middle rider.
5. Adjust the smallest rider until the pointer swings equally above and below zero.
6. Add the readings on the three scales to find the mass.

To measure the mass of a powdery solid such as sugar, start by measuring the mass of an empty beaker. Next, pour the solid into the beaker. Then measure the mass of the beaker and solid together. To find the mass of the solid, subtract the mass of the empty beaker from the mass of the solid and beaker.

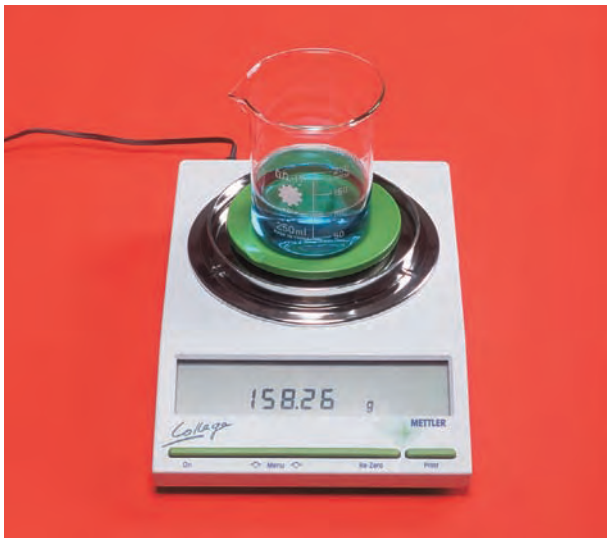
$$\text{Mass of sugar} = \text{Mass of sugar and beaker} - \text{Mass of empty beaker}$$

Instant Practice

1. Which takes more "muscle" to carry, your favourite paperback book or a calculator? Find out by using a balance to compare their masses.
2. Write the steps you would take to find the mass of the contents of a glass of juice.

The mass of the empty beaker is 61.5 g.

The mass of the sugar and beaker together is 161.5 g. The mass of the sugar equals the mass of the sugar and beaker together minus the mass of the beaker: 161.5 g − 61.5 g = 100 g.



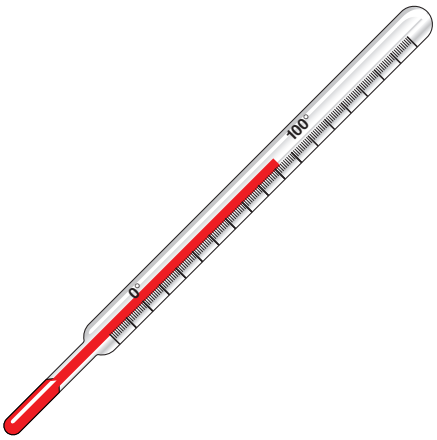
In advanced science courses, you might use an electronic balance like this. Just place the object on the pan and read the mass.

Measuring Temperature

Temperature is a measure of the average energy of motion of the particles in a substance. You can measure the temperature of a material by using a thermometer. You usually express the temperature of a substance in degrees Celsius. Zero degrees Celsius (0°C) is the freezing point of water. One hundred degrees Celsius (100°C) is the boiling point of water. The SI unit of temperature is the kelvin (K). Zero kelvins (0 K) is the coldest possible temperature. It is also called absolute zero. 0 K is equal to −273°C.

When using a thermometer to measure temperature, remember these three important tips.

- Handle the thermometer extremely carefully. It is made of glass and can break easily.
- Do not use the thermometer as a stirring rod.
- Do not let the bulb of the thermometer touch the walls of the container.



In school laboratories, you will probably use a thermometer like this one. The temperature scale is in degrees Celsius.

Instant Practice

Your teacher will supply your class with three large containers of water, each at a different temperature.

1. Twelve students will each be provided with a thermometer. When your teacher says "now," the students will take temperature readings of the water in the different containers. Four students will be asked to take a temperature reading of the water in one container. Four others will take the temperature reading of the water in the second container, and four others will take a reading of the water in the third container. Each student should keep the temperature reading a secret until putting it on a class chart.
2. Make a class chart on the chalkboard to record each of the students' temperature readings. The three columns will be:

Container 1	**Container 2**	**Container 3**
Temperature Reading (°C)	Temperature Reading (°C)	Temperature Reading (°C)

3. Each student will record the temperature reading of the water in the container used.
4. Did each person record the same temperature reading of the water in the same container? If the temperature readings were not all the same, explain why you think this might be so.

A digital thermometer like this one can be used to take your temperature.

Qualitative and Quantitative Observations

The rain has stopped and the Sun is out. You notice that a puddle has disappeared from the sidewalk. What happened to that puddle of water that was here a while ago? You could probably quickly answer that question, but how would you check the validity of your answer? You would start where all science starts: by making observations.

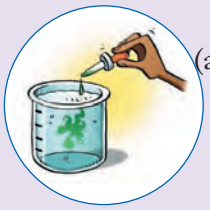
First, you might observe what happens to some other puddles. You would watch them closely until they disappeared and record what you observed. One observation you might make is, "The puddle is almost all gone." If you did, you would be making a **qualitative observation,** an observation in which numbers are not used. A little later, you might also say, "It took five hours for the puddle to disappear completely." You have made a **quantitative observation,** an observation that uses numbers.

Beginning your observations of water puddles

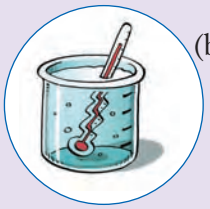
Concluding your observations of water puddles

Instant Practice—Making Qualitative and Quantitative Observations

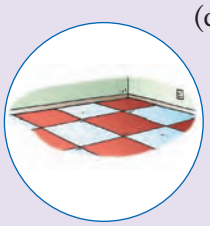
In your notebook, copy the observations below. Beside each, write "Qual" if you think it is a qualitative observation and "Quan" if you think it is a quantitative observation.



(a) Food colouring made the water blue.
Adding 3 mL of food colouring turned 250 mL of water blue.

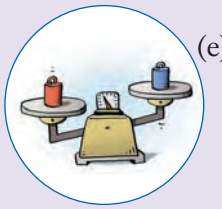


(b) The water became warmer.
The water's temperature increased by 5°C.



(c) We needed just over a dozen floor tiles for our model room.
We needed 14 floor tiles for our model room.

(d) The liquid boiled in 5 min.
The liquid took only a few minutes to boil.



(e) The mass of this solid is 5 g more than that one.
This solid is heavier than that one.

(f) He drinks eight glasses of water each day.
He drinks 2 L of water each day.

