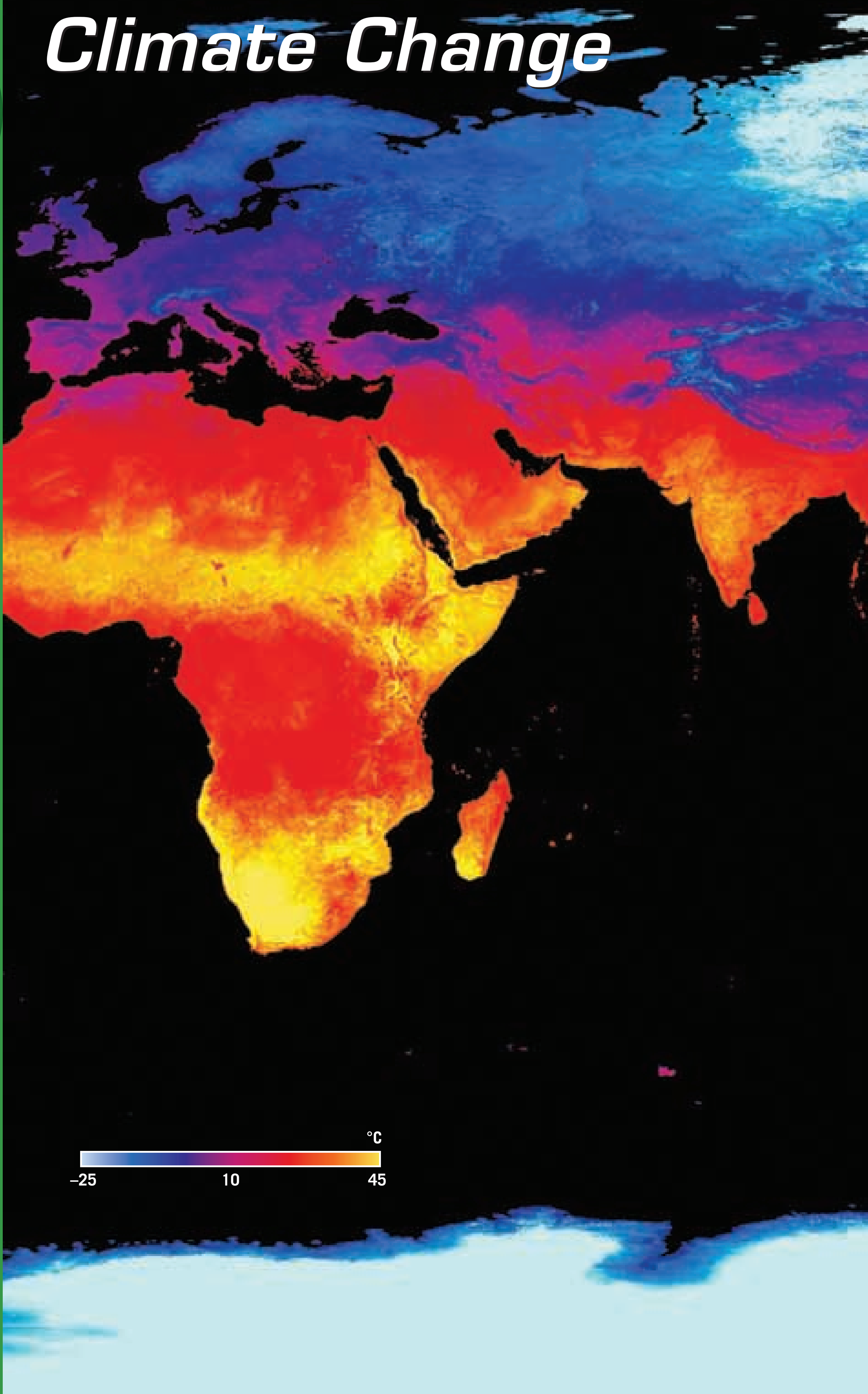
UNIT

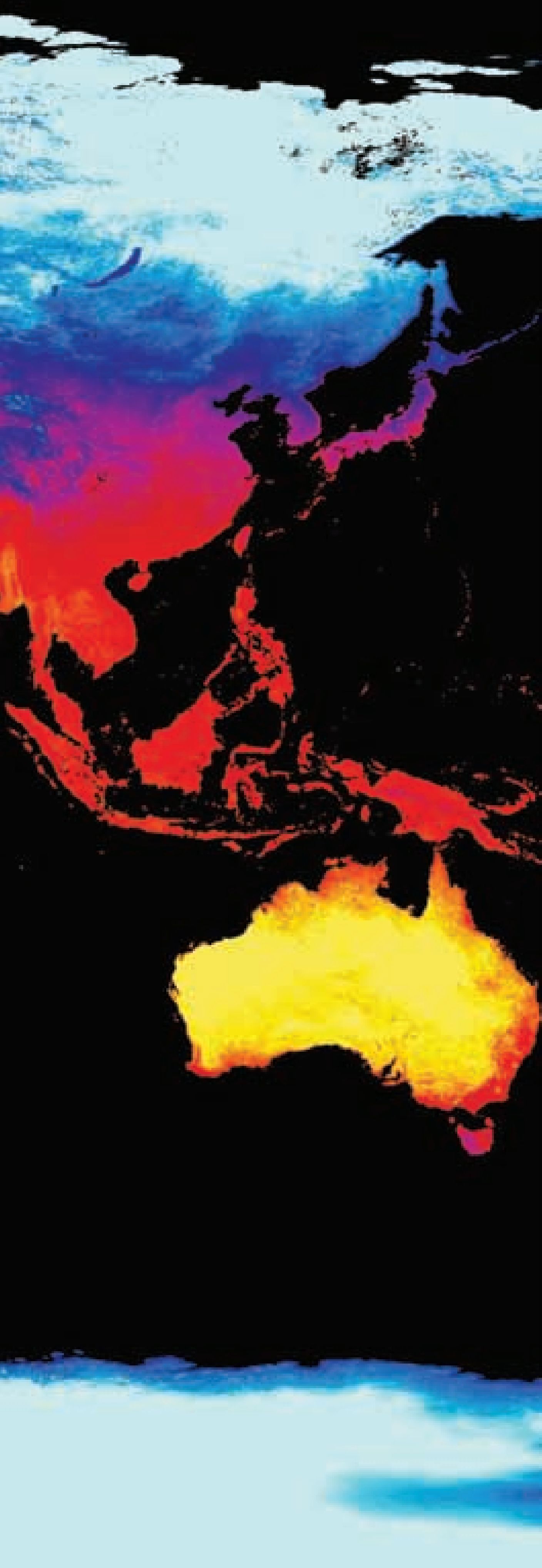
C

Climate Change



Satellites can detect Earth's surface temperatures. This NASA map shows the average daytime December temperatures between 2000 and 2008.

Home Quit



Contents

Unit Task

Climate change is a dynamic and rapidly evolving field of study, as well as a societal, economic, and political issue. Reducing our impact on Earth is essential to addressing climate change. Over the next few years, we may develop new ways to minimize our impact on Earth, while discovering as yet unknown effects of climate change on natural and human systems. Governments may also change their policies. International climate change organizations will continue to develop intensive mitigation and adaptation projects.

For your Unit Task, you will research a new technology, scientific study, economic event, or government policy related to climate change that has been highlighted in the media over the last 12 to 18 months. As you study this unit, you will assemble a portfolio of information that interests you. You will write a supplement to this unit that could be used by students taking this course next year.

Essential Question

How have technologies and issues related to climate change developed over the last 12 to 18 months?

Exploring

The Ward Hunt Island ice shelf, 20 km^2 in area, between Ellesmere Island and Ward Hunt Island (in the distance). This photo was taken in early July 2008.

