11.0 Heat plays an important role in nature.

The beautiful image of Hurricane Katrina from space does not suggest the destruction that Katrina caused on Earth.

What You Will Learn

In this chapter, you will:

- identify the layers of Earth's atmosphere
- describe the effects of radiant energy on large bodies of water and land
- explain the relationship between heat, the water cycle, and weather patterns

Skills You Will Use

In this chapter, you will:

- use appropriate equipment and tools
- record and organize data
- analyze patterns and report results

Why This Is Important

Natural events affect human lives. Learning about Earth's structure and environmental processes will help you understand the events and changes that influence your life and the lives of people in your family and community.

Before Reading

Thinking Literacy

Asking Questions

Asking questions before starting to read helps readers set a purpose for reading, as well as get more involved with the text. Scan the pictures, diagrams, and summary boxes in this chapter to get a sense of the heat and weather topics being covered. Develop some questions you have about these topics. Revisit your questions during reading to see which ones have been answered in the text.

Key Terms

- atmosphere
- ocean current
- volcano
- water cycle
- wind
- rock cycle

11.0 Getting Started

Figure 11.1 Severe storms can cause great damage to natural and mechanical systems.

August 2, 2006, was a day that many Ontario residents will remember for a long time. That day, much of Ontario was hit by severe thunderstorms and high winds, resulting in floods and outages of the electricity supply. The violent weather came after three days of extreme heat and humidity over southern and central Ontario. Trees were uprooted and power lines brought down, causing power outages in an area from Toronto north to Bracebridge and east to Tweed (Figure 11.1). About 150 000 customers were affected. It took several days to restore power to all the homes and businesses.

Minden was the area most affected by the storm, but the Tweed area, Barrie, Orillia, Huntsville, Newmarket, Peterborough, Kingston, Walkerton, Simcoe, Guelph, and Orangeville also felt the effects of winds up to 120 km/h (Figure 11.2). A tornado was reported in the middle of the afternoon in the area of Highway 401 and Highway 6.

You might wonder what causes such violent storms to happen. Scientists who study how heat affects the atmosphere also ask this question because heat is an important part of the environment and can affect weather events.

Humans produce and use a large amount of heat in their activities. The production of heat adds a variety of chemical pollutants to the environment. Canadians are among the groups of people around the world who are concerned about how these pollutants affect the environment, the living things that are part of the environment, and themselves.

Figure 11.2 The August 2006 storm covered a large area of southern and eastern Ontario.

D22 *Quick Lab*

Cycling Water and Heat

The Sun controls natural systems on Earth, including the water cycle and the weather. A model is a design, object, or idea used to explain or visualize something difficult to see. In this activity, you will create a model to show how heat plays a role in the water cycle.

Purpose

To create a model of Earth's water cycle

Materials & Equipment

- hot plate and beaker (or kettle)
- water
- ice cubes
- cake pan
- oven mitts

Figure 11.3 Set-up for Quick Lab

CAUTION: Steam is very hot. Wear oven mitts. Do not allow the steam to touch your skin.

Procedure

1. Place the beaker of water on the hot plate or fill and plug in the kettle.

2. Place the ice cubes inside the cake pan. Wait a few minutes.

3. When the water is boiling, use the oven mitts to hold the cold cake pan over the beaker.

4. Observe the bottom of the cake pan.

Questions

5. Describe what you saw on the bottom of the cake pan when you held it over the beaker of boiling water.

6. Draw and label a diagram to illustrate the materials and equipment and your results.

11.1 Heat Affects the Air Around Us

Here is a summary of what you will learn in this section:

- Human activities depend on the atmosphere.
- The atmosphere has five layers; humans live in the troposphere.
- Weather on Earth depends on heat transfer from the Sun.

Quick: take a deep breath, then breathe out. While you are reading this page, you are breathing easily. You probably realize you cannot do that just anywhere — in other words, you need to be somewhere where clean air is available.

Have you considered what it is that you are breathing and that surrounds you? It is called Earth's **atmosphere** — the blanket of gases that surrounds Earth. Whether you are reading this page at school, at home, or somewhere else, the atmosphere surrounds you.

The atmosphere includes the air humans need to live. It also includes a mixture of dirt, dust, and other substances — including some that human activities release into the air as pollution. When you breathe, you take air and a mixture of these other substances into your lungs. One of the gases in air, oxygen, is the gas that animals (including you) require to live.

D23 *Starting Point*

Skills A C

Coming Up for Air

Figure 11.4 shows situations where humans must be aware of the constant need for fresh air. By yourself or with a partner, give each photograph a title. Record the letter and title for each. Briefly, provide information about what is happening in each photograph. Add any personal connections that you may have to these activities.

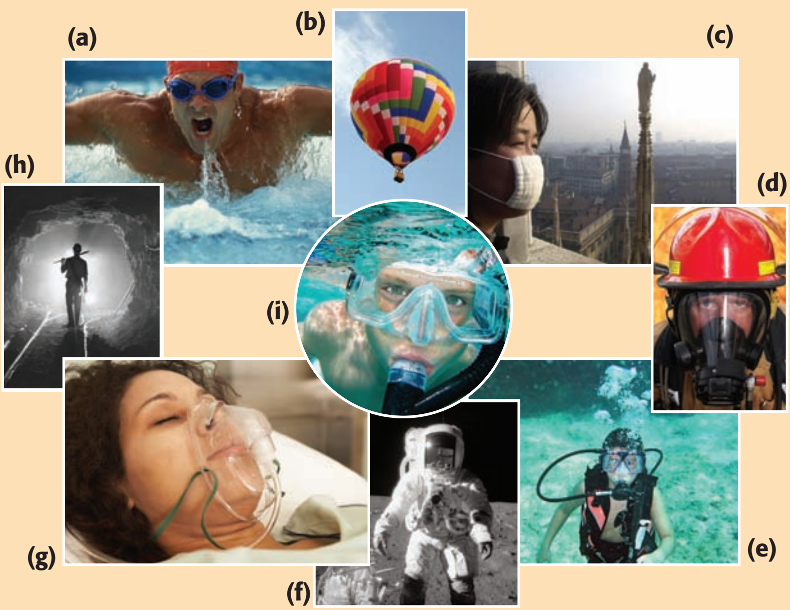


Figure 11.4 Humans need fresh air in all situations.

D24 *During Reading*

Thinking Literacy

Question Types

When readers ask questions and look for answers as they read, they are interacting with the text in a meaningful way. There are different types of questions readers can ask:

- literal or "on the line" questions. The answer is found in the text.
- inferential or "between the lines" questions. The reader interprets information from the text along with background knowledge to answer.
- evaluative or "beyond the lines" questions. The answer may not be in the text at all. Readers need to use their background knowledge and experiences to answer.

Revisit the questions you developed at the beginning of this chapter. Use the information above to determine whether each of your questions is literal, inferential, or evaluative. Where will you find the answers to each of your questions?

Learning about Layers of Air

Wherever you go above the surface of land or above the oceans, you are surrounded by the mixture of gases that make up Earth's atmosphere. Humans live in the bottom layer of the atmosphere. Of course, many types of birds, such as the peregrine falcon, and other animals who live in trees spend some of their time in the atmosphere at a higher level than humans. Trees like the eastern white pine (Figure 11.5) extend many metres up into the atmosphere.

Conditions in the atmosphere, including rain, wind, and temperature, all affect human life. Think about thunderstorms and blizzards. Also think about sunny days at the lake, and plants growing in the spring. All of these examples show how changes in the atmosphere above Earth's surface are important not only to scientists but also for everyday life.

Scientists who study the atmosphere divide it into five main layers according to the changes in temperature as you go higher above Earth's surface (Figure 11.6 on the next page):

- the troposphere — from 0 to 20 km
- the stratosphere — from 20 to 50 km
- the mesosphere — from 50 to 85 km
- the thermosphere — from 85 to 690 km
- the exosphere — from 690 to 10 000 km

Figure 11.5 The eastern white pine is the provincial tree of Ontario. It is the tallest tree in eastern North America. The record height for this species is more than 60 m.