Communicating Your Lab Work in a Lab Report

What if a scientist made a new and important discovery but didn't tell anyone? The discovery would do no good at all, because it would not be communicated to the scientific community. To communicate their discoveries, scientists submit papers to scientific journals where they are published. Then other scientists can verify the results and use the results for further experiments of their own. Your lab reports are similar to scientific papers. The sample report below shows you how you can use the headings in the Investigations to help you organize and write your report.

Give your report a title and write it at the top of the page.

Write the question or questions that you were trying to answer in the investigation. Use complete sentences to write the questions.

Make a hypothesis and write it out in a full sentence. In some investigations, you might have a prediction instead of a hypothesis. Your hypothesis or prediction should be something that can be verified or disproved. It also should be related directly to the question. If the investigation includes independent and dependent variables, the hypothesis should indicate a relationship between these variables.

Make a list of all of the materials that you used. This list includes all of the pieces of laboratory apparatus that are used over and over. It also includes chemicals and other materials that will be discarded at the end of the investigation. If specific quantities of the chemicals were used, include the amounts.

Write out every step in the procedure very clearly. Include safety precautions. Notice that most of the procedure steps start with an action word such as "put" or "prepare." These steps should be written in a way that another person could follow them and repeat the investigation. If diagrams are needed to show how different pieces of apparatus fit together, include a diagram.

If you collected data, include the data in a table. If you made a graph from your data, include the graph. Remember that you only include the data in this section. Save your analysis and conclusions for the later sections.

Acids and Bases in the Home

Question

Can you predict whether a household liquid will be an acid or base depending on its use?

Hypothesis

It is not possible to predict whether a household liquid is an acid or base.

Materials

8 test tubes	dilute acid
test tube rack	dilute base
glass stirring rod	vinegar
eye dropper	mayonnaise
labelling tape	liquid drain cleaner
paper towels	window cleaner
red litmus paper	cola soft drink
blue litmus paper	liquid laundry soap
water	

Procedure

CAUTION: Do not let any of the liquids get on your skin. If it does, rinse your skin with a lot of water.

1. Prepare a data table with the following headings: Sample, Blue Litmus Paper, Red Litmus Paper. Make eight rows and write the name of sample in the first column. Record the data in the other columns.
2. Put the eight test tubes in the test tube rack. Label each test tube with tape by writing the name of each of the eight liquids in the materials list on the tape.
3. With the eye dropper, put about 1 mL of each liquid into each of the test tubes with the correct label. Rinse the eye dropper with water between each type of liquid.
4. Place eight small pieces of red litmus paper and eight small pieces of blue litmus paper on a paper towel.

5. Use the eye dropper to transfer one drop of the dilute acid to a piece of red litmus paper. Transfer another drop of dilute acid to a piece of blue litmus paper.
6. Record the final colour of each piece of litmus paper.
7. Rinse the eye dropper with water and dry it with some paper towel.
8. Repeat steps 4 through 6 for each of the other seven liquids.

Data Table		
Sample	Blue Litmus Paper	Red Litmus Paper
dilute acid	turned red	stayed red
dilute base	stayed blue	turned blue
vinegar	turned red	stayed red
mayonnaise	turned red	stayed red
liquid drain cleaner	stayed blue	turned blue
window cleaner	stayed blue	turned blue
cola soft drink	turned red	stayed red
liquid laundry soap	stayed blue	turned blue

In this section, you examine your data and look for connections between variables or other factors. The questions in the "Analyze" section of the Investigation will guide you through this section. Be sure to answer all of the questions in the "Analyze" section. If you made tables, you explain what these tables revealed. If you made graphs, you explain the meaning of the graphs.

Analyze

1. When acid was placed on red litmus paper, it stayed red. When acid was placed on blue litmus paper, it turned red.
2. When base was placed on red litmus paper, it turned blue. When base was placed on blue litmus paper, it stayed blue.
3. The following table shows the results for the household liquids.

Red litmus paper stayed red.	Red litmus paper turned blue.
Blue litmus paper turned red.	Blue litmus paper stayed blue.
vinegar	drain cleaner
mayonnaise	window cleaner
cola soft drink	liquid laundry soap

Finally, you compare your results with your hypothesis or prediction. You state whether your hypothesis or prediction was verified of disproved. In either case, you state any conclusions that your results revealed. Once again, the questions in the "Conclude and Apply" section in the Investigation will guide you in writing this section. Be sure to answer all of the questions. If your conclusions can be used in everyday life, state how they can be used.

Conclude and Apply

4. Acid turns blue litmus paper red but red litmus paper stays red.
5. Base turns red litmus paper blue but blue litmus paper stays blue.
6. Vinegar, mayonnaise, and cola soft drinks are acids.
7. Drain cleaner, window cleaner, and liquid laundry soap are bases.
8. The hypothesis is not correct. It is possible to predict whether a household liquid is an acid or base.

Common Laboratory Equipment

When you do scientific experiments at school, you often will use equipment that is found in science laboratories throughout the world. In your science class this year and in future years, you will develop skills and safe practices in the use of laboratory equipment. A selection of equipment that you will be using is presented below and on the two pages that follow. Your teacher will show you how to use laboratory equipment properly and safely.

Protective equipment: specially designed coverings to protect your eyes, hands, and clothing from chemicals and heat that could cause harm or stains that are difficult to remove. For example, safety glasses (1), heat resistant gloves (2), and lab coats (3). Special rubber gloves are used to protect hands/skin from contact with chemicals.

Equipment for measuring: includes balances, graduated cylinders, and thermometers

balance (4)*:* used to measure the mass of an object or sample of matter. A traditional balance works by balancing the mass of one thing against a known mass (as in an equal-arm or a triple-beam balance). Modern electronic balances, seen within photo below, measure and display mass directly.

graduated cylinder (5)*:* used to measure the volume of a liquid or a granulated solid (one that can be poured, such as salt or sugar). Graduated cylinders come in different sizes to hold volumes of liquid that range from 10 mL to 1000 mL. The scale is divided (graduated) more finely than the scale on a beaker, so volume measurements are more precise and accurate.

Equipment for observing objects: includes tools that have lenses

microscope (6)*:* used to magnify (make larger) objects up to 400 times their actual size. (High-tech microscopes can magnify objects up to millions of times their actual size.) Microscopes are useful for seeing details of extremely small items.

magnifying glass (7)*:* used to magnify objects within a limited range so that various features are easier to observe. Magnifying glasses are useful because they allow objects to appear much larger than they are.

