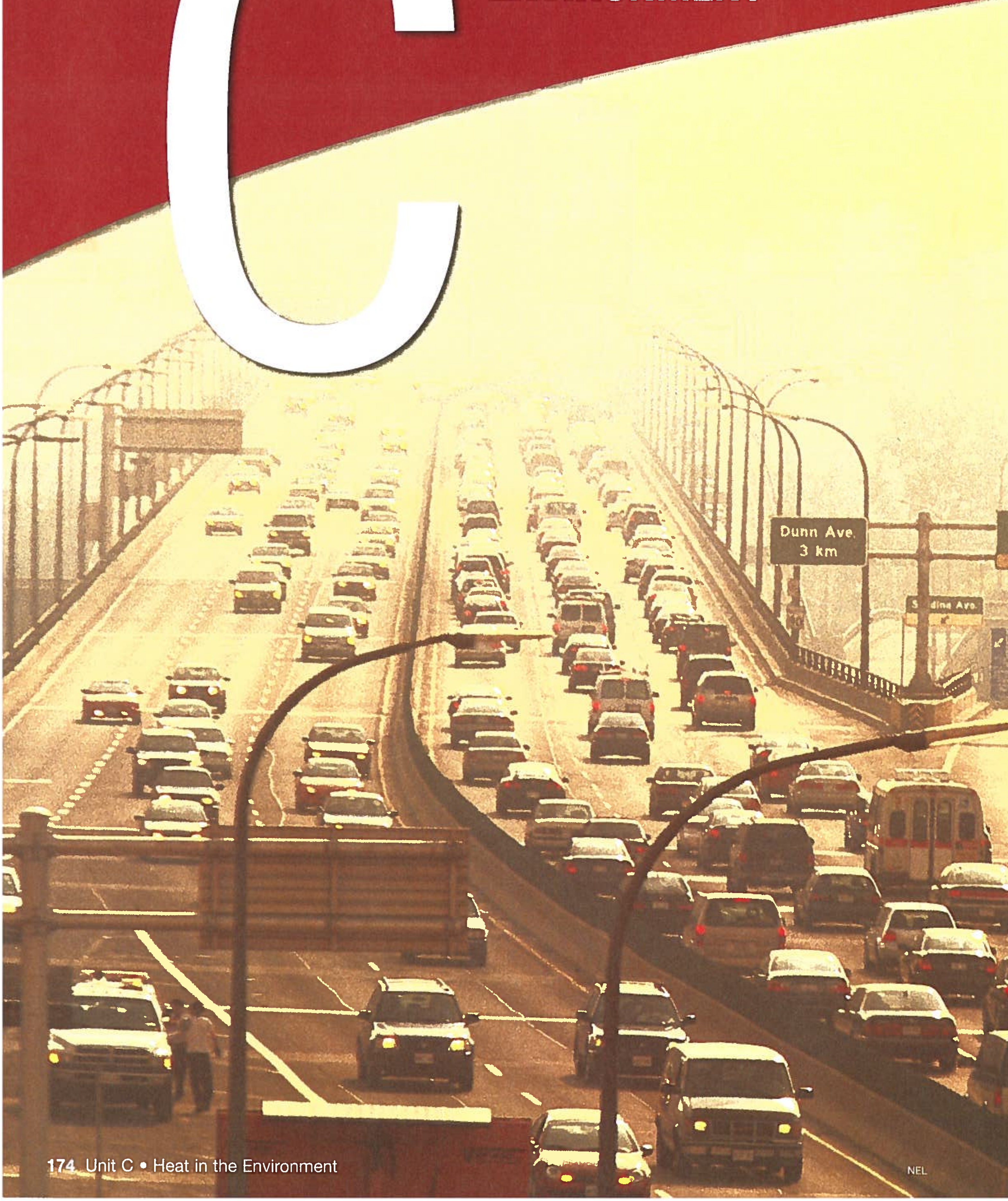
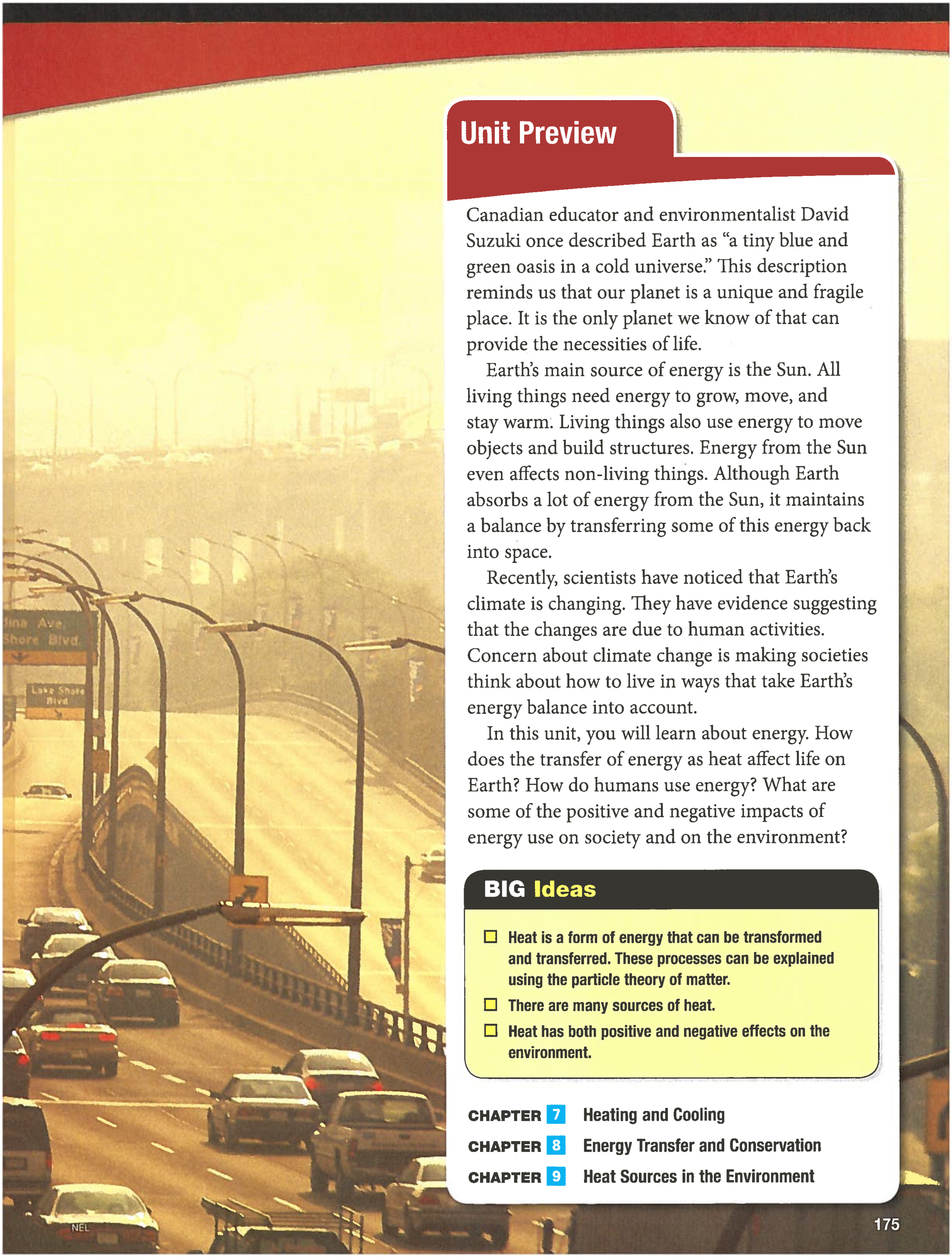
UNIT C

# HEAT IN THE ENVIRONMENT





# Unit Preview

Canadian educator and environmentalist David Suzuki once described Earth as "a tiny blue and green oasis in a cold universe." This description reminds us that our planet is a unique and fragile place. It is the only planet we know of that can provide the necessities of life.

Earth's main source of energy is the Sun. All living things need energy to grow, move, and stay warm. Living things also use energy to move objects and build structures. Energy from the Sun even affects non-living things. Although Earth absorbs a lot of energy from the Sun, it maintains a balance by transferring some of this energy back into space.

Recently, scientists have noticed that Earth's climate is changing. They have evidence suggesting that the changes are due to human activities. Concern about climate change is making societies think about how to live in ways that take Earth's energy balance into account.

In this unit, you will learn about energy. How does the transfer of energy as heat affect life on Earth? How do humans use energy? What are some of the positive and negative impacts of energy use on society and on the environment?

## BIG Ideas

- Heat is a form of energy that can be transformed and transferred. These processes can be explained using the particle theory of matter.
- There are many sources of heat.
- Heat has both positive and negative effects on the environment.