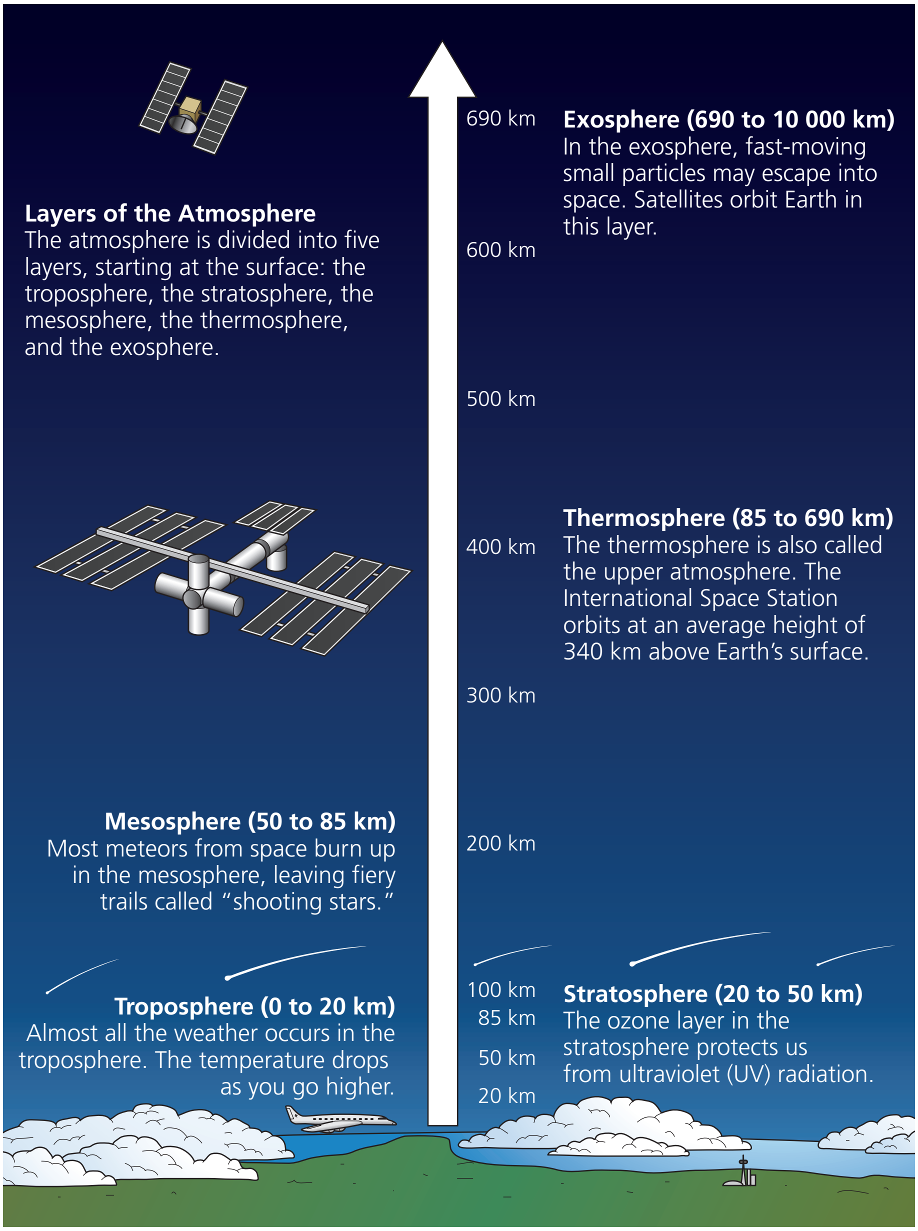


Figure 11.6 The atmosphere is divided into five layers, starting at the surface: the troposphere, the stratosphere, the mesosphere, the thermosphere, and the exosphere. Data are from National Oceanic and Atmospheric Administration (NOAA), U.S. Dept. of Commerce.

The Troposphere

Humans live in the lowest level of Earth's atmosphere — the **troposphere.** Almost all human activity, including air travel, goes on in this layer. As the word troposphere suggests, constant changes occur in the troposphere. In fact, it is the layer of the atmosphere in which Earth's weather occurs. But what is weather? **Weather** refers to the conditions of Earth's atmosphere at a particular time and in a particular place. The study of weather and weather patterns is called **meteorology**.

WORDS MATTER

Troposphere: The word troposphere comes from *tropo* (turning, changing) and *sphere* (ball-shaped).

Meteorology: The word meteorology comes from a Greek word meaning the discussion of things that happen in the sky.

Heat Transfer and Earth's Weather

What causes changes in our weather? For the answer, you have to consider not only Earth but also the source of much of Earth's energy — the Sun. The energy from the Sun that reaches Earth contributes to changes in Earth's weather systems and affects the weather in your local area.

Although it is an average-sized star, our Sun is the source of a huge amount of energy. Only a small fraction of it reaches our planet. Even so, the amount of energy reaching Earth's surface every day is more than 6000 times the amount of energy used by all humans on Earth in a day. Are you wondering what happens to this energy? Study Figure 11.7 to find out.

Take It Further

Scientists have learned a lot more about Earth's atmosphere. You can, too! Begin your search at ScienceSource.

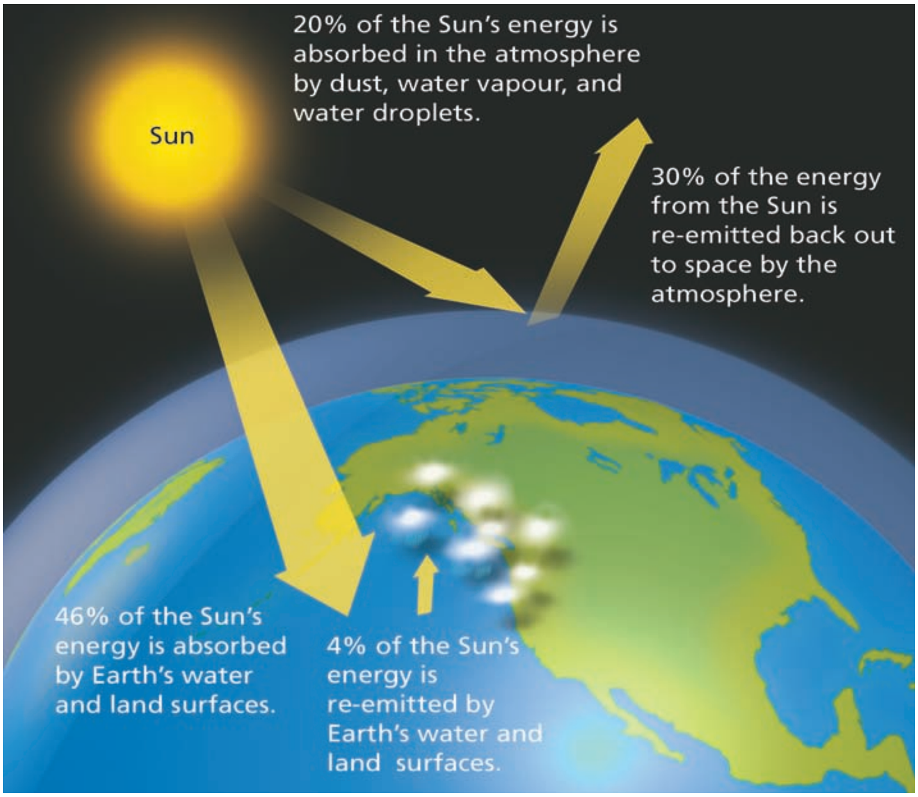


Figure 11.7 Scientists estimate that less than one-billionth of the Sun's total energy output each day actually reaches Earth. Even this small portion represents a huge amount of energy.

D25 *Learning Checkpoint*

Reflecting on the Sun

Draw a two-column chart in your notebook as shown in Table 11.1. Refer to Figure 11.7 to complete the table. Summarize what happens to the energy that reaches Earth.

Table 11.1 The Sun's energy

What Happens to the Sun's Energy?	Percent of the Sun's Energy

D26 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Recording and organizing data
- Analyzing patterns

Curious Candle

Air contains a mixture of gases, including oxygen. How long can a candle burn inside a closed container? How does the size of the container affect the time for a burning candle to go out? In this activity, you will use several beakers to observe the effect of heating different volumes of air inside the beakers of different sizes.

Question

How long can a candle burn under beakers of different sizes?

CAUTION: Do not touch the hot beaker after the candle has gone out.

Materials & Equipment

- pie plate
- small candle
- matches
- beakers of different sizes
- oven mitts
- modelling clay
- water
- clock or stopwatch

Hypothesis

Suggest how the size of a beaker might affect the time a candle can burn inside it. Record your answer.

Procedure

1. Copy Table 11.2 into your notebook.
2. Place a small piece of modelling clay onto the centre of the pie plate.
3. Stand the candle upright in the modelling clay.
4. Fill the pie plate with water.
5. Your teacher will light the candle.
6. As you place the smallest beaker over the candle, start timing. Closely observe the spout of the beaker and record your observations.
7. When the candle goes out, record the time in minutes and seconds in your table.
8. Use an oven mitt to lift the beaker out of the pie plate. Do not let water drip on the candle.
9. Repeat steps 5–8, replacing the small beaker with the middle-sized beaker.
10. Repeat steps 5–8 using the largest beaker.

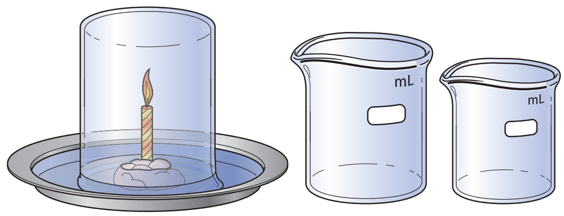


Figure 11.8 Set-up for activity

Table 11.2 Effect of beaker size

	Size of Beaker (mL)	Time That the Candle Lasted (min and s)
smallest beaker		
middle-sized beaker		
largest beaker		

Analyzing and Interpreting

11. Compare the three results you recorded in your table. Record your comparison.
12. Why did you need to start this activity by adding water to the pie plate?