Equipment for heating objects: includes hot plates and burners

hot plate (8)*:* used to heat liquids. Hot plates generate enough heat to boil water, but they do so without the

danger that is associated with flames from a burner. Hot plates are good for general heating of liquids in beakers or other flat-bottomed containers, but less useful for heating solids, or heating to very high temperatures. A Bunsen burner is the best choice in this situation.

Bunsen burner (9)*:* used to heat solids and liquids. Bunsen burners, like all burners, use fuel to produce an open flame, so extreme caution is necessary if they are to be used.

Glassware: includes beakers, test tubes, and flasks, and could be made of plastic instead of glass.

beaker (10)*:* used to hold, mix, and measure liquids. Beakers come in different sizes to hold volumes of liquid that range from 25 mL to 600 mL and more. For more precise and accurate measurements of the volume of liquids, you would use a graduated cylinder. It can also be used for heating substances or for mixing larger amounts of chemicals

test tube (11)*:* small tube that is closed at one end and used to hold samples of chemicals (usually liquids). The samples may be mixed with small amounts of other chemicals to observe possible changes. When heating substances in a test tube, make sure that the tube is made of material that will not break when heated.

flask: narrow-necked bottle with straight sides (Erlenmeyer flask, 12) or rounded sides (Florence flask, 13) used to hold, mix, and heat liquids. Only heat liquids within a flask that is approved to withstand heat.

Petri dish (14)*:* a clear, flat, round dish with a cover that can be used to hold small amounts of liquids or solids. (Petri dishes that contain a gelatin-like substance called agar can be used to grow bacteria, but this must be done under careful conditions.)

watch glass (15)*:* a concave disk that can be used as a cover (for a beaker, for instance) or to evaporate a small amount of liquid such as a solution.

stirring rod (16)*:* used to stir liquids and mixtures in beakers and flasks. Only use approved stirring rods to stir solutions.

Equipment for holding, supporting, containing, and transferring: includes stands, tongs, stoppers, and stationary holders

retort stand (17)*:* used, often along with a clamping device, to hold or support glassware so that chemicals can be heated or mixed and observed.

clamp (18)*:* a device that is usually attached to a stand to support or hold glassware such as a test tube, a flask, or a tube. A ring clamp is shown below. Other clamps are available for holding items in place. Remember to always put the clamp as low on the stand as possible to ensure the stand does not become top heavy.

tongs (19)*:* used to pour or move glassware such as test tubes or beakers. An example of test tube tongs appear in the photo below.

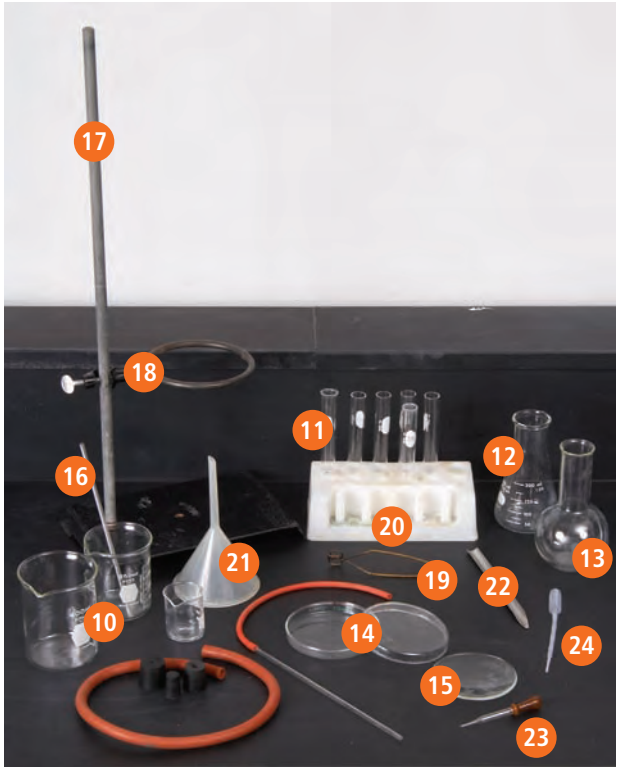
test tube rack (20)*:* used to hold one or more test tubes safely and securely, leaving your hands free for other tasks.

funnel (21): used to transfer liquids or granulated solids into containers that have small openings

scoopula (22)*:* used to transfer small amounts of solids to other equipment such as a test tube, beaker, flask, or watch glass. (You might also hear it referred to as a spatula scoop.) Remember to use a scoopula for transferring only one substance at a time to avoid cross contamination of chemicals.

eye dropper (23)*:* used to transfer very small volumes of liquid into other equipment. Some eye droppers are calibrated so that you can measure specific volumes ranging up to 1 mL. (You might also hear it referred to as a medicine dropper.)

pipette (24)*:* used to transfer small precise volumes of liquid from one container to another.



Using a Microscope

The light microscope is an optical instrument that greatly increases our powers of observation by magnifying objects that are usually too small to be seen with the unaided eye. It is called a compound light microscope because it uses a series of lenses (rather than only one as in a magnifying glass) and it uses light to view the object.

A microscope is a delicate instrument, so proper procedure and care must be practised. Before you use your microscope, review its parts and their functions.

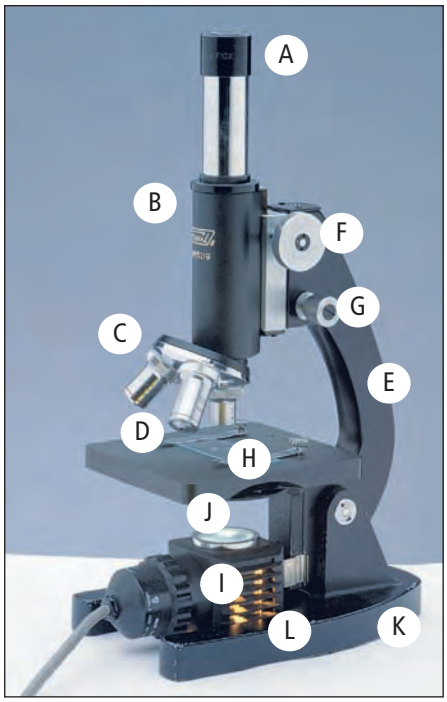
A. Eyepiece (or ocular lens)
You look through this part. It has a lens that magnifies the object, usually by 10 times (10×). The magnifying power is engraved on the side of the eyepiece.

B. Tube
Holds the eyepiece and the objective lenses at the proper working distance from each other.

C. Revolving nosepiece
Rotating disk holds two or more objective lenses. Turn it to change lenses. Each lens clicks into place.