**CHAPTER 7** Heating and Cooling

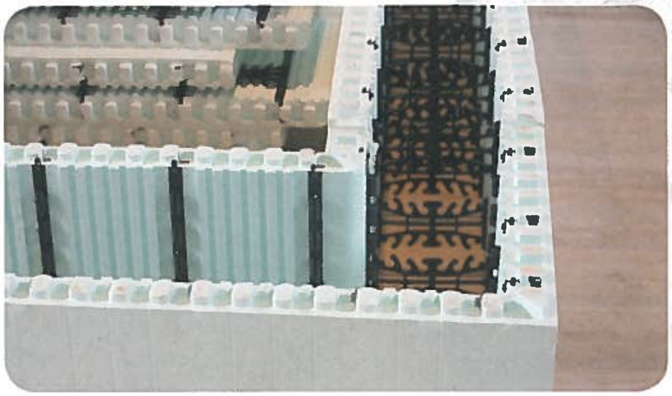
**CHAPTER 8** Energy Transfer and Conservation

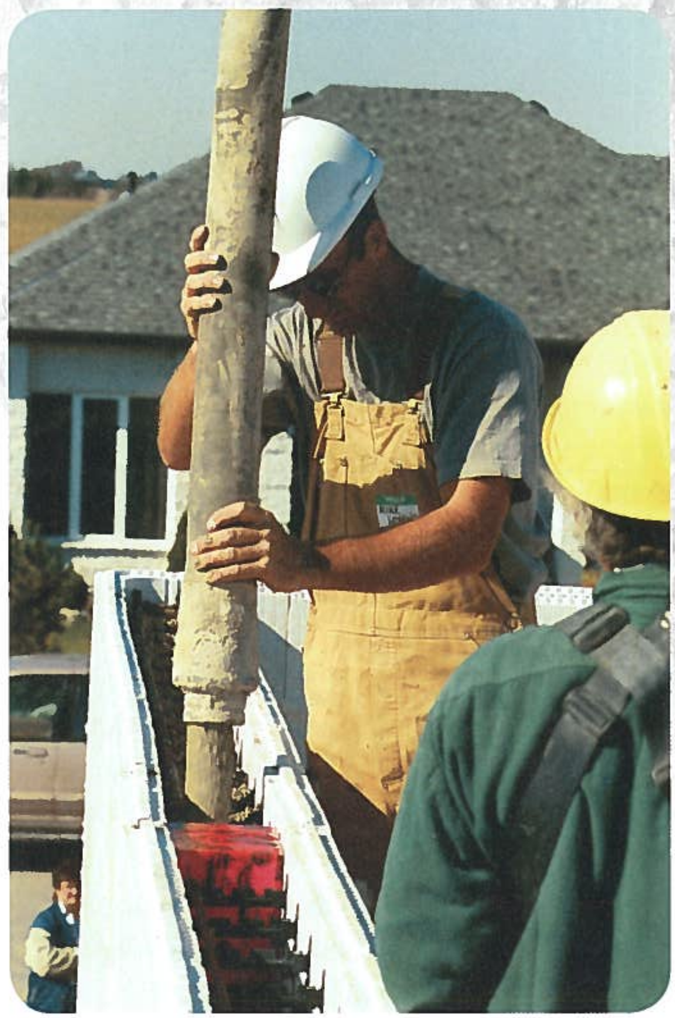
**CHAPTER 9** Heat Sources in the Environment

Discover Science and Technology

# LIVING IN A GIANT FOAM COOLER!

On the way home from a trip to Ottawa, Tara and her mom, Gatleen, stopped in Brockville to visit some friends. Their friends, the Narangs, were building a new home. Soon after arriving at the apartment, Tara and Gatleen were ushered into the Narang family car and taken to the construction site. When they arrived, Tara was surprised by what she saw. On a patch of muddy ground was a framework of walls made entirely of pure white foam. There were none of the typical building materials that Tara had seen before on construction sites—no bricks, no cement blocks, and no wood frames. It looked as if the Narangs were going to live in a giant foam cooler!





Fascinated by what she saw, Tara watched as a construction worker built a wall. He stacked foam blocks, one on top of the other. The blocks were about the size of backpacks, and they were light enough for the worker to stack them with one hand. Tara wondered why the Narangs were building their home with such lightweight materials. Could such a house ever withstand strong wind, rain, and heavy snow?

The Narangs explained that the workers were using Polystyrene Block Form Construction to build the house. They said that this type of construction would help keep the house warm in the winter and cool in the summer. Mr. Narang explained that the blocks are hollow. They are filled with concrete once the wall is built.

Tara was not sure how the foam and concrete walls would help keep the Narangs' house warm in winter and cool in summer. She did remember learning in science class that polystyrene is a plastic that may harm the environment. She asked the Narangs why they were using so much plastic in the construction of their home. The Narangs explained that the environmental benefits of using less fuel and electricity to heat and cool their home justified the use of the foam blocks in the walls. Tara thought about that, but was not convinced. How could having foam walls be so good for the environment? She planned to do some research on the Internet when she got home to find out if the Narangs were right.

## LINKING TO LITERACY

### Asking Questions

When you do not know the answer to something, you ask a question. The same is true for reading. But in reading, you end up answering most of the questions yourself. Questions can be asked before you start reading, while you are reading, or after you are finished reading.

1. Talk to a partner about the questions you had when you were reading about the Narangs' new home.
   - Which questions were answered for you as you read more?
   - What questions do you still have?
   - Pick one question that you can do further research on to find the answer.

# Feeling Cool

During this activity, you will explore the effect of heat on ice when the ice is placed on two different surfaces. You will then be asked to describe your observations in an expository paragraph. An expository paragraph is one that presents information, explains facts, or provides an opinion. This textbook contains many expository paragraphs. For example, see the paragraphs on page 182. The list of science terms on the right has been provided to help you write your paragraph.

**Science Terms**
warm
cold
heat
steel
plastic
conductor
insulator
temperature
melt

**Equipment and Materials:** dry metal surface (metal kitchen sink); dry plastic surface (plastic countertop or plastic plate); 2 ice cubes

1. Place yourself so that a dry metal surface (for example, a metal kitchen sink) and a dry plastic surface (for example, a plastic countertop) are both within reach.
2. Touch your fingers to the metal surface and the plastic surface at the same time (Figure 1). Do they feel different?

**Figure 1** Touch both surfaces at the same time.

3. Predict which ice cube will melt faster if you place one ice cube on the metal surface and another on the plastic surface at the same time. Using your observations from step 2, state your prediction in the form of a hypothesis.
4. Test your prediction by placing one ice cube on the dry metal surface and the other ice cube on the dry plastic surface. Observe both ice cubes for 3 min, especially where the ice cubes touch the surfaces.

**A.** Describe what you felt in step 2.

**B.** Brainstorm possible reasons why the two ice cubes melted at different rates.

**C.** Write an expository paragraph to describe your observations from step 2, your hypothesis from step 3, and your observations from step 4.

**D.** Evaluate your hypothesis. Did your observations support your prediction, and your reasons for it?

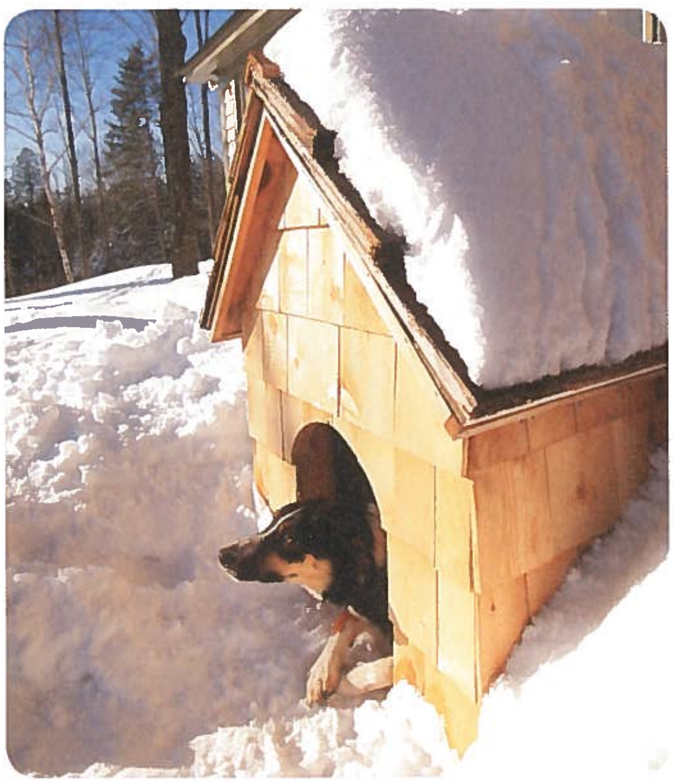
**E.** Use what you have just discovered to predict whether hot chocolate will remain hot longer in a plastic cup or in a metal cup. Give reasons for your prediction.

**Unit Task Preview**

# Designing an Energy-Efficient Doghouse

Most living things need to stay warm in the winter and cool in the summer. Humans, in particular, control the transfer of energy to stay comfortable year round. As you progress through this unit, you will learn about different sources of energy and how we can control them.

The K-9 Doghouse Company is interested in building a new doghouse that it can sell to dog owners in Ontario. The company is holding a competition to come up with a new doghouse design. Specifically, the company is looking for a doghouse that will keep a dog comfortably warm outdoors during the winter and cool during the summer.