Skill Builder

13. Predict how long the candle flame would last under a beaker twice as large as the largest beaker you used in step 10.

Forming Conclusions

14. What effect does the size of the beaker have on how long the candle will burn?

11.1 CHECK and REFLECT

Key Concept Review

1. Define "atmosphere" in your own words.

2. Name two locations where humans need technology to breathe.

3. Name the five layers of the atmosphere in order, starting from Earth's surface.

4. In which layer of the atmosphere do we find the most human activity?

5. What percent of the Sun's energy that reaches Earth is absorbed by Earth's water and land surfaces?

Connect Your Understanding

6. A friend tells you: "The atmosphere is just a bunch of gas." Do you agree with this statement? Defend your answer.

7. Invent a mnemonic sentence for the five layers of the atmosphere using the letters T — S — M — T — E.

8. The word atmosphere comes from *atmo* (vapour, smoke) and *sphere* (ball-shaped). Why is this a suitable name for the blanket of air that surrounds you?

9. A simile is a comparison that uses the words "like" or "as." Write sentences to compare something in your life with the layers of the atmosphere. Refer to the description of the atmosphere in this section. Start with the sentence: "The atmosphere is like a ________ because __________."

10. Scientists estimate that less than one-billionth of the Sun's total energy output each day reaches Earth. What do you think happens to the rest? (**Hint:** Consider the size of Earth.)

Practise Your Skills

11. Draw a bar graph of the data for the Sun's energy, shown in Figure 11.7. Use graph paper, a ruler, and coloured pencils.

12. Create a mini-poster using your mnemonic sentence from question 7. On your poster, include your mnemonic sentence along with the names of the matching five layers of the atmosphere. Add a colourful illustration for each layer. Give your mini-poster an original, creative title.

For more questions, go to ScienceSource.

D27 *Thinking about Science and the Environment*

Mapping the Atmosphere

You have learned what happens to the Sun's energy that reaches Earth. Human activity adds gases and small particles to the air that can trap heat and warm the atmosphere. Create a consequence map with the central question, "What are the consequences of humans adding gases and other substances to Earth's atmosphere?" The first level of your map will be the positive and negative consequences you think will result. The second and third levels of your map will provide more information for each positive and negative consequence.

11.2 Heat Affects Water

Here is a summary of what you will learn in this section:

- Water is continuously moving and changing states in nature.
- Heat creates the water cycle and affects weather.
- The water cycle and ocean currents depend on convection.

Figure 11.9 Water is an important consideration for farmers.

Air and water are valuable resources that humans need and use every day. The health of your family and the success of many businesses depend on these important natural resources. Just like air, water on Earth is a shared resource. How we use water or misuse it can affect people and human activities far away from us. Think about all the ways you use water or depend on water every day. It is a long list.

Water is important for farmers everywhere (Figure 11.9). A farm cannot exist without water for crops and animals. At one time, farmers may have been less concerned about the amount of water they used. Today, with technology like computers and satellites, farmers are able to monitor and closely control their water use. In addition, new farming techniques mean that farmers may need less water to grow crops.

Water use in Ontario and in all locations on Earth is influenced by the **water cycle** — the movement in nature of water from the surface of Earth to the atmosphere and back. How farmers use and recycle water affects how much water sinks into the ground, how much water flows over the surface, and even how much water evaporates from their cropland.

D28 *Starting Point*

Skills A C

Wonderful Water

It's time for some quick writing. Grab a pen or pencil. Record the title of this activity. Then, write non-stop for two or more minutes. The topic is: "How Do I Depend on Water?" Ready? Set? Write.

Heat Flow in the Water Cycle

The energy of the Sun is directly responsible for three very important natural systems that affect life on Earth — the water cycle, weather patterns, and ocean currents. Think about the water cycle. You have seen that adding heat to water by boiling causes the water to change from a liquid to a gas. But it is not necessary to boil water to cause this change of state. Adding a smaller amount of heat has the same result; it just happens more slowly. Figure 11.10 shows one example of this idea.

Water in a puddle slowly seems to disappear, even on a cloudy day. In fact, it evaporates — turning into invisible water vapour. On the other hand, when hot steam touches a cool surface, it condenses, changing from water vapour to liquid water that can cover or drip from the surface (Figure 11.11).

These observations indicate a **cycle**, a continuous movement of materials in nature that repeats. The mist on the bathroom mirror is a home version of part of Earth's water cycle — the movement in nature of water from the surface of Earth to the atmosphere and back (Figure 11.12).

Water in the atmosphere is not always invisible. When the temperature high above Earth starts to decrease, water droplets join together. Slowly, the smaller droplets become larger droplets, forming a cloud that we can see. As the water droplets grow even larger, they also become heavier and will begin to fall as rain, also called **precipitation**.

Puddles of water evaporate due to heat. As the temperature drops, water droplets in clouds join together and fall as rain. You can see that heat plays a role in the two changes of state in the water cycle:

- evaporation (liquid water on Earth absorbs heat and changes into water vapour)
- condensation (invisible water vapour in the atmosphere cools down and changes back into drops of water that fall as rain).

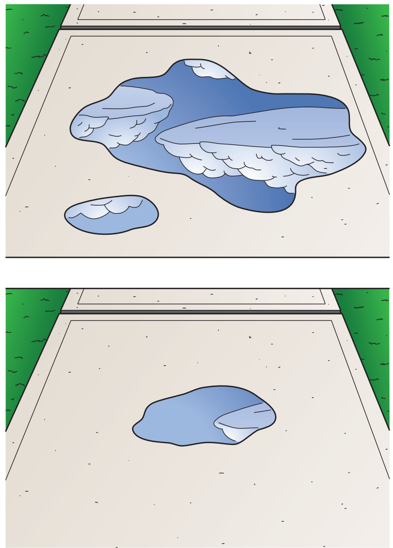


Figure 11.10 There is enough heat in the air on a warm day to evaporate the water in a puddle.

Figure 11.11 The mist is caused by water vapour that condensed on the cool mirror.

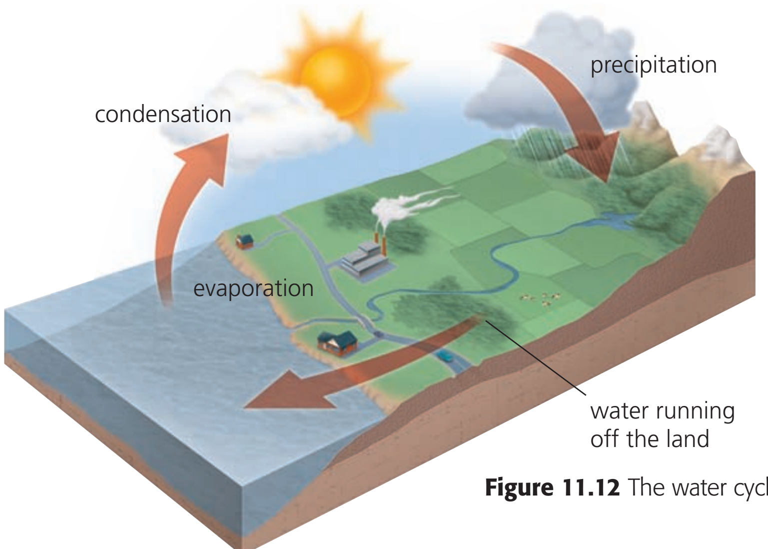


Figure 11.12 The water cycle

D29 *Learning Checkpoint*

Weather and the Water Cycle

Draw a chart in your notebook as shown in Table 11.3. In column A, print or write the three questions to consider. In column B, try to answer these questions. After reading "Weather and the Water Cycle," complete column C.

Questions to Consider

1. How does the Sun shine down on different parts of Earth?
2. What causes ocean currents?
3. How do ocean currents affect life in the oceans?

Table 11.3 Weather and the water cycle

Column A Questions about Weather and the Water Cycle	Column B What I Know before Reading	Column C What I Know after Reading

Weather and the Water Cycle

Since Earth is roughly a sphere the Sun's radiant energy does not fall evenly on Earth's land and seas (Figure 11.13). All year round, even though Earth is moving through space, the Sun shines more directly down on the land and ocean at and near the equator, heating them more strongly.

Ontario and the rest of Canada are north of the equator. This means that in Canada the Sun's rays fall less directly than at the equator. The same amount of heat is spread over a larger area on Earth's surface. Also, in winter, Canada receives far less sunlight, making most of Canada cold and snowy.

The differences in temperature between regions near the equator and northern and southern regions set in motion a continuous movement of air across Earth. This movement distributes heat from the Sun across the planet. The movement of air in the troposphere is called **wind**.