D. Objective lenses
Magnify the object. Each lens has a different power of magnification, such as 4×, 10×, 40×. (Your microscope may instead have 10×, 40×, and 100× objective lenses.) For convenience, the objective lenses are referred to as low, medium, and high power. The magnifying power is engraved on the side of each objective lens.

E. Arm
Connects the base and the tube. Use the arm for carrying the microscope.



F. Coarse focus knob
Moves the tube up and down to bring the object into focus. Use it only with the low-power objective lens.

G. Fine focus knob
Use with medium- and high-power magnification to bring the object into sharper focus.

H. Stage
Supports the microscope slide. Stage clips hold the slide in position. An opening in the centre of the stage allows light from the light source to pass through the slide.

I. Condenser lens
Directs light to the object being viewed.

J. Diaphragm
Controls the amount of light reaching the object being viewed.

K. Base
Supports the whole microscope

L. Light source
Shining a light through the object being viewed makes it easier to see the details. Your microscope might have a mirror instead of a light. If it does, it must be adjusted to direct the light source through the lenses. CAUTION: Use an electric light, not sunlight, as the light source for focussing your mirror.

Using the Microscope

These are the basic steps for finding and viewing an object with the microscope.

1. Make sure the low power objective lens is in place and that it is set at its lowest position.
2. Use the stage clips to secure the slide to the stage.
3. Slowly turn the coarse adjustment knob to bring the object on the slide into focus.
4. Then use the find adjustment knob to bring the object into sharper, clearer focus.
5. If you need to observe the object under higher magnification, rotate the revolving nosepiece to bring the medium power objective lens into place.
6. Use the fine adjustment knob to bring the larger image into focus. (**CAUTION!** Never use the coarse adjustment knob with the medium or high power objective lens.)
7. When you finish, return the low power lens into position. Then, using the coarse adjustment knob, move the low power lens to its lowest level.
8. When you return the microscope to its storage area, remember to use one hand to grasp it securely by the arm, and support the weight of the microscope with your other hand under the base. Hold the microscope in front of you, close to your body, as you bring it to the storage area. (**CAUTION!** Never move a microscope by holding it by the arm alone.)

Troubleshooting

You may encounter difficulties when using your microscope. The following list details the more common problems and how you can deal with them.

- *You cannot see anything.* Make sure the microscope is plugged in and the light is on. If the microscope has no light, adjust your mirror.
- *Are you having trouble finding anything on the slide?* Be patient. Follow all of the steps outlined in this procedure from the beginning and make sure the object being viewed is in the middle of the stage opening. While watching from the side, lower the low-power objective as far as it will go. Then look through the ocular lens and slowly raise the objective lens using the coarse-adjustment knob.
- *Are you having trouble focussing, or is the image very faint?* Try closing the diaphragm slightly. Some objects that you will examine are almost transparent. If there is too much light, a specimen may be difficult to see or will appear "washed out."
- *Do you see lines and specks floating across the slide?* These are probably structures in the fluid of your eyeball that you see when you move your eyes. Do not worry; this is normal.
- *Do you see a double image?* Check that the objective lens is properly clicked into place.
- *Do you close one eye while you look through the microscope with the other eye?* You might try keeping both eyes open. This will help prevent eye fatigue. It also lets you sketch an object while you are looking at it.
- Always place the part of the slide you are interested in at the centre of the field of view before changing to a higher-power objective lens. When you turn to medium and high power, you otherwise may not see the object you were viewing under low power.

How to Prepare Specimens for Viewing.

When using a compound microscope to view specimens, the specimen must be placed on a small glass slide and covered with a very thin square of glass called a **cover slip.** There are two main types of specimen slides used in schools. These are **permanent slides** and wet mounts. Permanent slides may be used over and over. Often the specimen has been stained with a chemical to make certain parts of the specimen more visible. A special type of glue is used to permanently hold the cover slip in place.

The other type of specimen slide is called a **wet mount.** The wet mount is very useful when viewing living specimens, particularly microscopic organisms, as you can see them moving, eating, and even reproducing. A wet mount is a

temporary specimen slide because the specimen is disposed of after viewing and the slide and cover slip can be reused.

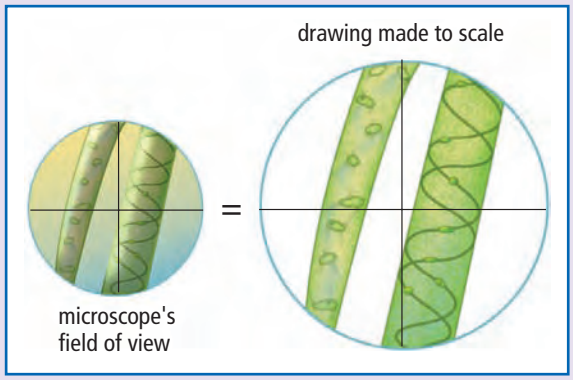
To Make a Wet Mount

1. Place the specimen/sample on a slide.
2. Using an eye dropper, add a drop of water. Sometimes a stain is used to make the specimen more visible. The water helps support and prevents living specimens from drying out.
3. Carefully put the cover slip over the specimen/sample as follows: Place the cover slip at an angle onto the slide so that it touches the drop of water. Using a tooth pick or other small pointer, slowly lower the cover slip onto the drop. This will prevent the formation of air bubbles under the cover slip, which will interfere with your viewing of the specimen. **CAUTION:** Be careful when handling the cover slip as it is very thin glass and can break easily.
4. If there is too much water and the cover slip is "floating around" you can remove some of the excess water by holding the edge of a paper towel next to the edge of the cover slip.
5. If there is too little water you can add more water by adding a drop next to the cover slip. This water will get pulled under the cover slip.
6. If you need to add stain to the specimen after you have made a wet mount, you can do this by putting a drop of the stain on one side of the cover slip. Then hold a paper towel to the other side of the cover slip. As water is pulled into the paper towel the stain will be pulled in under the cover slip to replace the water that was removed.
7. To view your specimen/sample, follow the directions for "using the microscope".
8. When you are finished viewing your specimen, dispose of the specimen as directed by your teacher. Then wash the slide as directed by your teacher. Because they are so fragile, cover slips are difficult to clean and should be disposed of in the broken glass container as directed by your teacher.

Instant Practice—Drawing

A scale drawing is a drawing in which you keep constant the proportions of what you see through the microscope. This is important because it allows you to compare the sizes of different objects and helps you form an idea of the actual size of an object. Also, a scale drawing makes it easier to explain what you see to someone else. Do the following to make a scale drawing.

1. Draw a circle (the size does not matter) in your notebook. The circle represents the microscope's field of view.
2. Imagine that the circle is divided into four equal sections (see the diagram below). Use a pencil and a ruler to draw these sections in your circle, as shown below.