Ice shelves are breaking off in both the Arctic and the Antarctic. In March 2008, over 400 km^2 of the Wilkins Ice Shelf broke away from Antarctica.

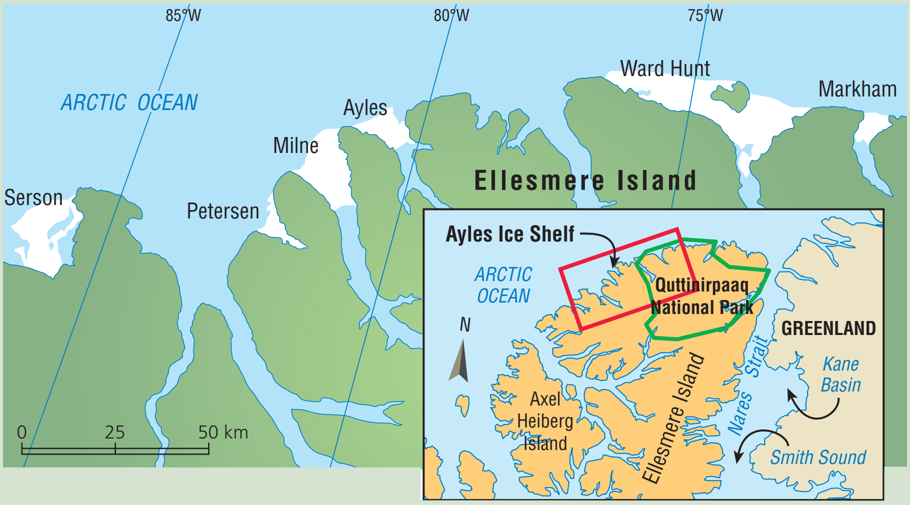
Disappearing Ice

In July 2008, a huge slab broke off the ice shelf attached to Ward Hunt Island off the coast of Ellesmere Island in Nunavut. This was one of the largest remaining ice shelves in the Arctic.

An ice shelf is a thick slab of ice that is attached to land. Part of it may float on the ocean or sit on the ocean bottom. Ice shelves form where sea ice piles up against a coastline or where glaciers flow past the coastline into the ocean. The bottom layers of ice of the Ward Hunt Ice Shelf were about 4500 years old, according to evidence collected by scientists. Usually, ice shelves melt slowly every summer, and small pieces fall off where the ice floats on the ocean. But rarely in the past have huge slabs, measuring several square kilometres in area, broken off completely and floated away. Scientists estimate that where there was once 9000 km^2 of ice shelves on Ellesmere Island, less than 1000 km^2 remain.

According to researchers, five ice shelves remain in the Canadian Arctic. All are retreating. Originally, these five ice shelves were one, called the Ellesmere Ice Shelf. In the early 20th century, the ice shelf extended about

Ward Hunt Island Ice Shelf in mid-August 2008, after the ice shelf broke off and floated away



The north coast of Ellesmere Island showing the location of the ice shelves in 2008

500 km along the coastline of Ellesmere Island. Since then, over 90 percent of the ice shelf has disappeared. No new ice is forming, which is a sign that Earth is warming. As the ice melts, the white, sunlight-reflecting surface of the vast ice sheets is replaced by dark, sunlight-absorbing water.

Climate scientists are becoming concerned because the Arctic Ocean has changed dramatically. Over the past 30 years, the amount of summer ice cover has decreased by almost half. The Arctic Ocean and the oceans around Antarctica are warming. Thus, ice shelves are also melting more quickly. Because this is happening at both ends of Earth, scientists have determined that it is happening everywhere on Earth. They believe that the ice shelves are breaking because of a phenomenon called climate change, a gradual, long-term change in Earth's average weather conditions.

C1 STSE *Science, Technology, Society, and the Environment*

The Message in the Media

Climate change is an issue that is often seen in the media. It appears in the news, in magazine articles, on Internet sites, and in television documentaries. You may have noticed that different media tell somewhat different versions of the same story. It is important to think critically about all media.