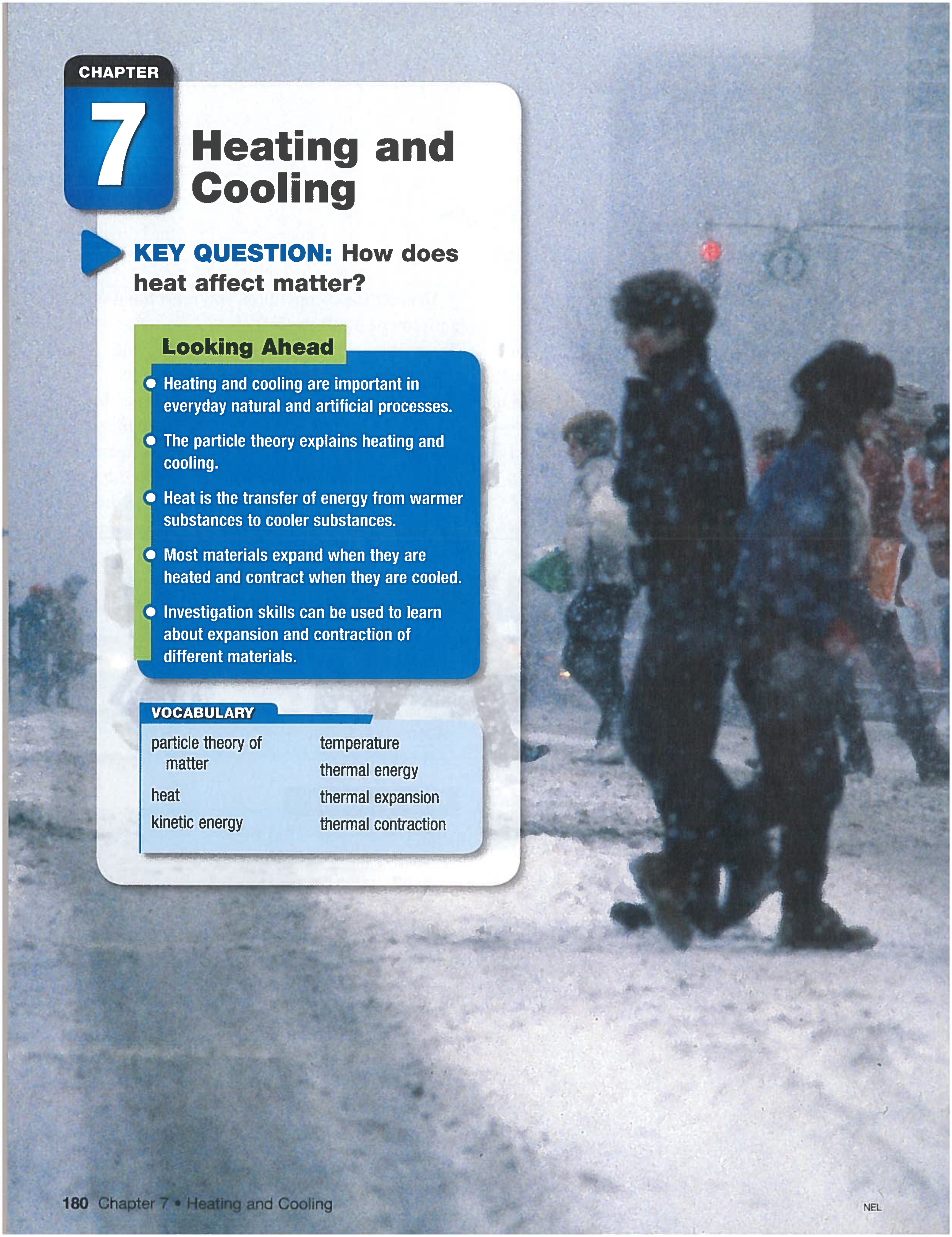
To enter the competition, you must build a prototype (scale model) of a doghouse. The prototype will be tested in hot and cold conditions to see how long the inside of the doghouse will stay at a comfortable temperature. The K-9 Doghouse Company would like the designers to present the prototype to its Board of Directors. The designers need to point out the pros and cons of their design, and convince the Board that the prototype deserves to be mass-produced.

**Unit Task** By the end of the Heat in the Environment unit, you will be able to demonstrate your learning by completing this Unit Task. As you work through the unit, continue to think about how you might meet this challenge. Read the detailed description of the Unit Task on page 254, and look for the Unit Task icon at the end of selected sections for hints related to the task.

## Assessment

**You will be assessed on how well you**

- identify several possible designs
- develop a plan for building a prototype based on one of your possible designs
- build a prototype based on one of your designs
- test your prototype and make modifications that improve its effectiveness
- use the concepts and terminology of the unit to communicate the development and testing of your prototype



CHAPTER 7

# Heating and Cooling

## KEY QUESTION: How does heat affect matter?

### Looking Ahead

- Heating and cooling are important in everyday natural and artificial processes.
- The particle theory explains heating and cooling.
- Heat is the transfer of energy from warmer substances to cooler substances.
- Most materials expand when they are heated and contract when they are cooled.
- Investigation skills can be used to learn about expansion and contraction of different materials.

### VOCABULARY

particle theory of matter
heat
kinetic energy
temperature
thermal energy
thermal expansion
thermal contraction

# Reading Science and Technology

## Warm and Cold


It is a freezing cold winter morning and I am waiting for a bus at a crowded bus stop. Although I am wearing thick wool gloves, my hands feel cold.

As I look around, I notice that people are pacing. I realize that everyone is breathing out puffs of white mist. Why does this happen in the winter, but not in the summer? As the bus arrives, I notice that the windows are frosted and white smoke is coming out of the bus' exhaust pipe. I wonder what the white smoke is made of, and what it could be doing to the environment.

I start to feel warm as soon as I get on the bus. I notice that I can no longer see everyone's breath. As the bus pulls away from the stop, I look out the window and see a bright yellow sign on the side of the road that says "Danger Bridge Ices." Soon, the bus goes over a bridge, and I feel several bumps and hear some thumping noises. Why are bridges always bumpy? And why are there special signs warning motorists about ice on bridges? It is cold enough outside for ice to form on all roads, whether the roads go over bridges or not. I wonder…

Cold hands, cloudy breath, icy bridges, and frosty windows are some of the signs of cold weather that I have noticed all my life. I have often wondered why certain things happen in cold weather but not in warm weather.

### LINKING TO LITERACY

**Verifying Understanding**

After reading, effective readers verify their understanding by reflecting on the ideas presented and discussing what they have read. They may even research some aspect of the topic.

**1** The story you read introduced some of the ideas that will be discussed in Chapter 7. Create and complete a 3-2-1 table (Table 1). In the table, record three things that you discovered by reading the story, two interesting things, and one question that you have after reading the story. Discuss your table with a partner.

**Table 1**

| Three things I discovered | Two interesting things | One question I'd like answered |
| --- | --- | --- |
| | | |

# 7.1 Warmth and Coldness

Living things are sensitive to warmth and coldness. They need a certain amount of warmth to survive. Humans keep warm by wearing clothes, performing physical activities, and burning various fuels in fireplaces and furnaces. Many birds fly south when it gets cold in northern regions (Figure 1(a)). Snakes and lizards bask in the sun to keep their bodies warm (Figure 1(b)).



**Figure 1** Animals such as geese (a) and lizards (b) need warmth in order to survive.

**Figure 2** A dog pants to cool down.

However, living things avoid excessive warmth because it is dangerous for their health. Animals that overheat can suffer damage to their internal organs and can even die. Different types of living things have developed different ways of dealing with excessive warmth. For example, dogs cool off by panting (Figure 2). Honeybees flap their wings to cool their hives in hot weather. People use electric fans and air conditioners to cool their homes and other buildings when the weather is too warm.

## Heating and Cooling Our Buildings

Homes and buildings are designed to keep their interiors warm in winter and cool in summer. In fact, heating, ventilation, and air conditioning (HVAC) is a $12 billion industry in North America. About 250 000 people have jobs in the HVAC industry. It is not easy to keep homes and other buildings comfortable during the hot, humid summers and cold winters of Ontario (Table 1).

**Table 1** Average Monthly Temperatures for Ottawa, Ontario

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average temp (°C) | –10 | –9 | –2 | 6 | 14 | 18 | 21 | 20 | 15 | 6 | 1 | –7 |

For thousands of years, people have warmed their homes in winter by burning wood in fireplaces. They have cooled their homes in the summer by placing blinds on windows and planting shade trees in their gardens. In ancient Rome, some buildings were sometimes cooled by running cold river water through the walls. Other buildings were cooled by installing a shallow indoor pool. In ancient China, some palaces had raised floors. This design permitted servants to tend fires beneath the floors during the winter. In the early 1800s, a few wealthy people began to install central heating systems in their homes. These systems consisted of furnaces that moved warm air or water to the rooms of a building. Modern electric air conditioners were first used in North America in the early 1900s (Figure 3).

Today, most Ontario homes are built with central heating systems. Some also contain central air conditioners (Figure 4). The furnaces in these systems typically burn fuels like oil (petroleum) or natural gas. Oil and natural gas are found in limited supplies deep within Earth's crust. If we continue to use these fuels at our current rate, scientists estimate that we will run out of them within a few decades. In some cases, buildings are heated with electric heaters, which use electricity to produce warmth. Electric heaters may consume fuels indirectly, depending on the electricity source.

**Figure 3** Air conditioners are often fitted into building windows, where they draw in outside air, cool it, and blow it back into the building.

To learn more about the history of air conditioning,
Go to Nelson Science

**LINKING TO LITERACY**

**Cause-and-Effect Text Pattern**

Science text is often written in a cause-effect order. It explains events that have occurred (cause) and what happens as a result of these events (effect). As you read this page, consider the effects or drawbacks of the way we heat or cool buildings.