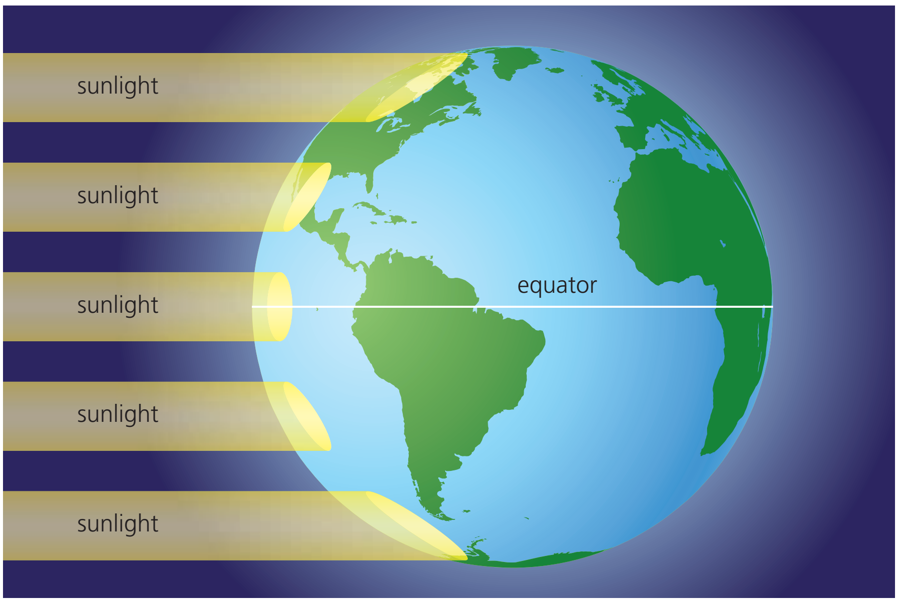


Figure 11.13 Near the equator, the Sun's rays are more direct and therefore stronger all year round.

When air in one region is warmer than the surrounding air, it becomes less dense and begins to rise, drawing more air in underneath. A convection current is set up. For example, during the day, land heats up more than water. The air above the land near large lakes or an ocean heats up and rises. Cooler air from above the water rushes in, creating a cool sea breeze. At night, when the land cools down more quickly than the water, the opposite is true. Warm air above the water rises while cooler air from the land takes its place, creating a cool land breeze.

All the while, air is carrying water vapour and water droplets that circulate from Earth into the atmosphere and back again in giant convection currents. The water cycle is one of several factors that influence the weather in your region of Ontario and around the world. In one location, the weather may be warm and sunny; only a few kilometres away, it could be raining and windy.

Take It Further

Be an amateur weather watcher! Track Canada's weather patterns yourself. Environment Canada posts weather maps for regions in Canada on the Internet. You can find 5-day forecasts for your region of Ontario as well as any region in Canada. Begin your search at ScienceSource.

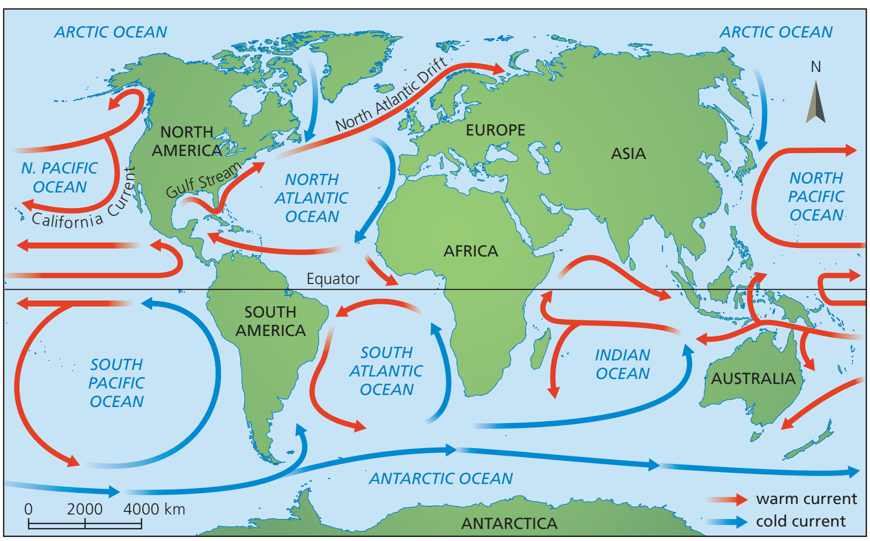
Heat and Ocean Currents

An **ocean current** is a pattern of movement of the water in a large region of the ocean. Ocean currents contribute to the movement of thermal energy from the warm regions of Earth near the equator to the colder regions in the Arctic and Antarctic. In effect, these convection currents partially balance the extremes of temperature on Earth's surface.

An ocean current is like a river of warm or cold water moving in a more or less circular pattern. This pattern influences the **climate**. The climate is the long-term weather conditions over large areas of Earth. Ocean currents affect the land areas that form Canada's western, eastern, and northern coasts, as well as the routes taken by ships carrying products and people (Figure 11.14).

Ocean currents flow in convection patterns that depend on wind, the minerals dissolved in the water, the shape of the ocean floor in different locations, heat from the Sun, the pull of the Moon's gravity, and even Earth's rotation (spin).

Figure 11.14 Major ocean currents



Scientists have discovered more than 50 different ocean currents. Ocean currents and their patterns are of interest in studies of Earth's air and water systems and changes in climate.

Keeping It Warm, Keeping It Cool

Ocean currents flow in a circular pattern — clockwise in the northern hemisphere, where Canada is found, and counterclockwise in the southern hemisphere, south of the equator. There are three categories of ocean currents (Table 11.4).

Table 11.4 Categories of ocean currents

Category of Current	Ocean Layer	Flow Direction	Factors That Drive Current
warm surface current	at and near surface	from near equator toward north and south poles	wind spinning of Earth
cold surface current	at and near surface	from polar regions toward equator	mainly wind
deep ocean current	deep ocean	form at poles; flow toward equator and rise to surface	density of water differences in temperature between layers

Ocean currents influence life in the oceans. The ocean is layered: warmer on top, cold at the bottom. The range of water temperatures in each layer controls which organisms can live there. Ocean organisms are sensitive to changes in temperature. A change in temperature of even a few degrees may be enough to cause these organisms to change their location. Other organisms that depend on them for food must also move or die of starvation.

Figure 11.15 A tornado may form as the result of a thunderstorm, at the boundary between warm, moist air and hot, dry air.

Spinning Systems

The moving atmosphere and oceans circulate continuously. The results are wind and storms in the troposphere and currents in the oceans. Strong winds can be very destructive and may produce **hurricanes** and **tornadoes.** A hurricane is a strong, spinning weather system over the ocean that has continuous winds exceeding 119 km/h. Hurricanes form and grow stronger as they pick up heat from warm tropical ocean water. Tornadoes are strong, spinning columns of air in contact with the ground. They are unpredictable, usually local, and last only a short time (Figure 11.15).

DI Anchor Activity

D30 Inquiry Activity

Toolkit 2

SKILLS YOU WILL USE
- Analyzing patterns
- Reporting results

Bottled Weather — Teacher Demonstration

A 2-L plastic bottle with some smoke particles inside can provide a model of a common event that occurs every minute in the atmosphere.

Question

How can you model cloud formation?

Materials & Equipment

- 2-L or smaller colourless plastic bottle with cap (remove the label)
- warm water
- booklet of matches
- black paper

CAUTION: Be careful when using matches.

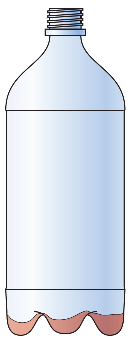


Figure 11.16 Set-up for activity

Hypothesis

Predict what might happen when you squeeze a 2-L bottle that is filled with smoke and water vapour.

Procedure

1. Place just enough warm water in the bottle to cover the bottom. Replace the cap.
2. Shake the bottle vigorously for one minute.
3. Light a match and let it burn for a few seconds. Blow out the match and immediately place the head of the match into the bottle. Let the smoke fill the bottle. Remove the match.
4. Observe that, after a few seconds, the smoke will seem to disappear.
5. Screw the cap on the bottle, being careful not to let too much smoke escape.
6. Hold the bottle over a dark surface such as a dark counter top or black paper. Quickly squeeze the sides of the bottle really hard, then release. Do this six or seven times (more squeezing may be necessary). Hold the last squeeze for a few seconds, and then quickly release it. As soon as you release the squeeze, look for a change inside the bottle.

Analyzing and Interpreting

7. Do you think that there was invisible water vapour inside the bottle before you placed the head of the match into the bottle? Suggest how you know this.
8. Interpret the changes that occurred quickly after squeezing and releasing the bottle.
9. Why do you think you needed to squeeze the bottle several times?

Skill Builder

10. Use drawings to illustrate the steps in the procedure. Include your observations of changes inside the bottle. Number each drawing with the matching step in the procedure.

Forming Conclusions

11. Suggest how your observations in this activity could help explain the formation of clouds in the atmosphere.
12. Suggest conditions in the atmosphere that might lead to more clouds forming.