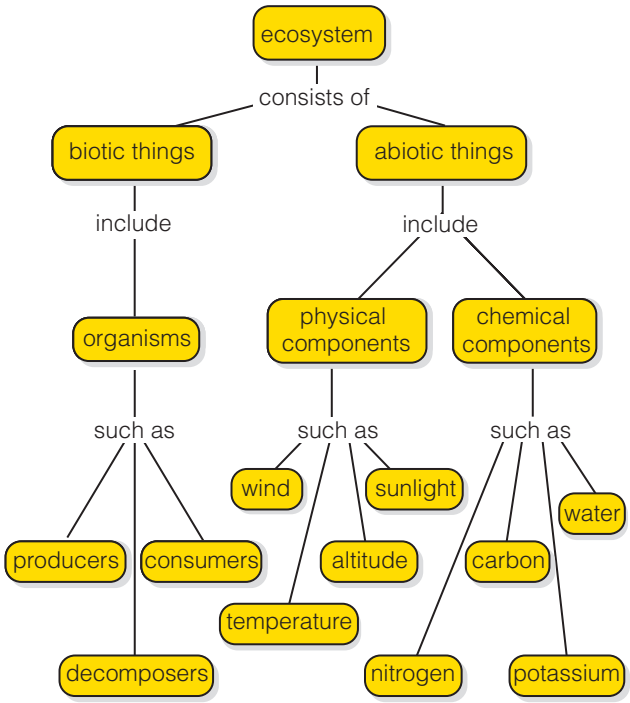
3. Using low or medium power, locate a sample from the prepared slide that interests you. Imagine that the field of view is also divided into four equal sections.
4. Note in what part of the field of view the object lies and how much of the field of view the object occupies.
5. Draw the object in the circle. Position it so that it is in the same part of the circle as it appears in the field of view. Draw the object to scale. This means that it should take up the same proportion of space on the circle as it does in the field of view.
6. Label your drawing.
7. Estimate the size of the object in your drawing.

Using Graphic Organizers

A **graphic organizer** is a way of arranging ideas visually. A typical graphic organizer consists of a group of boxes or circles in which key terms or concepts are written. Lines connecting the boxes show how the concepts are connected. Sometimes a short phrase is written on the lines to explain the connection. Graphic organizers are tools that help you understand and remember new ideas and information. You can often recognize new relationships when you use a graphic organizer. Several examples of graphic organizers are described below. These graphic organizers are sometimes also called *concept maps*.

Network Tree

A graphic organizer called a **network tree** starts with a description of one central concept or idea written in a box. Terms that describe characteristics or smaller parts of the central concept are written in more boxes. The lines, or branches of the tree, show how the central concept is broken down into smaller parts. The example below shows the things that make up an ecosystem.

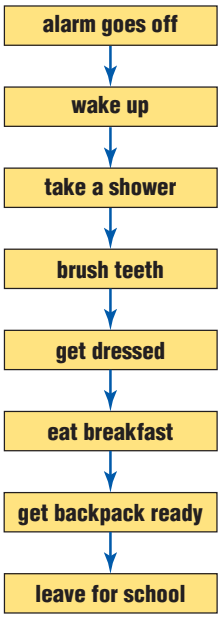


Flowchart

A graphic organizer called a **flowchart** shows a sequence of occurrences or steps in a process. The flowchart below shows the events that follow a volcanic eruption.

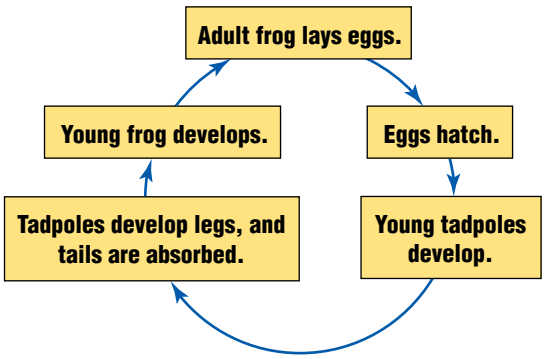
Events Chain

A graphic organizer called an **events chain** shows the order in which events occur. The events chain on the right shows what happens after your alarm goes off in the morning.



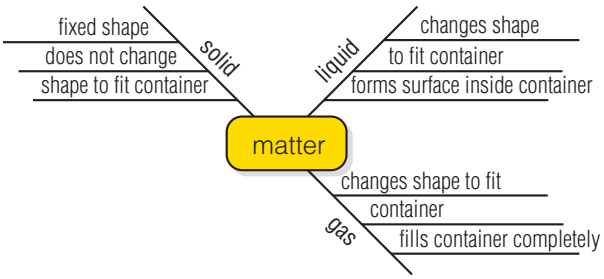
Cycle Map

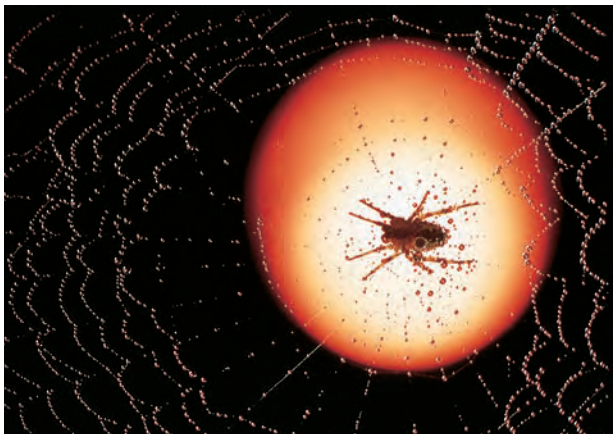
A graphic organizer called a **cycle map** is like an events chain that has no beginning and no ending. The events occur over and over. Since the events are placed in a circle, you need arrows to show the order in which the events occur. The cycle map below shows the life cycle of a frog.



Spider Map

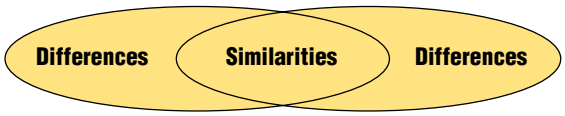
A graphic organizer called a **spider map** connects several objects or ideas to one central event or object. You can use a spider map for brainstorming. To draw a spider map, you place the most important event or object in the centre of the page. Then you write related ideas, events, or descriptions on lines drawn outward from the centre. These topics might not be related to each other, but they are related to the central topic. Finally, you write other ideas or descriptions on horizontal lines connected to the lines that point outward. The map soon begins to look like a spider, as shown here. This spider map describes the three states of matter. The central idea, matter, is the "body" of the spider. The related ideas, solid, liquid, and gas, are the "legs" of the spider.