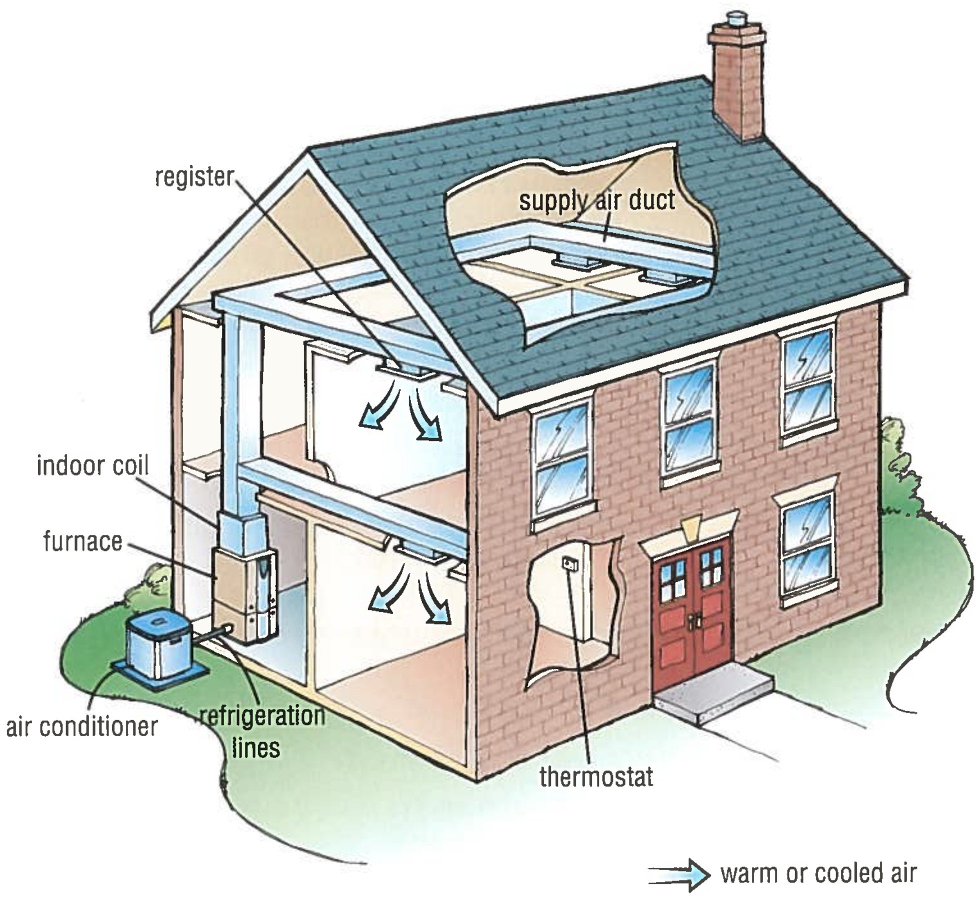



**Figure 4** A typical home central heating and cooling system. The furnace heats the home in the winter; the air conditioner cools it in the summer. The same air ducts are used for both heating and cooling.

**Figure 5** Many buildings have chimneys on their roofs to allow toxic waste gases to escape.

Wood, coal, oil, and natural gas release energy and gases as waste when they burn. Some of these waste gases are toxic and must be removed from the building. Chimneys are vents that carry these gases to the air outside (Figure 5).

In the summer, buildings can be cooled by fans, window air conditioners, or central air conditioners. These devices do not normally produce toxic fumes during their use, but they do consume electricity. Air conditioners use much more energy than fans do.

Keeping interiors comfortable all year long is important to consider in the construction and maintenance of all buildings. Heating and cooling are expensive processes. They are also harmful to the environment. We should use them as little as possible. Imagine if we only had to turn on the air conditioner for a few minutes once a day to cool a building. The building would then stay at a comfortable temperature for the rest of the day. Think how much electricity we could save! Understanding more about heating and cooling may help people keep buildings comfortably warm or cool, while minimizing negative effects on the environment.

## TRY THIS: Conduct a Heating and Cooling Survey

**SKILLS MENU: questioning, planning, analyzing, evaluating, communicating**

SKILLS HANDBOOK 3.K.2., 6.D.2.

In this activity, you will survey people to find out how they keep their homes, or businesses, warm in the winter and cool in the summer. You may ask about the heating and cooling methods they currently use, or have used in the past. You may also ask about methods they may have used in other parts of the world.

**Equipment and Materials:** writing instruments (pencils, pens); paper

1. Think of 6 to 10 questions that ask participants how they keep (or kept) their homes or businesses warm in cold weather and cool in hot weather. Your questions may ask about the types of devices used, the sources of energy used to run the devices, the effectiveness of the methods used, or effects on the environment.
2. Organize your questions into a questionnaire.
3. Ask at least six people to answer your questionnaire. Collect their responses.

**A.** Analyze the answers. Write a brief report describing your findings. You may organize your findings using tables and graphs if appropriate.

**B.** Exchange reports with a classmate. Read your classmate's report and note any differences and similarities in your findings. Together with your classmate, write a brief expository paragraph that summarizes your joint findings. Your paragraph should answer the following questions:

- What methods do people use to heat and cool the buildings in which they live?
- How effective are the methods that people use to heat and cool their buildings?
- How do the heating and cooling methods employed affect the environment?

## CHECK YOUR LEARNING

1. (a) Give two examples of ways in which animals keep themselves warm or cool.
   (b) Give one example each of ways in which people keep themselves warm and cool.
2. Describe how home heating and cooling has changed over time, and how it has remained the same.
3. Why do buildings have chimneys?
4. List two costs, or drawbacks, of using an electric air conditioner, and two benefits.
5. Why should we try to use less oil, natural gas, and electricity?

# Explaining Hot and Cold

7.2

We use the word "heat" to describe something that produces warmth. But what is heat? How does heat affect matter? Scientists have tried to understand the causes of warmth and coldness for a long time. Eventually, they developed several explanations for these ideas. Today, scientists explain heat using a theory called the particle theory of matter.

## The Particle Theory of Matter

In the early 1800s, scientists suggested that warmth is caused by the motion of the small particles that make up matter (Figure 1). The faster the particles move, the warmer the material feels. The slower the particles move, the colder the material feels. This explanation of warmth and coldness eventually became part of the **particle theory of matter** (also shortened to "the particle theory"). The main points of the particle theory are listed below:

- All matter is made up of tiny particles.
- Particles have spaces between them.
- Particles are moving all the time.
- Particles move faster when they are heated.
- Particles attract each other.

**particle theory of matter:** a theory that explains what matter is made of, and how it behaves

**LINKING TO LITERACY**

**Summarizing**
After reading, good readers summarize by thinking about the most important details. Ask yourself, "What are the key ideas of particle theory? What were some of the text features and clues that helped me identify the important ideas?"

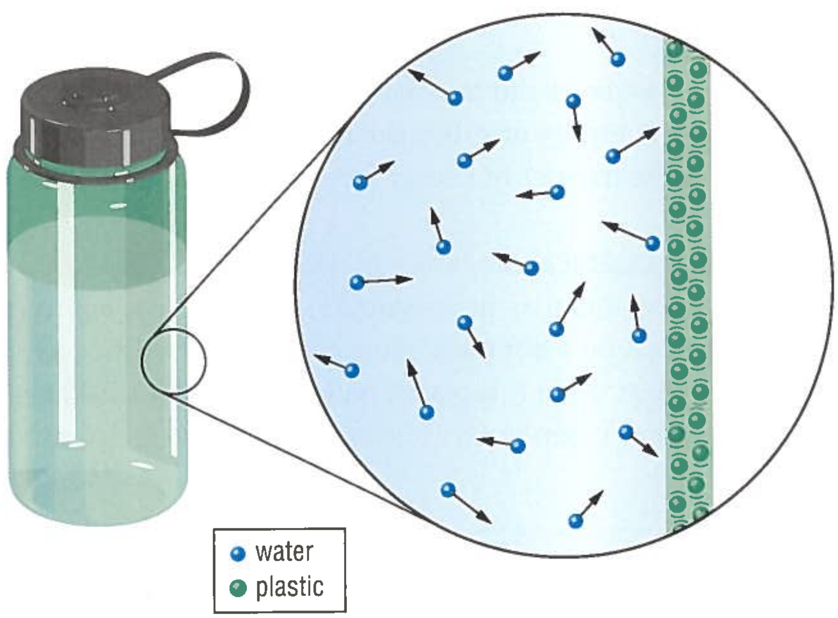



**Figure 1** The particle theory applies to all matter, including the water in this bottle and the bottle itself.

## Heat

The particle theory helps us explain many characteristics of matter, including how matter warms up and cools down. When an object is heated, its particles move faster. When an object is cooled, its particles move slower.

**LINKING TO LITERACY**

**Reading a Diagram**

Diagrams help you understand what is written in the text. Figures 2(a) and (b) are described in the paragraph. As you read, move back and forth between the text and diagram to help you understand each idea.

When a warm object comes into contact with a cold object, the faster-moving particles of the warm object bump into the slower-moving particles of the cold object. As a result, energy is transferred. This causes particles of the cold object to speed up and the particles of the warm object to slow down. If you watch a game of billiards being played, you will see a similar transfer of energy. When a fast-moving billiard ball (the white cue ball in Figure 2(a)) collides with a stationary ball, some energy is transferred. The stationary ball starts to move and the white ball slows down (Figure 2(b)).