11.2 CHECK and REFLECT

Key Concept Review

1. Why is the name water cycle suitable for the movement of water on Earth?
2. How does heat cause ocean currents?
3. Suggest a reason why the oceans near the equator are warmer than the oceans closer to Earth's poles.

Connect Your Understanding

4. List two examples of ways human activity influences the water cycle.
5. Compare the steps in the water cycle to another cycle of events in daily life. You can start your comparisons with a statement such as : "The water cycle is like ______________ because _____."

Practise Your Skills

6. Design, draw, and label your own illustration of the water cycle. Alternatively, plan a physical activity to represent the water cycle.
7. Design, draw, and label a series of illustrations to represent the six factors that influence ocean currents. (See page 325).

For more questions, go to ScienceSource.

D31 *Thinking about Science and the Environment*

Monitoring the Oceans — Argo

The International Argo Project (or Argo) is a global network of 3000 free-drifting floats that measure the temperature and salt content of the upper 2000 m of Earth's oceans (Figures 11.17 and 11.18). For the first time, scientists can continuously monitor several characteristics of the water in the upper regions of the oceans, including temperature, direction, and speed. All data are sent via satellites to centralized computers.

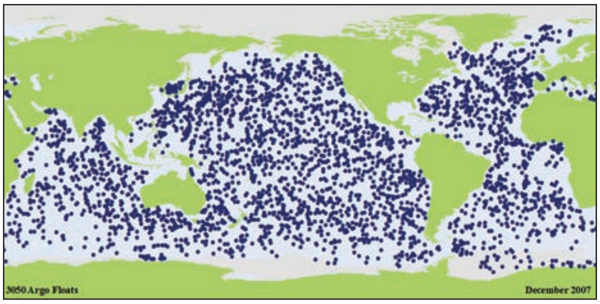


Figure 11.18 This image shows where many of the Argo floats were located on one particular day.

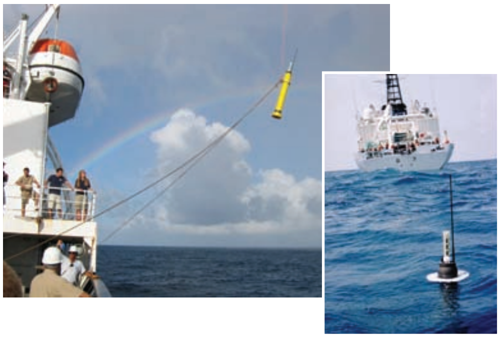


Figure 11.17 A ship installing Argo floats

Consider This

With a classmate or as a whole class, discuss the following questions.

1. What four categories of data do the Argo floats collect?
2. Why are the data gathered by Argo important to meteorologists?

11.3 Heat Affects Land

Here is a summary of what you will learn in this section:

- Earth is made of several layers.
- Many of Earth's features were and are formed by heat.
- The rock cycle helps us understand how heat causes changes in Earth.

The dramatic announcement "Vancouver! Vancouver! This is it!" was made by vulcanologist David Johnston over the radio link from Coldwater Observation Post, north of Mount St. Helens in Washington State, on Sunday morning, May 18, 1980. A few seconds later, Mount St. Helens exploded (Figures 11.19 and 11.20).

Hot gases and ash shot 19 km into the sky. The top and northern side blew away, reducing the height of the mountain by about 400 m. The temperature reached 350°C, and the blast was so loud it could be heard across the Canada–United States border in Vancouver, British Columbia. For days, ash was carried east by winds, settling on cars, buildings, and houses in Calgary, Regina, and as far as Winnipeg — a distance of over 2200 km.

Volcanic eruptions grab our attention. People wonder how hot, melted rock deep in Earth can flow upward and onto the surface. But below the surface, Earth is constantly changing every day — changing due to heat.

Figure 11.19 Mount St. Helens erupting on May 18, 1980

Figure 11.20 Mount St. Helens is south of Vancouver in Washington State.

D32 *Starting Point*

Skills A C

Earth's Mysterious History

The many changes in Earth's long history are closely tied to heat. It is like a mystery story. Changes on and below Earth's surface occur but we do not understand all of them. For example, heat causes mountains to form on land and on the ocean floor. Think about, and then discuss with a classmate, several reasons why scientists are interested in studying how heat causes changes on Earth. You could also describe what you know about *how* scientists research these changes.

D33 *During Reading*

Thinking Literacy

Facts-Questions-Responses

Volcanoes and earthquakes are an interesting topic, but some information may be complex and detailed. An FQR chart can help readers interact and make sense of information while taking notes. Create an FQR chart in your notebook. Label the first column "Facts," the second "Questions," and the third "Responses." (See Figure 11.21.)

As you read the information on volcanoes and earthquakes on pages 329-333 (up to Rocks and Minerals), pause to record facts that are presented. For each fact, record a question you have about it. In the last column, you can record your response to the fact or a connection or reaction you had. Not all facts need both a question and response. Once you have completed reading, share some of your facts, questions, and responses with the class.

Facts	Questions	Responses
Mt. St. Helen's erupted May 18, 1980	Did this affect our weather in Ontario?	

Figure 11.21 FQR chart

Questions about Earth

Humans live on the outside skin of Earth. For hundreds of years, we have asked questions similar to those you might ask before tasting a new piece of fruit (Figure 11.22). How thick is Earth's skin? Are there layers inside? What would we find at the centre? Several models for Earth are shown here (Figures 11.23–11.25). Which would you choose as a model of Earth? Why? Keep reading to see how your choice compares with the scientific evidence.

Figure 11.22 An unusual fruit

Earth — The Inside Story

You live on Earth's surface. But what about the ground beneath your feet? Scientists divide Earth into four layers. Using Figure 11.26, let us travel through these layers, starting at the surface, in an imaginary vehicle, the *Earth Explorer*.

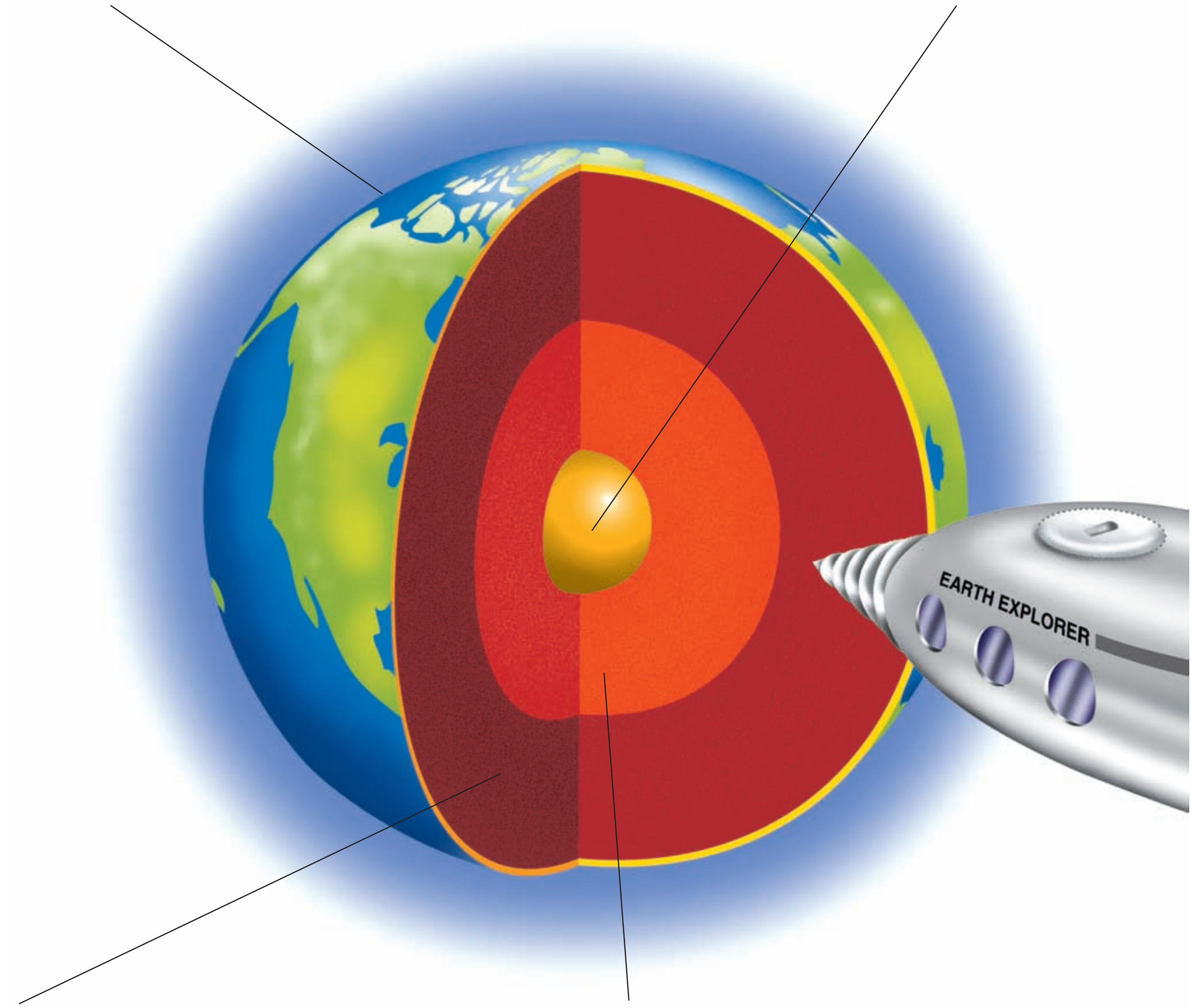
Figure 11.23 Model 1

Figure 11.24 Model 2

Figure 11.25 Model 3

1 Earth's outer layer is the **crust**. All the features we see around us—mountains, valleys, plains, hills, plateaus—are part of the crust. You will start your trip through Earth from the bottom of the ocean because the crust is thinnest here—only about 6 km thick.