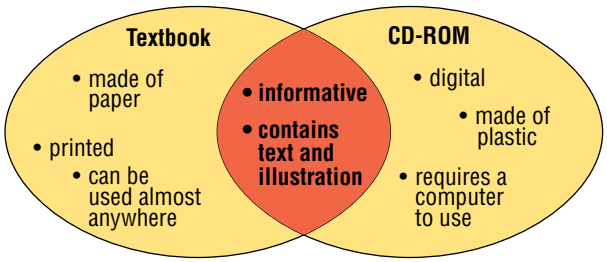


Venn Diagram

A graphic organizer called a **Venn diagram** shows the similarities and differences among objects or ideas. Venn diagrams are made of two or more overlapping ovals or circles. Each oval represents a concept, an object, or an idea. In the area in which the ovals overlap, you write the *similarities* between the objects or ideas. You write the *differences* in the parts of the circles that do not overlap. Study the following example to see the similarities and differences between a print textbook and an e-book CD-ROM.



Example



Instant Practice

1. Use these words to produce a network tree: hockey, team sports, ice, diamond, field, bat, puck, hardball, cleats, ice skates, baseball, soccer ball, stick, soccer, feet.
2. Produce an events chain that starts with lunch and ends with your return home from school.
3. Produce a cycle map using the following words: summer, winter, fall, spring.
4. Make a Venn diagram to compare and contrast a video cassette and a DVD.
5. In a group, create a spider map based on one of the following topics:
   (a) food and nutrition
   (b) music
   (c) scientific discoveries
   (d) communication

Glossary

How to Use This Glossary

This Glossary provides the definitions of the key terms that are shown in boldface type in the text. (Instructional boldfaced words such as "observe" and "explain" are not included.) The Glossary entries also show the sections where you can find the boldfaced words. A pronunciation guide, using the key below, appears in square brackets after selected words.

a = mask
ae = same, day
ah = car, farther
aw = dawn, hot
e = met, less
ee = leaf, clean
ih = idea, life
i = simple, this
oh = home, loan
oo = food, boot
u = wonder, Sun
uh = taken, travel
uhr = insert, turn

A

abiotic [AE-bi-o-tik] non-living; refers to non-living things in the environment, such as water, soil, or air (1.1)

acid rain burning fossil fuels produces nitrogen and sulphur which combine with water vapour to make acid; this falls to the ground as acid rain (3.2)

adaptation a characteristic that is inherited and that helps an organism survive in its environment (1.1)

algal blooms huge increases in the amount of algae in water caused by certain nutrients (phosphates and nitrates) from fertilizers that enter aquatic ecosystemsfertilizer run-off (12.3)

alloy a solution that is made from two or more metals (7.2)

B

baseline data measurements that form a starting point from which later changes can be monitored (3.3)

bedrock the solid rock that lies beneath the soil (11.2)

beds visible layers of sedimentary rocks formed by cementation and compaction (10.2)

bimetallic strip the strip is made of two different types of metals that expand by different amounts when heated (4.2)

biotic [bih-O-tik] living; refers to living things in the environment, such as humans, trees, or fish (1.1)

body temperature an important indicator of your health; a normal human body temperature is 37°C (4.1)

boiling point the temperature at which a liquid boils to become a gas (5.3)

C

calibrate to accurately assign the numbers on a scale (4.2)

carnivores animals that eat other animals; examples include wolves and hawks (2.2)

Celsius scale the most common scale for measuring temperature; on the Celsius scale, water at sea level boils at 100°C and freezes at 0°C (4.2)

cementation the process in which pieces of sediment are held together by another material (10.2)

change of state the change from any of the three states (solid, liquid, gas) to any other state (5.3)

chemical weathering the break-up or disintegration of rocks through the effects of chemical reactions upon them (12.1)

cleavage the splitting of a mineral along smooth, flat planes (10.1)

climate change by monitoring the environment, scientists have noted that the Earth is undergoing major shifts in climate that will result in warmer average temperatures (3.3)

climax community a diverse group of species that form a stable ecosystem which can remain relatively unchanged for centuries if there is no disturbance (3.1)

commensalism a symbiotic relationship between two different types of organisms, in which one partner benefits and the other partner does not appear to lose or gain anything (2.1)

community a group made up of all the interacting populations that live in an area (1.3)

compaction the process in which layers of sediment are squeezed together by the weight and pressure of water and other sediment, to form sedimentary rock (10.2)

composting the breakdown of plant material; decomposition (12.3)

concentrated solution a solution that has a large mass of dissolved solute for a certain quantity of solvent (8.2)

concentration the quantity of solute that is dissolved in a certain quantity of solvent (8.2)

condensation the process in which a gas or vapour changes in state to become a liquid; for example, water vapour condenses into liquid water (5.3)

conduction the transfer of thermal energy that occurs when warmer particles come in contact with cooler particles and transfer energy to the cooler particles (6.1)

consumers organisms that eat other organisms (other consumers as well as producers) the food made by producers; can be a herbivore, carnivore, or omnivore (2.2.)

continental drift the theory that the continents move very slowly over the Earth's surface (11.1)

convection the process in which a warm gas or liquid moves from one place to another, carrying heat with it (6.1)

convection currents in geology, a movement of material produced by the rising of warmer magma and the sinking of cooler and denser magma (11.1); also, patterns of movement where a warm gas or liquid rises and cooler gas or liquid falls to replace it (6.1)

convergent boundary a plate boundary at which the plates move towards each other and collide (11.1)

crust the thin, outer layer of Earth; made of solid rock (11.1)

D

decomposers organisms that break down (decompose) dead or waste materials, such as rotting wood, dead animals, or animal waste (2.2.)

deposition a change of state from a gas to solid (5.3); the process in which eroded material is deposited in another area (12.1)

desertification [de-zuhrt-i-fi-KAE-shuhn] the process in which deserts are formed through the erosion of nutrient-rich topsoil; after desertification the soil is no longer able to support plant life (12.3)

dilute solution a solution that contains a small mass of solute for a certain quantity of solvent (8.2)

dissolve to mix a solute completely with a solvent to form a solution; the physical properties of the solute and solvent combine into one set of properties (8.1)

divergent boundary a plate boundary at which the plates move away from each other (11.1)