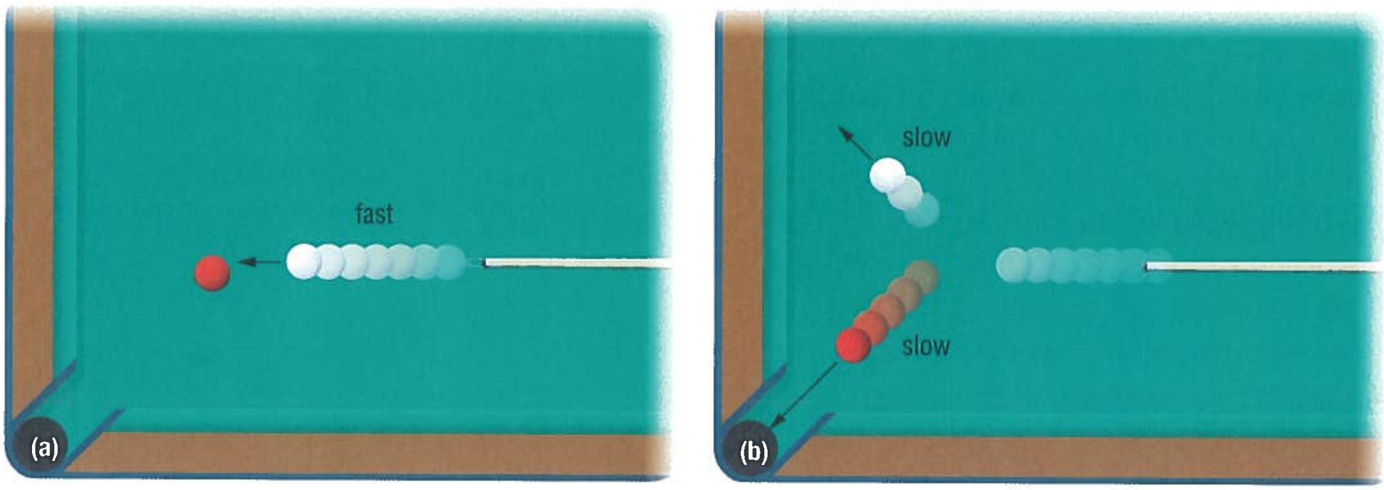



**Figure 2** (a) The white cue ball causes the red ball to move by transferring energy to it. (b) When the cue ball hits the red ball, the cue ball slows down and the red ball speeds up.

**heat:** the transfer of energy from the particles of a warmer object to the particles of a cooler object

To heat an object means to transfer energy to the particles of that object. Heat is not a thing or substance that an object can contain. Instead, **heat** is the transfer of energy from warmer things to cooler things.

You should be careful about how you use the word "heat." In an investigation, you may be instructed to "Heat the water in the beaker by placing it on a hot plate." You should not, however, say, "Water absorbs heat when it is placed on a hot plate." A substance cannot absorb heat. When water is heated, it absorbs energy, not heat.

## CHECK YOUR LEARNING

1. **(a)** Describe a key idea about heat that you understood from this section.
   **(b)** How does the scientific definition of heat compare to the use of the word "heat" in conversational English?
   **(c)** Discuss this idea of heat with a classmate or with your teacher. Write an explanation of heat in your own words. If you like, you may use diagrams or pictures.
2. Summarize the key ideas of the particle theory in your own words or with labelled diagrams.
3. How does the particle theory help to explain the difference between a drop of cold water and a drop of hot water?
4. Explain what is wrong with the statement: "A mug of hot chocolate contains more heat than a glass of cold water."

# Kinetic Energy, Heat, and Temperature

7.3

Warmth and coldness involve the motion of the particles of matter. Since they are always moving, the particles of matter possess a form of energy called **kinetic energy**. All moving objects, large and small, possess kinetic energy (Figure 1). Flying airplanes, the flapping wings of a bird, and invisible vibrating particles all possess kinetic energy.

**kinetic energy:** energy that all moving objects possess; a particle has more kinetic energy when moving faster and less kinetic energy when moving slower


**Figure 1** All objects that move have kinetic energy. There are even moving particles inside of a balloon.

All of the particles in a substance are attracted to each other. So, why do the particles not stick together and stop moving? Particles have a lot of kinetic energy, which keeps them moving. When the environment gets colder, they slow down and come closer together. They never slow down enough to come to a complete standstill.

If you could see the particles of an object, you would notice that they are not all moving at the same speed. Particles of matter collide with each other much like bumper boats in an amusement park ride. Bumper boats collide randomly as they move from place to place (Figure 2). Sometimes, several boats collide in such a way that some slow down and some speed up. Particles of matter also move and collide randomly, some speeding up and some slowing down. Particles do not all possess the same amount of kinetic energy at any given time. Some particles have more kinetic energy than others.

**Figure 2** Bumper boats move and collide with each other randomly. The particles of matter do the same thing.

## Temperature

If you could see the particles of a hot object and the particles of a cold object, you would see that *most* of the particles of the hot object move faster than *most* of the particles of the cold object. Thus, the average kinetic energy of the particles of a hot object is higher than the average kinetic energy of the particles of a cold object.

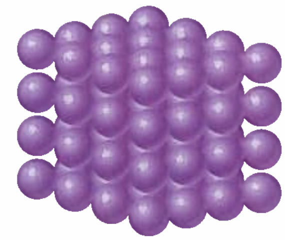
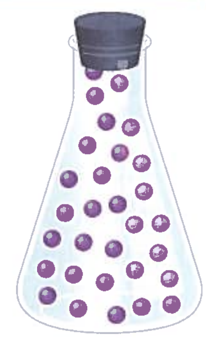
**Temperature** is a measure of the average kinetic energy of particles. If most of the particles of air in your kitchen are moving faster than most of the particles of air in your bedroom, then the temperature of the air in your kitchen is higher than that of the air in your bedroom.

**temperature:** a measure of the average kinetic energy of the particles of a substance

## Particle Theory and the States of Matter

Matter exists in three common states: solid, liquid, or gas (Table 1). The particle theory can be used to explain the characteristics of solids, liquids, and gases.

**Table 1** States of Matter

| State of matter | Description | |
|---|---|---|
| solid | The shapes and volumes of solids do not change because the particles of a solid vibrate. They cannot move past each other. The kinetic energy of the particles is too low to overcome the forces holding the particles together. The particles are packed close together, and are difficult to squeeze into a smaller space. |  |
| liquid | Liquids take the shape of their containers and have fairly constant volumes. The particles of a liquid move faster than the particles in a solid of the same substance. The particles vibrate, rotate, and move past one another. The speeds of the particles prevent the forces of attraction from holding them in one place. However, there is still enough attraction between the particles to keep them from separating completely. The particles of a liquid are slightly more spread out than the particles of a solid. The particles of liquids strongly resist being squeezed closer together. |  |
| gas | Gases expand to fill an empty container. This means that both their volume and shape can change. The particles of a gas vibrate, rotate, and move past one another much more than the particles of solids and liquids. The fast motions of the particles prevent their forces of attraction from holding them close together. Gas particles have very large spaces between them. Their movement is only limited by the size of the container. Gases are relatively easy to compress. |  |

## Particle Theory and Changes of State

According to the particle theory, particles of matter are constantly moving and are attracted to each other. The motions of the particles of a substance (their kinetic energies), and their attraction for each other, determine whether the particles form a solid, a liquid, or a gas. The kinetic energy of the particles *and* the energy of attraction between them are called **thermal energy**. We can increase the thermal energy of a substance by heating it, and we can decrease the thermal energy by cooling the substance. Changes in thermal energy can also cause a substance to change state (Figure 3 on the next page). For example, increasing the thermal energy of a solid may cause it to melt, becoming a liquid.

**thermal energy:** the total kinetic energy and energy of attraction of all the particles of a material

To review the particle theory and the states of matter,
Go to Nelson Science

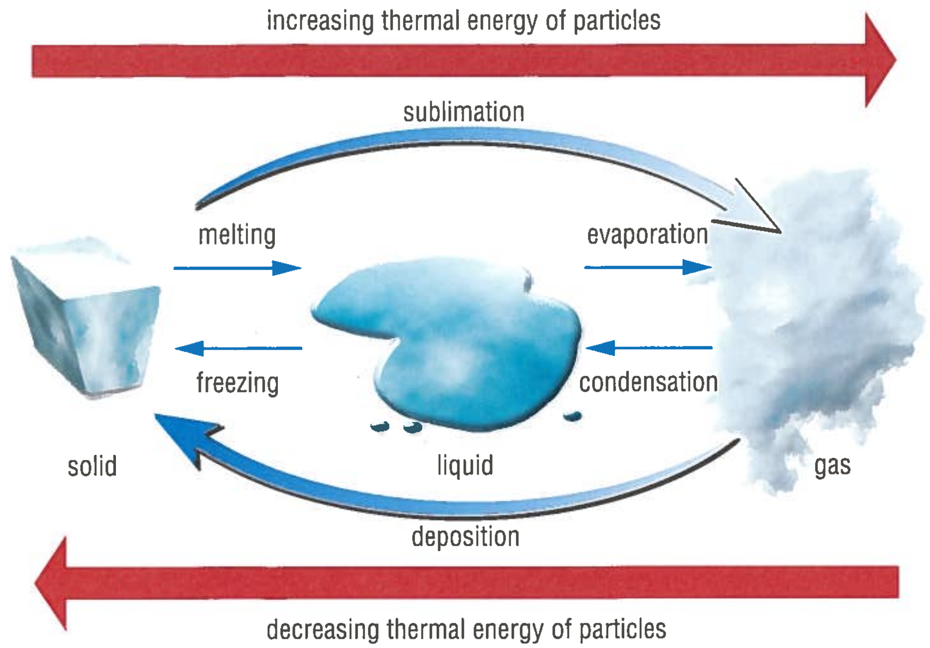



**Figure 3** Changes of state involve changes in thermal energy.

**LINKING TO LITERACY**

**Skimming**

Good readers realize that they may not have understood all of the ideas presented when reading. They verify understanding by skimming through the section to locate important information to reread. Skim the text to recall the meanings of thermal energy, thermal expansion, and thermal contraction.