4 Finally, you reach the **inner core**. This layer is solid, even though it is very hot. The weight of the other layers has pressed the inner core into an extremely hard ball. There are still another 1250 km to the centre of Earth. But the inner core is so hard that even your special vehicle cannot drill through it.



2 Now you are inside the next layer, called the **mantle**. The mantle is about 2900 km thick, but it is not the same all the way through. The upper part of the mantle is solid, like the crust. Below the solid upper part of the mantle, the temperature and pressure are higher. However, your vehicle can move more easily through this lower layer of the mantle because the rock is partly melted. This rock can flow very slowly.

3 When you leave the mantle, you enter Earth's molten **outer core**. The temperatures are so high here that the rock is completely liquid. Even though the rock is molten, it still takes you a long time to get to the inner core because this layer is also very thick–about 2200 km.

Figure 11.26 Earth's four layers

New Crust Forms All the Time

Suggested Activity •
D35 Quick Lab on page 336

Earth's crust is constantly changing. The three types of heat transfer (conduction, convection, and radiation) all play their part in the continuing story of the changes on and beneath Earth's surface. Conduction occurs in the solid inner core. Heat is transferred to the neighbouring molten outer core. This molten (melted) rock below Earth's surface is called **magma**. The magma in the outer core and the deeper part of the mantle is hotter than the magma in the upper part of the mantle near Earth's crust. This difference in temperature creates convection currents in the molten rock in the mantle. Hot, molten rock rises toward the top of the mantle and moves to the side (Figure 11.27). Heat is also transferred during this sideways movement by conduction and radiation. Sometimes, molten rock sinks back down toward the outer core and the cycle continues.

Earth's crust sits on large, thick sections of rock called **plates**. Because the mantle is made of hot, molten rock, these large rock plates can move apart or move together. Sometimes, the movement allows magma, ash, and gases to shoot upward toward the crust through cracks, producing rumbling in the ground and a lighting of the night sky as a **volcano** erupts (Figure 11.27). At other times, the shifting of the plates produces shaking and sliding in the crust as an **earthquake** takes place.

WORDS MATTER

Molten: The word molten means fused or liquefied by heat, from an older form of English, *melten*, meaning to melt.

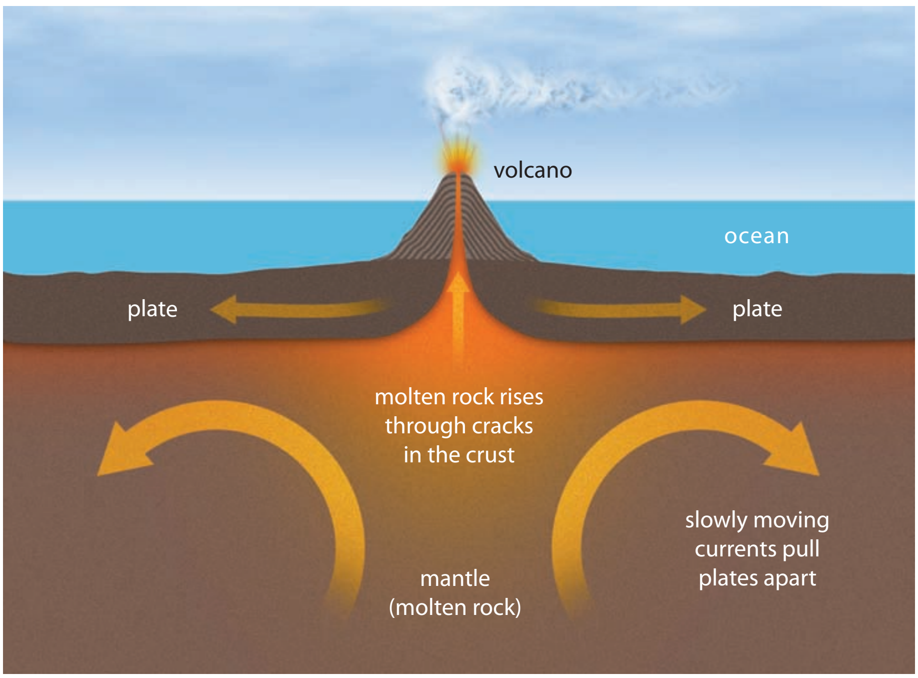


Figure 11.27 When the plates of rock that float on the mantle move apart, molten rock can shoot upward and onto Earth's surface, forming a volcano.

Deep under the oceans, hot magma may squeeze upward where rock plates are moving apart. The hot magma is released onto the ocean floor as **lava** (Figure 11.28). When it meets the cold ocean water, the lava begins to cool, spreads out, and then forms new crust.

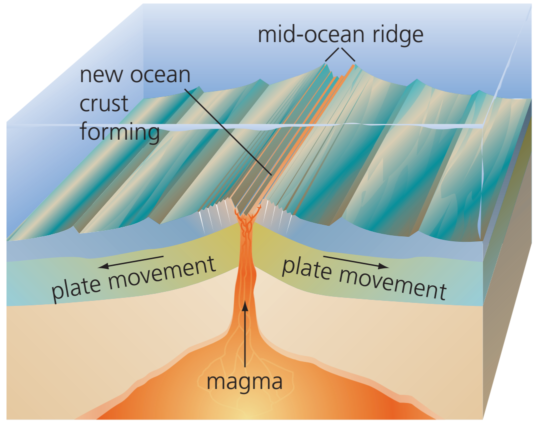


Figure 11.28 Deep under the oceans, new crust is forming continuously as hot lava reaches the ocean floor, begins to cool, spreads out, and then hardens.

Rocks and Minerals

Earth's crust is made up of rocks of different kinds. **Rocks** are naturally formed solid material made up of one or more minerals. **Minerals** are naturally occurring solid pure substances. The first step in identifying a rock is to look at the minerals it contains. There are over 4000 known minerals. **Crystals** are the special shapes of minerals found in rocks made from molten rock (magma) that cooled slowly. Each type of mineral has a special crystal shape (Figure 11.29).

Figure 11.29 Minerals have unique crystal shapes.

Three Classes of Rocks — Igneous, Sedimentary, and Metamorphic

Just as students in school are grouped into different classes, so too are rocks placed into different classes. Scientists have named three large classes (families) of rocks.

Igneous rock is the class of rock that forms from molten rock that has cooled and hardened. There are many different kinds of igneous rock. Rock that forms when magma cools slowly often contains large crystals. If the magma reaches Earth's surface, it is called lava. Lava cools quickly when it is exposed to the air or water. Lava contains small crystals or no crystals at all. Figure 11.30 shows three examples of igneous rocks. Obsidian and pumice form from lava. Granite forms from magma.

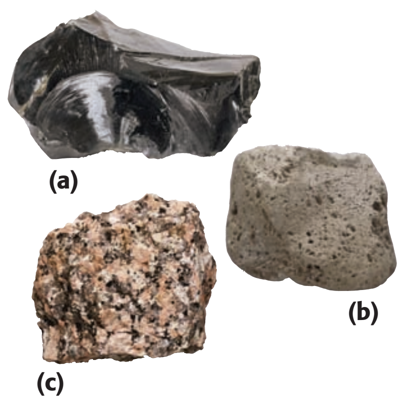


Figure 11.30 Igneous rocks (a) obsidian, (b) pumice, (c) granite

Sedimentary rock is the class of rock that forms from small pieces of rock, shells, or other materials that pile up in layers. The bottom layers pack together from the pressure of the layers above them, like snow at the bottom of a snowbank compressing from the weight of the layers of snow above it. The layers of rock at the bottom harden, forming sedimentary rock, like snow at the bottom of several layers turning to ice. Just as there are many different kinds of minerals that can pile up, there are many different kinds of sedimentary rock.