E

earthquake shaking of the ground caused by the sudden release of energy stored in the bedrock (11.2)

ecosystem all the interacting organisms that live in an environment, as well as the abiotic (non-living) parts of the environment that affect the organisms (1.1)

endangered when a species has such a low population it is nearly extinct (3.2)

energy pyramid a model that shows how energy is lost at each link in a food chain; animals at the top of the pyramid are less numerous than those below them because there is less energy available for them to use (2.3)

environmental impact assessment a report that outlines how an activity will affect the environment (3.3)

environmental monitoring checking and monitoring different parts of the environment at regular intervals; indicates how well ecosystems are functioning and how they change over time (3.3)

epicentre [e-pi-sen-tuhr] the location on Earth's surface that is directly above the focus of an earthquake (11.2)

erosion the process of moving soil and rock from one place to another; caused by the effects of wind and/or water (12.1)

evaporation the process in which a liquid changes into a gas or vapour as energy is added; also, a common separation technique to recover the solid solute from a solution (9.1) for example, liquid water evaporates to become water vapour (5.3)

extinct when there are no longer any living individuals of a species anywhere in the world (3.2)

extrusive rock a type of igneous rock formed when lava cools on Earth's surface (10.2)

F

Fahrenheit scale the first widely used temperature scale; on the Fahrenheit scale, water at sea level boils at 212°F and freezes at 32°F (4.2)

fault the surface along which rocks break and move during an earthquake (11.2)

fermentation the process where yeast cells feed on sugary food, breaking down the sugars and producing alcohol and carbon dioxide gas; this process is used to make beer, wine, bread, cheese, pickled vegetables, and some sausages (2.2)

fertilizers substances that provide nutrients for plants (12.3)

filtration a type of mechanical sorting that relies on particle size to separate particles from a solution by pouring the solution over a device with holes in it (9.1)

focus the place deep in Earth's crust where an earthquake begins (11.2)

fold a bend in rock layers (11.3)

food chains models that show how food energy passes from organism to organism (2.3)

food webs networks of interconnected food chains in an ecosystem (2.3)

fossil evidence of once-living organisms (11.3)

fractional distillation a process that uses the boiling points of substances to separate a complex mixture into its parts (9.2)

fracture in a mineral, the characteristic of breaking with rough or jagged edges (10.1)

freezing the process in which a liquid changes into a solid; for example, liquid water freezes into ice (5.3)

G

gas one of the phases or states of matter; a gas has no particular shape or size and can be compressed; a gas is sometimes known as a vapour (5.2)

geological timescale divides Earth's history into smaller units based on the appearances of different kinds of life forms in the fossil record (11.3)

H

habitat the place in which an organism lives (1.1)

hardness in a mineral, the characteristic of resisting being scratched (10.1)

heating curve a graph that demonstrates the changing of states of a substance by plotting temperature versus time, when energy is continuously added to the substance (5.3)

herbivores animals that eat only plants (2.2)

heterogeneous mixture a combination of two or more different types of matter that retain their own properties and that can be detected quite easily (7.1)

homogeneous mixture a combination of two or more different types of matter that appear to be the same throughout the mixture and have the same properties (7.1)

host the organism that a parasite lives and feeds on (2.1)

humus [hyew-mus] the dark-coloured part of soil that is rich in nutrients, such as nitrogen, phosphorus, potassium, and sulfur (12.2)

hypothermia the condition where your body temperature drops a few degrees below 37°C; the heart begins to slow down and body organs do not function properly (4.1)

I

igneous the type of rock that forms when hot magma or lava cools and becomes solid (10.2)

individual a single organism (1.3)

inner core the deepest and hottest layer of the earth (11.1)

insoluble unable to dissolve in a particular solvent (8.1)

insulators materials that are very poor conductors of heat (6.2)

introduced species species that have spread beyond their natural range into new territory because of human activity (3.2)

intrusive rock a type of igneous rock that forms when magma slowly cools beneath Earth's surface (10.2)

K

Kelvin scale a scale used for measuring temperatures in scientific experiments; on the Kelvin scale, pure water freezes at 273 K and boils at 373 K; the coldest possible temperature (also known as absolute zero) is 0 K (4.2)

kinetic energy [kin-E-tic] energy that particles or an object has due to its motion (5.1)

L

leaching the process by which materials in soil are dissolved and carried away by water (12.2)

liquid one of the states or phases of matter; in the liquid state, a material has a specific size or volume but not a specific shape (5.2)

long-term monitoring checking and monitoring the environment over a period of many years; used to determine if an environment is changing in a significant way (3.3)

lustre a measure of how much light is reflected from the surface of mineral; how shiny the mineral is (10.1)

M

magma molten material found below Earth's surface (10.2)

magnetometer a sensitive instrument that can detect the direction and strength of a magnetic field (11.1)

mantle a large and complex layer of rock, both solid and molten, that lies under Earth's crust (11.1)

matter anything that takes up space, has mass, and is made up of particles (5.1)

mechanical sorting a way to separate parts of a mixture based on properties such as particle size or magnetism (9.1)

mechanical weathering [of rocks], the break-up or disintegration by the actions of physical forces generated by ice, plants, or animals (12.1)

melting the process in which a solid changes into a liquid; for example, solid water (ice) melts into liquid water (5.3)

melting point the temperature at which a solid melts to become a liquid; also called the freezing point (5.3)

metallic ores rocks that contain a high proportion of metals and metal oxides (10.3)

metamorphic rocks types of rocks produced when heat, pressure, or fluids change one type of rock into a new form (10.2)

mineral a pure, naturally occurring, inorganic solid substance (10.1)

mixture a combination of two or more different types of matter that can be separated by physical changes (7.1)

monoculture planting large areas with a single crop (3.2)

mutualism [MYOO-choo-al-is-uhm] a symbiotic relationship between two different types of organisms, in which each partner benefits from the relationship (2.1)

N

native species wild species that have lived in their environment since before humans settled the land (3.2)

natural resources materials and products found in nature that people use to meet their basic needs (3.2)

niche [NEESH] the role that is undertaken by an organism in an ecosystem; one organism may fill several different niches (1.3)

no-till farming plant stalks are left in the field to prevent erosion; farmers push the new seeds through the stubble of the previous crop into undisturbed soil (12.3)

nutrient cycles the processes that move nutrients back and forth between the biotic and abiotic environment (2.4)

nutrients contained in food, nutrients are used to repair cells and tissues (2.4)

O

omnivores animals that eat both plants and animals (2.2.)

ore a rock mixture that contains one or more valuable substances (9.2)

organism any living thing, such as a plant or animal (1.1)

outer core the deep layer close to the centre of Earth that is made of liquid iron and nickel (11.1)