**thermal expansion:** an increase in the volume of a substance caused by heating

**thermal contraction:** a decrease in the volume of a substance caused by cooling

## Thermal Expansion and Contraction

When solids, liquids, and gases are heated, their volumes usually increase. This process is called **thermal expansion** (Figure 4). Heating a substance speeds up its particles, so they have more kinetic energy. The faster-moving particles travel greater distances, so they occupy more space.

When solids, liquids, and gases are cooled, their volumes usually decrease. This process is called **thermal contraction**. Cooling a substance slows down its particles, so that they have less kinetic energy. The slower-moving particles travel shorter distances, so they occupy less space.

During thermal expansion and contraction, the mass of the object stays the same. The change in volume is not due to an addition or removal of particles, or to a change in the size of the particles. The change in volume is due to an increase or decrease in the spaces between particles. In general, for a given change in temperature, gases expand and contract more than liquids and solids, and liquids expand and contract more than solids.

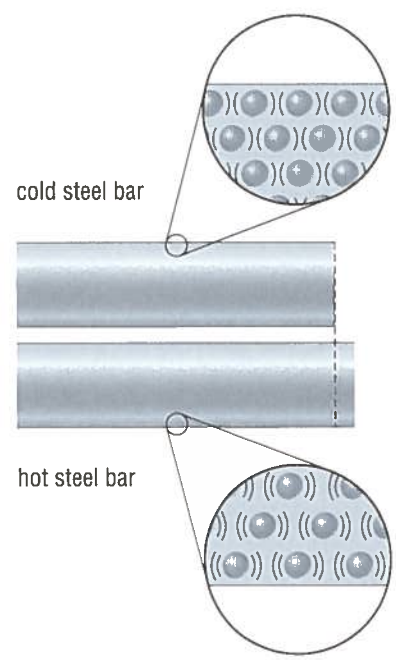



**Figure 4** Thermal expansion occurs when particles move farther apart.

## CHECK YOUR LEARNING

1. Name and briefly describe the two kinds of energy that all particles possess.
2. Describe the relationship between temperature and energy.
3. List the three states of matter in order of decreasing kinetic energy.
4. **(a)** Which state of matter is most easily compressed to take up a smaller volume?
   **(b)** Write a sentence explaining this observation.
5. When a substance is cooled, what happens to its particles? How does cooling affect the volume of the substance?

7.4 CONDUCT AN INVESTIGATION

# Expanding and Contracting

All forms of matter change when they are heated or cooled. In this investigation, you will study the effect of heat on the volume of a liquid (water), a gas (air), and a solid (brass).

**SKILLS MENU**

- [x] Questioning
- [x] Hypothesizing
- [x] Predicting
- [x] Planning
- [x] Controlling Variables
- [x] Performing
- [x] Observing
- [x] Analyzing
- [ ] Evaluating
- [x] Communicating

## Testable Questions

SKILLS HANDBOOK 2.B.1.

**Part A**: Read Part A of the Experimental Design and the Procedure, then write a testable question for Part A.

**Part B**: Read Part B of the Experimental Design and the Procedure, then write a testable question for Part B.

**Part C**: Read Part C of the Experimental Design and the Procedure, then write a testable question for Part C.

## Hypothesis/Prediction

SKILLS HANDBOOK 2.B.3.

**Part A**: Make a hypothesis regarding your testable question for Part A. Your hypothesis should include a prediction and reasons for it.

**Part B**: Make a hypothesis regarding your testable question for Part B. Your hypothesis should include a prediction and reasons for it.

**Part C**: Make a hypothesis regarding your testable question for Part C. Your hypothesis should include a prediction and reasons for it.

## Experimental Design

**Part A**: Coloured water in a test tube fitted with a narrow plastic tube is warmed up, and then cooled down. Any change to the water level in the tube is measured and recorded.

**Part B**: A glass bottle with an empty rubber balloon stretched over its mouth is warmed up, and then cooled down. Any changes to the balloon are observed and recorded.

**Part C**: A brass ball that barely passes through a brass ring is warmed up, and then cooled down. Any changes to the ball are observed by attempting to stick the ball through the ring.

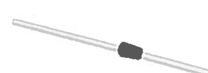
## Equipment and Materials

- eye protection
- apron
- test tube
- rubber stopper with plastic tubing
- glass marking pen
- 2 large beakers
- glass bottle with narrow neck
- empty rubber balloon
- brass ball and ring
- water
- food colouring
- ice


eye protection


apron


test tube


rubber stopper with plastic tubing


glass marking pen


2 large beakers


glass bottle with narrow neck


empty rubber balloon


brass ball and ring


water


food colouring


ice

Be careful when handling glass. Report any breakages to your teacher immediately.

## Procedure

SKILLS HANDBOOK 2.B.5., 2.B.6.

### Part A: Heating a Liquid

1. Put on your apron and eye protection.
2. Add room temperature water to a beaker. Add a few drops of food colouring and swirl the water to mix the colour in. Fill a test tube with the coloured water and then rinse the beaker.
3. Insert a stopper with plastic tubing into the test tube. Ensure that there is no air trapped in the test tube. The coloured water should move up the tube. Use the glass marking pen to mark the water level.
4. Add 300 mL of hot tap water to a beaker.

Be careful not to scald yourself with the hot water.

5. Add 200 mL of cold tap water to a second beaker. Add ice to the water, bringing its volume to 300 mL.
6. Place the test tube in the hot water bath. After 3 min, mark the water level on the plastic tubing and record your observations.
7. Transfer the test tube to the cold water bath. After 3 min, mark the water level on the plastic tubing and record your observations.
8. Remove the test tube from the cold water.

### Part B: Heating a Gas

9. Add new hot water and ice to the water baths.
10. Stretch the opening of an empty rubber balloon over the mouth of a glass bottle.
11. Place the glass bottle in a hot water bath for 5 min. Observe any changes in the balloon, and record your observations.
12. Remove the bottle from the hot water bath and place it in a cold water bath for 5 min. Observe any changes in the balloon, and record your observations.

### Part C: Heating a Solid (Demonstration)

13. Your teacher will show you a brass ball and ring apparatus.
14. Your teacher will attempt to pass a brass ball through a brass ring when both are at room temperature. Record your observations.
15. Your teacher will heat the brass ball, and attempt to pass it through the cooler brass ring. Record your observations.
16. Your teacher will cool the brass ball to room temperature, and attempt to pass it through the brass ring. Record your observations.

## Analyze and Evaluate

SKILLS HANDBOOK 2.B.7.

**(a)** Did the evidence you obtained in Part A support your hypothesis? Explain.

**(b)** Did the evidence you obtained in Part B support your hypothesis? Explain.

**(c)** Did the evidence you obtained in Part C support your hypothesis? Explain.

**(d)** Answer your Testable Questions.

**(e)** How confident are you about your answers to your Testable Questions? Explain.

**(f)** In Part B, what happened to the air in the glass bottle when it was placed in the cold water bath? Provide evidence and explain the results using the particle theory.

**(g)** In Part C, what happened to the brass ball when it was heated? What happened when it was cooled? Provide evidence and explain the results using the particle theory.

## Apply and Extend

**(h)** State an everyday example in which you observe

(i) a gas expanding when heated

(ii) a solid contracting when cooled

**(i)** Materials do not expand by the same amount when heated. What problems might this cause when designing products? Give an example.

# 7.5 Living with Thermal Expansion and Contraction

Materials in our world are exposed to changing temperatures. Computer chips warm up when a computer is turned on and cool down when it is turned off. Buildings and bridges warm up during the day, and then cool down again at night. Buildings also have to withstand the changes that occur between the seasons. Materials expand and contract, sometimes dramatically, during temperature changes. When different materials are used to build a structure, designers must understand how the materials behave when they are heated or cooled.

## Expansion and Contraction of Solids

**Figure 1** The steel rods (at the worker's feet) used to reinforce concrete are designed to expand and contract in the same way the concrete expands and contracts.

It is important to choose the right materials when designing structures that are exposed to changing temperatures. Imagine that designers choose to use two solids that expand or contract differently when heated or cooled. The structure could be damaged by the different amounts of expansion and contraction. For example, the concrete used to build bridges and buildings is reinforced by steel rods (Figure 1). The steel used to make the rods is designed to expand at the same rate as the concrete. If the rods expanded at a different rate, the concrete would crack. The structure could, over time, crumble and fail. In the same way, when a dentist fills a decayed tooth, the filling material must change its volume to the same degree as the tooth itself. Some scientists specialize in the development of dental filling materials that expand and contract just like real teeth.

Bridges and sidewalks are built in segments. They have spaces called expansion joints between them. The expansion joints allow the concrete and steel to expand without buckling and cracking (Figure 2). The thumping sound you hear when you drive over a bridge in a car or bus is the sound of the tires going over the expansion joints.