Table 11.5 Rock types

Name of Rock	Class (Family) of Rock	Name of Metamorphic Rock That It Changes To
granite	igneous	gneiss
sandstone	sedimentary	quartzite
limestone	sedimentary	marble
shale	sedimentary	slate

Metamorphic rock is formed from igneous or sedimentary rocks that have been changed from their original form by heat (from Earth) or by the pressure of the rocks above them. As there are many different minerals that make up igneous rocks and sedimentary rocks, there are also many different types of metamorphic rocks. Examine Table 11.5 to find out the names of several types of metamorphic rocks. Two rocks can contain exactly the same set of minerals but look very different because they formed in different ways. The ways the minerals in the rocks are arranged and the sizes of the crystals can all give clues to how the rock was formed.

Suggested Activity •

D36 Inquiry Activity on page 336

D34 *Learning Checkpoint*

How Rocks and Minerals Form

Match the following descriptions with the new terms you have learned.

1. the class of rock formed from layers of particles, shells, plants, or animals piled up
2. the class of rock that forms when molten rock cools and hardens
3. molten rock beneath Earth's surface
4. molten rock that reaches Earth's surface
5. the special shapes of minerals found in rocks that are made from molten rock that cools slowly
6. an opening in Earth's crust through which solid and molten rock, ash, and gases escape

Figure 11.31 High-quality diamonds, sold as Polar Bear Diamonds™, are mined, cut, and polished in Canada's Northwest Territories.

What Are Gemstones?

Gemstones (or gems) are minerals that are valuable because of their exceptional beauty, colour, and rarity. Their main physical properties are colour, lustre (shininess), how light passes through them, and hardness. Gemstones are often made into jewellery. Some common gemstones, like quartz and amethyst, are fairly inexpensive. Others, like ruby, emerald, sapphire, and diamond, can be very valuable. Many gemstones have important uses in manufacturing and electronics.

How and Where Are Diamonds Formed?

Diamonds, with all their beauty and sparkle, are a form of carbon (Figure 11.31). According to geologists, diamonds were first formed underground more than 2.5 billion years ago. They were crystallized in the mantle below Earth's crust at great depths, usually more than 150 km down. Here is how we believe this happens. Rocks in Earth's upper mantle were carried deeper into the mantle where they melted. These rocks contained carbon, and on melting released carbon particles. The carbon particles formed crystals under the very high pressure from the molten rock above. Under the right conditions of heat and pressure, diamond crystals formed. The diamonds were carried toward the surface by volcanic eruptions of flowing magma in the mantle. Below the volcano, carrot-shaped deposits of rock (called kimberlite pipes) formed. These deposits contain diamonds, volcanic rock, and fragments of the mantle.

Take It **Further**

The newest rocks on Earth are found around active volcanoes. Find out where these rocks are forming and what they are made of. Begin your search at ScienceSource.

The Rock Cycle

During an Ontario spring, it is common for ice to melt during the day and then freeze back into ice overnight. The next day, the ice can melt again and freeze again. This back-and-forth behaviour is an example of a cycle.

Rocks also go through cycles. The **rock cycle** is the repeating pattern in which one family of rock changes into a different family. Figure 11.32 shows the role that heat plays in the rock cycle. The rock cycle occurs because of the heat produced, stored, and released inside Earth. Earth is not the unchanging planet it might appear to be. Old rock is continuously being pushed into the mantle, where it melts. Hot magma reaches the crust, cools, and forms new rock. Rocks change constantly. For example, pressure from the weight of layers of rock pushing down may change one form of rock into another. Water, wind, chemicals, and even living things, lead to **weathering**, or wearing away, of rock. This is the first stage of **erosion** — the breakdown and movement of rocks and soil by wind, water, or ice.

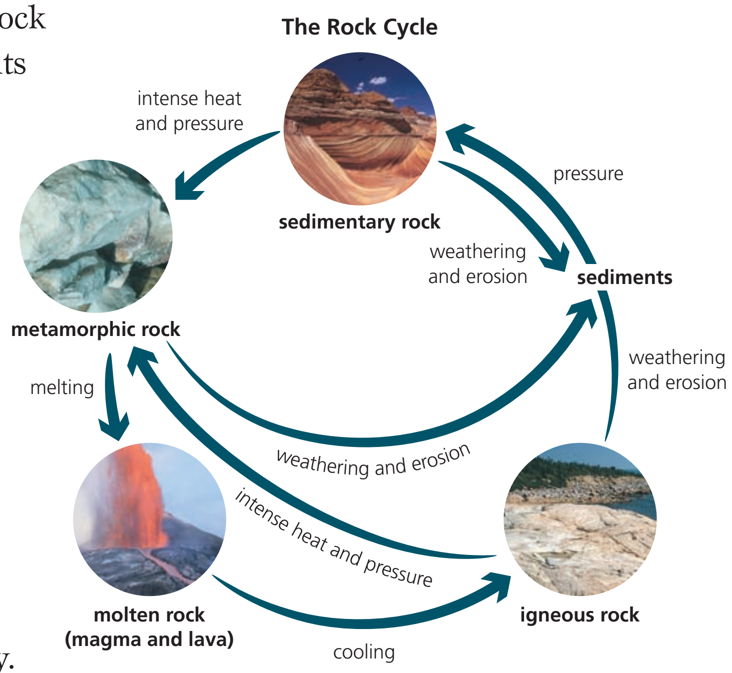


Figure 11.32 The rock cycle

D35 *Quick Lab*

Colour in a Beaker

Purpose

To create a model of the convection currents that cause molten rock to move in Earth's mantle

Materials & Equipment

- large beaker
- hot plate
- water
- food colouring
- long medicine dropper

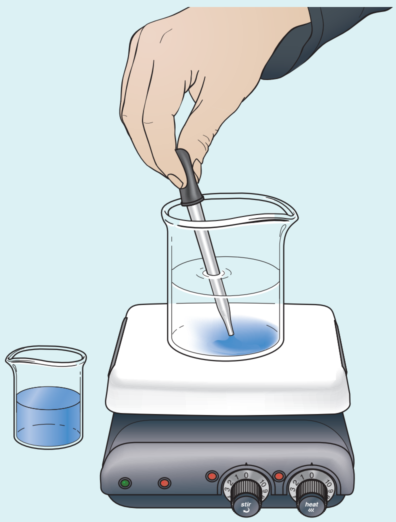


Figure 11.33 Set-up for Quick Lab

Procedure

1. Add water to the large beaker until it is half full.
2. Set the beaker on the hot plate. Allow the water to become still.
3. Use a long medicine dropper or hollow glass tube (with your thumb on the end) to pick up some food colouring. Place the food colouring inside the beaker so that it forms a layer of colour at the bottom (Figure 11.33).
4. Slowly heat the beaker of water. Observe what happens to the food colouring.

Questions

5. What did you observe in the beaker as it was heated? Illustrate your answer with labelled "before" and "after" drawings of the beaker and food colouring to show the changes that occurred.
6. Compare the results of this activity with the information you have learned about convection currents in Earth's mantle. How is this activity similar? How is it different?

D36 *Inquiry Activity*

Toolkit 2

SKILLS YOU WILL USE

- Using appropriate equipment
- Reporting results

Crystallize Your Thinking

What happens when molten rock from deep in Earth's mantle travels upward toward the crust? It cools — in two different ways, depending on where it stops flowing. In this activity, you will observe both types of cooling by using a common element — sulphur.

Question

What happens when molten rock cools quickly or slowly?

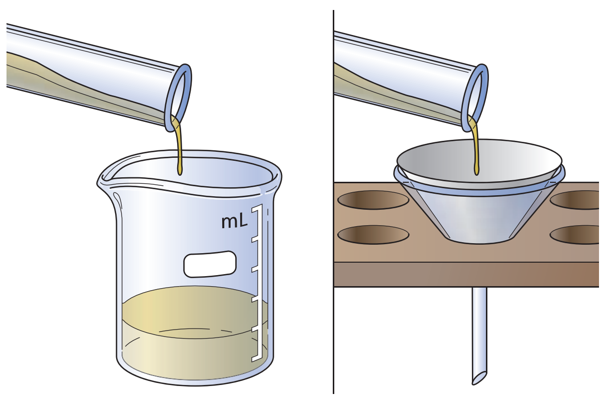


Figure 11.34 How does quick cooling affect the appearance of solid sulphur?

CAUTION:
- Use a fume chamber or adequate ventilation.
- Be careful when using a hot plate or Bunsen burner.
- Place the glass funnel upside down so that it will not roll off your lab surface.
- Do not remove any powdered or solid sulphur from the classroom.

Materials & Equipment

- powdered sulphur
- metal scoopula
- test tube holder
- 2 test tubes
- hot plate or Bunsen burner
- 400-mL beaker (if using a hot plate)
- 250-mL beaker of cold water
- circle of filter paper
- glass funnel
- test tube rack
- paper towel
- water

Hypothesis

When molten sulphur cools quickly, it will look like...
When molten sulphur cools slowly, it will look like...

Procedure

Part 1 — Quickly! Quickly!

1. Using the metal scoopula, add powdered sulphur to a test tube to about 6 cm depth.
2. Gently melt the sulphur following your teacher's directions.
3. When the sulphur has melted, quickly pour it into the 250-mL beaker of cold water.
4. Cool the test tube in the test tube rack.
5. When the sulphur has cooled, pour off the water from the beaker and place the solid sulphur on a piece of paper towel.