P

Pangaea [pan-JEE-uh] a theoretical, huge land mass that once, hundreds of millions of years ago, included all the continents (11.1)

paper chromatography a type of separation technique used to separate the coloured substances in a mixture; the solution is poured onto a paper to see how fast the dissolved substance is carried by the solvent as the solute is absorbed by the paper (9.1)

parasites organisms that live on or in another organism (the host) and feed on it (2.1)

parasitism a symbiotic relationship between two different types of organisms, in which one partner benefits and the other partner is harmed (2.1)

parent rock the original rock that has been changed by pressure and heat into a metamorphic rock (10.2)

particle theory of matter a scientific model of the structure of matter; according to the particle theory, all matter is made up of extremely tiny particles, and each pure substance has its own kind of particle, different from the particles of other pure substances (5.1)

permanent plot sample areas of habitat that scientists monitor year after year (3.3)

permeability a measure of the ease with which liquids and gases pass through a soil or a rock (12.2)

petroleum a complex mixture of liquid, solid and gaseous substances; also called crude oil; the source of most of the fuels and lubricants that run the machines we use (9.2)

pioneer species species that are the first to appear in an area and can establish themselves with little or no soil and few nutrients (3.1)

plate tectonics the theory that the Earth's crust is broken up into pieces (called plates) that are moving on Earth's mantle (11.1)

pollutants substances that cause harm to the air, soil, water or living things (3.2)

population a group of organisms of the same species, living together in one ecosystem (1.3)

porosity the amount of empty space in a soil or rock (12.2)

primary succession the sequence of changes that starts with bare rock and eventually develops into a complex community of plants and animals (3.1)

producers organisms that make their own food rather than eating other organisms to obtain food; for example, a plant (2.2)

pure substance a material that is composed of only one type of particle; examples of a pure substance include gold, oxygen, and water (7.1)

R

radiation the transfer of energy in a wave-like form (6.1)

range of tolerance the range of abiotic conditions within which an organism can survive (1.2)

renewable resources living natural resources that, after harvesting, can be replaced by natural processes in a relatively short period of time (3.2)

resource of a rock or mineral, mined and used for a specific purpose (10.3)

Richter scale [RIK-tuhr] a scale used to describe the magnitude (strength) of an earthquake (11.2)

Ring of Fire the volcanoes encircling the Pacific ocean (11.2)

rock cycle the naturally occurring processes by which rocks are continually changed over long periods of time (10.3)

rock a natural material composed of one or more minerals (10.2)

room temperature the temperature at which most people are comfortable; usually between 20°C and 23°C (4.1)

S

saturated solution a solution in which no more of a solute will dissolve at a particular temperature (8.2)

scavengers organisms that eat decaying plant or animal matter (2.2)

secondary succession the re-growth of a community in an area that has changed dramatically after a disturbance such as a fire (3.1)

sedimentary rocks types of rocks formed by compacting and/or cementing sediment (loose material) (10.2)

seismic waves [SIHZ-mik] the energy waves that are released by an earthquake and that travel outward from its focus (11.2)

seismograph [SIHZ-moh-graf] a machine used by scientists to measure the strength of earthquakes (11.2)

simple distillation a type of separation technique used to recover a single solute and a single solvent from a solution; the solution is heated until the solvent becomes a gas and the cooled until it becomes a liquid; the solute is left behind (9.1)

soil profile a description of the characteristics of the different layers that make up a particular soil (12.2)

soil a mixture of weathered rock, organic matter, mineral fragments, water, and air (12.1)

solid one of the states or phases of matter; in the solid phase, materials keep a specific shape and size (5.2)

solubility the mass of a certain solute that can dissolve in a certain volume or mass of solvent, at a certain temperature (8.2)

soluble able to dissolve in a particular solvent (8.1)

solute a substance that can be dissolved in a solvent, to form a solution (8.1)

solution a homogeneous mixture of two or more substances; the composition of the mixture is the same throughout the sample and from one sample to another (7.2)

solvent a substance into which a solute dissolves, to form a solution (8.1)

sonar a technology used to gather information about the sea floor, in which the time that the sound waves take to bound back from the ocean floor is recorded (11.1)

species a group of organisms that can successfully mate with each other and reproduce (1.3)

specific heat capacity the amount of energy required to raise the temperature of 1.00 g of a substance 1.00°C (6.3)

streak the colour of the powdered form of a mineral (10.1)

subduction zones places on the Earth's crust where high pressure pushes an oceanic plate under another plate into the mantle (11.1)

sublimation the process in which a solid changes directly into a vapour, for example, dry ice (frozen carbon dioxide) will sublime into carbon dioxide gas at room temperature (5.3)

subsoil the layer of soil underneath topsoil; it is more tightly packed and lighter in colour than topsoil because there is little or no humus (12.2)

succession the process by which a biological community changes over time (3.1)

sustainable when resources are replaced by natural processes or human activity at the same rate as they are used up by humans (3.2)

symbiosis [sim-bih-OH-sis] a biological relationship in which two species live closely together in a relationship that lasts over time (2.1)

symbiotic a word used to describe a situation in which two species live closely together in a relationship that lasts over time (2.1)

T

temperature a relative measure of how hot or cold something is; the average kinetic energy of the particles in a substance (5.1)

texture of soil, how it feels to the touch; texture is affected by the size of the particles in the soil (12.2)

thermal conductivity the rate at which a substance conducts heat (6.2)

thermal contraction the decreases in the volume of a substance as the temperature decreases (5.2)

thermal energy the total kinetic energy of the particles of a substance; heat (6.3)

thermal expansion the volume of an object or substance increases when the temperature increases (5.2)

thermocouple used to measure temperature; thermocouples are made of two different types of metal wires that are connected at both ends; temperature differences between the ends cause an electric current to travel along the wires (4.2)

thermogram an image generated by a device that detects infrared radiation and converts it into colours that represent temperature differences (4.2)

thermometer a device used to measure temperature (4.2)

thermoscope developed before thermometers; a thermoscope shows whether the air is hot or cold but does not measure temperature since there is no numerical scale (4.2)

theory of continental drift a theory proposing that the continents change position very slowly, moving over the surface of the Earth a few centimetres every year (11.1)

topsoil the topmost layer of soil, which is dark-coloured and rich in humus (12.2)

transform boundary a plate boundary at which plates slide past each other (11.1)

U

unsaturated solution a solution in which more solute can be dissolved in the solvent at a particular temperature (8.2)

unsustainable when resources are used faster than they can be renewed (3.2)

V

volcano an opening in Earth's crust that can release lava, smoke, and ash when it erupts (11.2)

W

weathering the process in which rocks are broken down and sediment is formed by mechanical and chemical means (12.1)

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