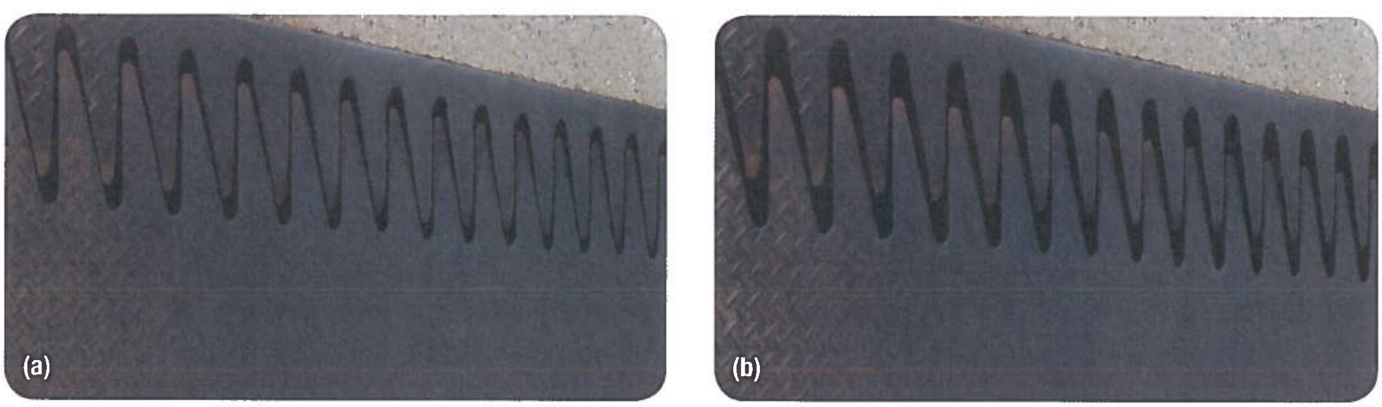



**Figure 2** **(a)** The expansion joints narrow when bridge segments expand in hot weather. **(b)** Expansion joints in a bridge separate when the side-by-side segments of a bridge contract in cold weather.

## Expansion and Contraction of Gases

When a gas in a container is heated, the kinetic energy of the gas particles increases. The particles of the warmer gas hit the walls of the container more often and with greater force. If the walls of the container are flexible, as in a balloon, the more frequent and faster collisions may cause the walls of the container to expand (Figure 3).

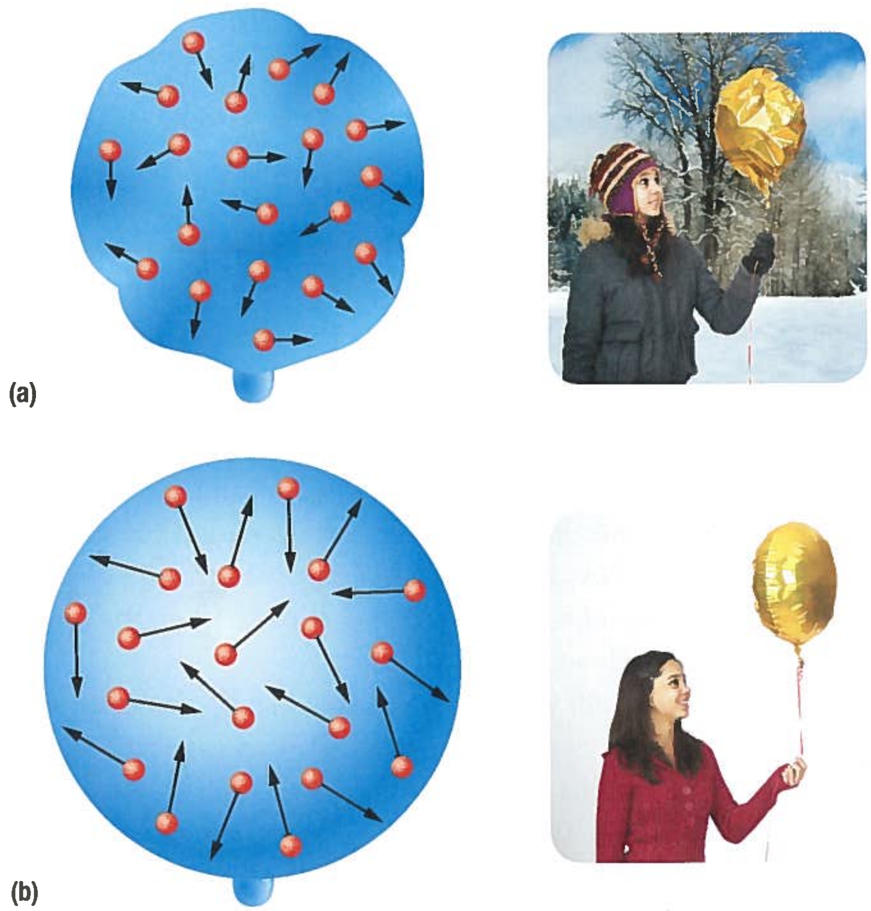


**Figure 3** The helium gas in a Mylar balloon expands a great deal when the balloon is taken from the cold outdoors into a warm room.

(a) At a low temperature, the average kinetic energy of the particles in the balloon is low, so the frequency and force of collisions on the inside walls of the balloon are low.

(b) As the temperature of the gas inside the balloon rises, the particles collide more often with the walls of the balloon. They are also travelling faster. These stronger collisions cause the balloon to expand.

Thermal expansion and contraction affect the volume and pressure of tires, volleyballs, and basketballs. When cars are moving quickly, the rubbing between the tires and the road increases the temperature of the air in the tires. This causes the tires to expand. Tires must be inflated according to manufacturers' recommendations. If they are overinflated when cool, they can burst when they warm up. Volleyballs and basketballs left out in the cold become smaller and softer because of the thermal contraction of the air inside.

## TRY THIS: Hot and Cold Balloons

**SKILLS MENU: hypothesizing, observing, analyzing**

SKILLS HANDBOOK 2.B.3., 2.B.7.

In this activity, you will observe the thermal expansion and contraction of the air in rubber balloons.

**Equipment and Materials:** 3 rubber balloons (same type and same size); black marker; flexible tape measure; refrigerator/freezer

1. Read the procedure, and then write a hypothesis about how the volume of an air-filled rubber balloon may change when it is (a) placed at room temperature for 10 min, (b) placed in a cold freezer for 10 min, and (c) immersed in hot tap water for 10 min. Your hypotheses should include both a prediction and an explanation.
2. Number the balloons 1, 2, and 3.
3. Blow up the balloons to the same volume. Tie the openings to seal the balloons.
4. Using a flexible tape measure, measure and record the circumference at the widest point of each balloon.
5. Expose the balloons to the conditions described in step 1.
6. After 10 min, measure and record the circumference at the widest point of each balloon. (Quickly measure the balloon in the freezer without removing it from the freezer compartment.)

A. Compare the volumes of balloons 1, 2, and 3 before and after the treatments in step 5.

B. Evaluate your hypotheses by comparing them to the evidence you gathered in steps 4 to 6.

## Expansion and Contraction of Liquids

Thermal expansion and contraction affect the volumes of liquids that are used every day. Cars provide a good example of this. Cold gasoline in a car's gas tank expands in hot weather. If the tank is filled to the brim, the gas may overflow. Also, if a car engine is filled with cold liquid coolant, the coolant will warm up and expand when the car is running, and may overflow.

Studies over the past 100 years show that the average temperature of Earth's oceans has been steadily increasing. As the ocean water warms up, its volume increases due to thermal expansion. The greater volume leads to rises in sea levels. This could lead to floods in coastal cities.

**LINKING TO LITERACY**

### Making a Connection

Relating things you have read to events or issues happening in the world is a text-to-world connection. Make a text-to-world connection by asking yourself, "What are some effects of rising sea levels?"

**Unit Task** How can you apply what you have learned about thermal expansion and contraction of solids to the design of your doghouse?

## CHECK YOUR LEARNING

1. Carefully read the following statements and decide if they are true or false. If the statement is false, then rewrite the statement to make it true. (Do not simply restate the statement in the negative.)
   - (a) The particles of a material get bigger when heated.
   - (b) The particles of a material move faster when heated.
   - (c) Of the three states of matter, gases expand the least.
   - (d) The particles of a solid vibrate.
2. A metal entrance door swings freely in the winter, but when the weather turns warm, the door sticks and seems too big for the doorframe. Using your knowledge of particle theory, explain what is happening.
3. When building a device or structure, engineers must carefully consider how the materials they choose will change when heated and cooled. List four situations where thermal expansion and contraction could be a problem.
4. List three unique examples of situations in your daily life where expansion and contraction occur.
5. You want to inflate an air mattress to use in a swimming pool on a hot summer day. Should you fill the mattress with as much air as possible? Why or why not?

# Tech CONNECT

## Sun Kinks, Breather Switches, and Train Disasters

Travelling by train is popular. Passenger trains carry people between towns and cities every day. Freight trains transport products over long distances.

Train cars glide on long parallel steel rails. Train tracks are manufactured in 20 m lengths that are welded together. This ensures a smooth, quiet ride. The continuous welded rail can be several kilometres long.

Railway tracks in Canada are exposed to extreme changes in temperature. These changes can cause a lot of thermal expansion of the rails in summer, as well as contraction in winter. To avoid these changes, the tracks are heated before being put together. Nevertheless, sudden bouts of extremely hot weather can cause a rail to buckle. This forms a twist in the rail that some people call a “sun kink.” Sun kinks are extremely dangerous and have been linked to some serious train disasters.

On July 4, 2005, a train carrying 51 empty fuel cars derailed near Ottawa (Figure 1). It is believed that sun kinks were the cause. Luckily, there were no injuries or deaths in this accident. However, the derailment disrupted normal passenger service between Montreal and Toronto for several days. Passenger train derailments involving sun kinks have caused many injuries and deaths. Scientists and engineers are working to develop rail technology that minimizes the possibility of sun kinks.

One method used to avoid sun kinks is to cut the rails at sharp angles. This leaves a small gap between the cut surfaces. These gaps are called “breather switches” (Figure 2). Engineers continue to work on methods that will improve train transportation safety.