Part 2 — Slow as Can Be

6. Fold a piece of filter paper to form a cone.
7. Fit the filter paper into the glass funnel. Add a few drops of water to stick the paper to the glass. Place the funnel into the test tube rack.
8. Using the metal scoopula, add powdered sulphur to a test tube to about 6 cm depth. Melt the sulphur.
9. When the sulphur has melted, quickly pour it into the filter paper. Allow the sulphur to cool slowly.
10. Place the test tube into the rack to cool.
11. Compare the two samples of cooled sulphur. Break them open and observe the inside of each piece. Record your observations.
12. Clean up. Leave all pieces of sulphur in your classsroom.

Skill Builder

13. Compare the insides of the solid sulphur samples from Parts 1 and 2. Draw and label a diagram of each sample of cooled sulphur.

Analyzing and Interpreting

14. Suggest reasons to explain any differences between the sulphur samples from Parts 1 and 2.

Forming Conclusions

15. Consider your answers to points 13 and 14. Suggest how your observations in this activity might explain differences in rock formed in the mantle and at the surface of Earth.

11.3 CHECK and REFLECT

Key Concept Review

1. Name the four layers of Earth in order, from the outside to the centre.
2. Why is the term "crust" suitable for the layer of Earth where you live?
3. What are the names of the three classes of rocks?
4. What are the differences between magma and lava?
5. Suggest reasons why scientists are interested in studying Earth's layers.
6. A classmate suggests that heat is involved in producing all three classes of rock. Do you agree or disagree? State reasons to support your answer.
7. Suggest reasons to explain why garnet, opal, and topaz are considered to be gemstones.
8. Describe two differences between Earth's inner core and Earth's outer core.

Connect Your Understanding

9. Schist, shown on the right, is a type of rock formed when certain minerals are changed by heat and pressure. Which of the three classes of rock includes schist?

10. Compare the rock cycle to a cycle of events in your daily life. How are they similar? How are they different?

Practise Your Skills

11. On Page 330, three possible models are shown for Earth. One of these models is an accurate comparison. Which one is it? Explain the reason for your choice. Then, choose two or more additional examples that you could use to explain the layers of Earth to a friend.
12. Figure 11.32 on page 335 illustrates the rock cycle. Explain how weathering, erosion, heat, and pressure all cause changes in rocks. Design and draw a separate illustration for each part of your explanation.

For more questions, go to ScienceSource.

D37 *Thinking about Science and the Environment*

A Volcano in the Neighbourhood

People in many parts of the world (like Hawaii) live on or near an active volcano. Suggest several reasons to explain why people choose to do this. List the costs and benefits of such a life choice. Share your ideas with a partner, a group, or the whole class. Your teacher may ask you to research communities where people live close to volcanoes. Add the results of your research to your cost-benefit analysis.

Hurricane Katrina

Figure 11.35 A hurricane is a strong, spinning weather system over the ocean that has continuous wind speeds exceeding 119 km/h. Hurricanes form and grow stronger over tropical regions of the ocean as they pick up heat from the warm ocean water. This photograph shows Hurricane Katrina in August 2005.

At the end of August 2005, a devastating hurricane, Katrina, destroyed portions of the U.S. coast from southeast Louisiana to Alabama (Figure 11.35). Katrina was one of the worst natural disasters in North American history. Katrina's journey began in south Florida. While moving northward toward the central Gulf coast, Katrina strengthened into a Category 5 hurricane. Category 5 means continuous wind speeds greater than 250 km/h.

Katrina's winds became weaker before she touched down. But they were still strong enough to cause a near-record storm surge of ocean water. The winds and water caused widespread destruction and loss of life. The city of New Orleans was particularly hard hit when the dikes surrounding the city broke. Large sections of the city were flooded. Over 80 percent of the city and many areas of neighbouring communities were under water for weeks.

At least 1836 people lost their lives in Hurricane Katrina and in the flooding. Damage to buildings and farmland due to the storm is estimated to have been more than $80 billion (Figure 11.36).

Questions

1. You have read about the destruction caused by Hurricane Katrina. Propose at least three questions about the storm and damage. Record your questions in your notebook.
2. Hurricanes rarely strike Ontario. But on October 16, 1954, Hurricane Hazel, one of the most notable hurricanes in history, moved into Ontario as a powerful storm from the United States. Flash flooding from Hazel in Canada destroyed 20 bridges, killed 81 people, and left more than 2000 families homeless. Suggest several ways Ontarians can protect themselves from such powerful storms.
3. Imagine that you are a radio, television, or newspaper reporter. Write a script in which you describe the effects of a powerful hurricane on your community. Include the names of landmarks, cities, towns, and events that are affected by the hurricane you are describing.

Figure 11.36 Some of the flooding in New Orleans caused by Hurricane Katrina

11.0 Chapter Review

Assess Your Learning

After Reading — Thinking Literacy

Reflect and Evaluate

Revisit your original questions from the beginning of the chapter. Have they all been answered? Summarize what you have learned about the value of asking questions as you read using the following organizer:

3-2-1 Review

- 3 things I learned about the comprehension strategy of asking questions
- 2 ways this strategy helped me as a reader
- 1 question I still have about asking questions

Share your 3-2-1 Review with a partner and discuss similarities and differences. Try to answer each other's final question.

Key Concept Review

1. Suggest three ways in which human activities depend on the atmosphere. k

2. The atmosphere is a mixture of materials. Name two of them. k

3. What is the name of the layer of the atmosphere in which we live? k

4. Which of the following would be a more accurate statement? Provide reasons for your answer. (a) The weather in Sudbury is warm and cloudy. (b) The weather in Ontario is warm and cloudy. t

5. What is the main source of Earth's energy? k

6. Name the two changes of state that are part of the water cycle. k

7. A classmate tells you that a meteorologist studies meteors (chunks of rock that travel through space). Explain why this statement is not accurate. t

8. Do the Sun's rays fall more directly on Ontario or on Florida? Explain your answer. Include a drawing with labels. t

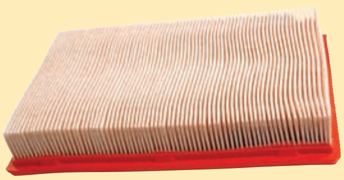
9. How is heat distributed across Earth? Suggest two ways. k

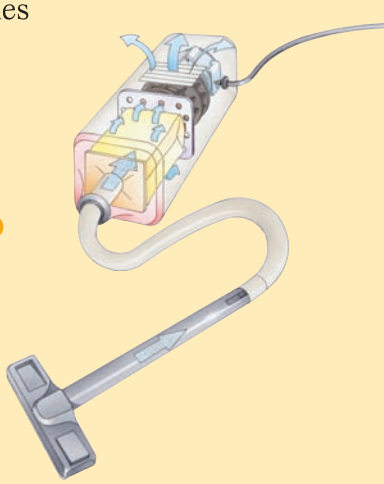
10. How is weather different from climate? k

Connect Your Understanding

11. Name and describe two situations or machines in which it is important to filter air before it is used. You may want to use some of the items shown on this page in your answer. a

12. Ocean currents flow in patterns. Name three factors that influence these patterns. t





ACHIEVEMENT CHART CATEGORIES

k Knowledge and understanding   t Thinking and investigation   c Communication   a Application

13. A chart of numbers, similar to the one below, can help you summarize new information. Draw your chart and fill it in, using information in this chapter. You may include more than one set of information in each box. The first box has been filled in for you.

Number	New Information and Descriptions
2	two types of melted rock: magma (underground) and lava (on the surface)
3	
4	
5	

14. Summarize the three categories of ocean currents. Copy the chart below into your notebook.

Type of Ocean Current	Description
warm surface currents	
cold surface currents	
deep ocean currents	

Practise Your Skills

15. Design and create a chart for the activities you have completed in this chapter. In your chart, include:
- each activity's number
- each activity's name
- a brief description of each activity
- a summary of your observations for each activity

Unit Task Link

Driving cars, producing consumer goods, using electronic devices: all these use energy. Using energy releases heat into the air and into the bodies of water. Improved insulation in buildings would prevent or reduce heat loss. This would reduce the amount of energy used. Go to ScienceSource to research systems of insulation used in homes, schools, and office buildings.

D38 *Thinking about Science and the Environment*

Disaster Preparedness

Think about several ways that families and local communities can prepare for disasters such as hurricanes, ice storms, and wind storms.

What to Do

1. Draw a four column chart with the following column titles: Type of Emergency or Disaster, How Can My Family Prepare? How Can My Community Prepare? and, Why Is It Important?
2. Fill in the chart for several types of emergencies and disasters.

Consider This

Share your chart with a classmate. Add information to all four columns. Then, share your chart with a group or the whole class. Your teacher may ask you to prepare a poster so that other students can learn more about disaster preparedness.

Use the Internet to learn more about preparing for disasters and emergencies.

Begin your search at ScienceSource.