To learn more about sun kinks and breather switches,

**Go to Nelson Science**


**Figure 1** If the cars had been filled with fuel, the derailment would have caused serious damage to wildlife and the surrounding environment.

**Figure 2** A breather switch. The sharp angle at which rails are cut ensures a relatively smooth and quiet ride for passengers.

# CHAPTER 7 SUMMARY

## Heating and Cooling

### BIG Ideas

- [x] Heat is a form of energy that can be transformed and transferred. These processes can be explained using the particle theory of matter.
- [ ] There are many sources of heat.
- [ ] Heat has both positive and negative effects on the environment.

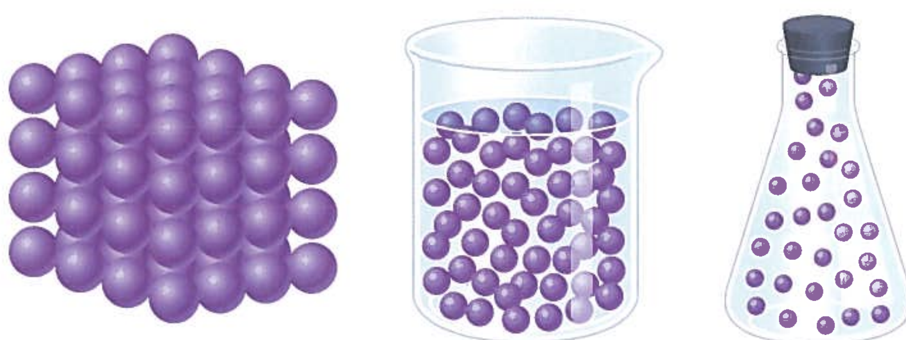
## Looking Back

**Heating and cooling are important in everyday natural and artificial processes.**

- All living things are most comfortable within a certain temperature range.
- Many animals adapt their behaviour to keep their bodies at a comfortable temperature.
- Humans adapt to their surroundings by using heating and cooling technologies.

**The particle theory explains heating and cooling.**

- All matter is made of invisible particles. Particles have spaces between them. Particles are moving all the time. Particles move faster when they are heated. Particles attract each other.
- Heating and cooling a substance affects the motion of its particles.
- Solids, liquids, and gases can be described in terms of the arrangement and motion of their particles.
- Moving particles possess kinetic energy. A faster-moving particle possesses more kinetic energy than a slower-moving particle.
- Thermal energy includes the kinetic energy of all the particles in a substance and the energy associated with the attractive forces between the particles in the substance.



**Heat is the transfer of energy from warmer substances to cooler substances.**

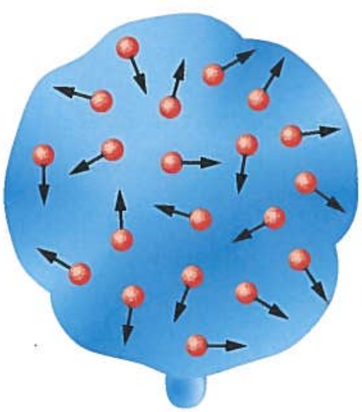
- Temperature is a measure of the average kinetic energy of the particles in a substance.
- The faster the particles of a substance move, the hotter the substance is; the slower the particles of a substance move, the colder the substance is.
- When a hot object comes into contact with a cold one, the fast-moving particles of the hot object bump into the slow-moving particles of the cold object. The fast-moving particles slow down as they transfer energy to the slow-moving particles.

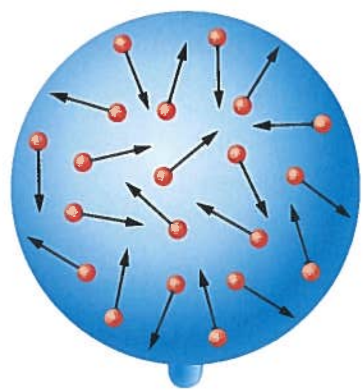
**VOCABULARY**

particle theory of matter, p. 185
heat, p. 186
kinetic energy, p. 187
temperature, p. 187
thermal energy, p. 188
thermal expansion, p. 189
thermal contraction, p. 189

**Most materials expand when they are heated and contract when they are cooled.**

- When a material is heated or cooled, the motion of its particles is affected. When heated, the particles move faster and farther apart. When cooled, the particles move slower and come closer together.
- The expansion and contraction of solids, liquids, and gases must be considered when designing structures or devices that are subjected to changes in temperatures.
- When the temperature changes, solids expand and contract the least, while gases expand and contract the most.





**Investigation skills can be used to learn about expansion and contraction of different materials.**

- Expansion and contraction of solids, liquids, and gases can be observed and analyzed.
- The particle theory can be used to explain observations made about expansion and contraction.

CHAPTER 7

# REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding, T/I Thinking/Investigation, C Communication, A Application

## What Do You Remember?

1. (a) Describe two things that humans do to warm up.
   (b) Describe two things that animals other than humans do to warm up. K/U
2. Briefly summarize the particle theory in your own words. K/U
3. Copy Table 1 into your notebook and complete it. K/U

**Table 1** Descriptions of Three States of Matter

| | Solid | Liquid | Gas |
|---|---|---|---|
| volume | | | |
| shape | | | |
| type of particle motion | | | |
| spaces between particles | | | |

4. Use the particle theory to explain why gases expand more than liquids or solids when they are heated. K/U
5. Write a definition of "heat," using your own words. K/U
6. From what you have seen or read, list two examples each of
   (a) thermal expansion in solids
   (b) thermal expansion in liquids
   (c) thermal expansion in gases K/U A

## What Do You Understand?

7. (a) List five situations where heat plays a role in your daily life (for example, cooking an egg). T/I A
   (b) Give three examples of state changes that you see happening in your daily life. A
8. Solids expand slightly when heated. For this reason, bridges and railway tracks are built with expansion joints. Use the particle theory to explain what might happen on a hot day if expansion joints were not used. K/U A
9. Use diagrams and words to explain what happens to the particles of matter in each of the following situations (Figure 1(a) to 1(c)). Consider these questions: Are the particles moving faster or slower? Are the particles getting closer or farther apart? What change of state is occurring?
   (a) Droplets of water form on the outside surface of a glass of water.
   (b) Butter melts in a hot skillet.
   (c) The red line in a liquid thermometer gets shorter as the temperature drops. K/U C

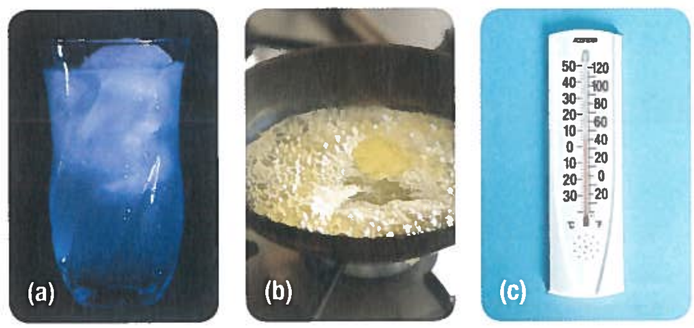



**Figure 1**

10. Perspiration (sweat) helps a person cool down. What change of state is involved in sweating? K/U A
11. You are boiling vegetables on the stove and notice the lid of the pot moving up and down. Use the particle theory to explain what is happening. K/U
12. Thermal expansion can be useful or it can be a problem. Research the effects and uses of thermal expansion. Choose one example of thermal expansion and write a summary paragraph about it. K/U A

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## Solve a Problem!

**13.** (a) Many containers that hold food are made of glass sealed with a metal lid. These lids can be difficult to remove. Holding the lid of the jar under hot water for a short time makes the lid easier to remove. Explain why this works.

(b) An auto mechanic is having difficulty loosening the nut on a bolt using only a wrench and a pair of pliers. How can the mechanic use the ideas in this chapter to solve this problem? K/U A

**14.** (a) Some people hang wet clothing out to dry on warm, sunny days. Why does wet clothing dry in this weather?

(b) Some people hang wet clothing out to dry even on freezing cold days. Will wet clothes dry in this weather?

(c) What would happen to juicy vegetables left on a plate in a freezer for a long time? How can this be prevented? K/U A

**15.** A bimetallic strip is made of one type of metal on one side and a different metal on the other side (Figure 2). The strip bends one way when heated.

Figure 2

(a) Explain why the strip bends when heated.

(b) Conduct library or Internet research to determine how bimetallic strips are useful.

(c) How could a bimetallic strip be used to help you perform a practical task in everyday life? K/U A

Go to Nelson Science

## Create and Evaluate!

**16.** An amount of ice is lighter than an equal amount of liquid water. Use the library or the Internet to research and explain what this statement means. Write a short script, story, or poem describing the implications of this effect for life on Earth. T/I A C

Go to Nelson Science

**17.** Using the Internet, research the thermoscope. Write a short description of this instrument, indicating how it worked and what it was made of. Compare the thermoscope with thermometers used today. How useful would the thermoscope be in everyday tasks? T/I A

Go to Nelson Science

## Reflect on Your Learning

**18.** Think back to the Key Question on the first page of this chapter.

(a) In a brief paragraph, answer the Key Question. You may use diagrams.

(b) Write one or two more questions about the topic of this unit that you would like to explore.

**19.** Think about a new idea regarding heat that you have learned in this chapter. How may this idea change some of the things you do on a daily basis?

**20.** Which concept presented in this chapter did you find the most interesting? What new questions do you have about this concept?