1. Form a group of 3–4 and gather markers, a piece of chart paper, and tape. Your teacher will give you newspaper and magazine articles.
2. Write the words "climate change" in the middle of the chart paper.
3. Discuss the implications of the Exploring section.
4. Discuss what the group members know about climate change and what their media sources were.
5. Create a collage of articles, drawings, and key words to represent the group's current knowledge of climate change.
6. Have each member of the group add at least one question that he or she would like to investigate during this unit.
7. What is the media's role in educating the public about climate change?
8. Do you think the general public is interested in stories about climate change? Why or why not?
9. What types of media do you think are the most effective in reaching the public with information about climate change?
10. Why is it important to consider different views about stories in the media?

Home Quit

7 Earth's climate system is a result of interactions among its components.

Today's weather can bring a sudden storm or a sunny day. Your area's climate, however, is the average temperature and amount of precipitation (rain, snow, and hail) over a long time.

Skills You Will Use

In this chapter, you will:

- build a model to illustrate the natural greenhouse effect
- investigate the effects of heat transfer within the hydrosphere and atmosphere
- investigate the influence of ocean currents on local and global heat transfer and precipitation patterns
- classify the climate of your region

Concepts You Will Learn

In this chapter, you will:

- describe the principal components of Earth's climate system
- describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents
- describe the natural greenhouse effect and explain why it is important

Why It Is Important

People, including scientists, economists, and politicians, are discussing climate and climate change. An understanding of weather and climate, the natural greenhouse effect, and the global movement of heat will help you to participate in this discussion.

Before Reading

Thinking Literacy

Connecting to Prior Knowledge

Good readers recognize when a topic is familiar. They connect new information to things that they already know about the topic.

Preview the subheadings for Section 7.1, choosing one key word from each. Now, use the words to create a probable passage — a statement or prediction about the content of this chapter based on your prior knowledge.

Key Terms

• albedo • atmosphere • biome • biosphere • climate
• conduction • convection • Coriolis effect
• greenhouse gases • hydrosphere • insolation • lithosphere
• natural greenhouse effect • net radiation budget • radiation
• solar radiation • thermal energy • weather • wind

7.1 Climate

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

- The climate of a region is the long-term average of regional weather conditions.
- Climate affects all organisms that live in that region.
- The Sun provides all of the energy necessary for life on Earth.
- Earth's biosphere provides conditions suitable to support life.
- Earth's climatic regions are classified into biomes.

Figure 7.1 It's best to plan a visit to an amusement park in good weather. Amusement parks shut down many of the open-air rides during rainstorms.

Weather Effects

Imagine that you and your friends are going to an amusement park today (Figure 7.1). You checked the weather forecast three days ago, and it said that today would be sunny and warm. All of you have lots of fun enjoying the rides in the great weather. But in mid-afternoon, dark clouds start to cover the Sun. First you hear thunder, a distance away. Then, the amusement park shuts down the rides you like best. As you make your way to the bus stop, the rain comes pouring down. You are drenched in seconds. Lightning flashes across the darkened sky, and the thunder booms.

Once you are on the bus, your friends accuse you of not checking the weather forecast. You say you did, but three days ago. A while later, you arrive at your stop and get off the bus, only to notice that the sky has cleared and the sun is reappearing. Luckily, you had your hands stamped at the park, so you can hurry back to enjoy the rest of your day.

Almost everyone uses weather forecasts to help plan daily activities. Weather changes quickly, so weather forecasters, called meteorologists, prepare forecasts at least three times a day for more than 160 communities in Ontario (Figure 7.2).

Figure 7.2 Sometimes, weather can change very quickly. Here, the coming storm creates a beautiful sky.

Sometimes, however, we need to plan events, such as skiing competitions and track-and-field days, weeks or even months in advance. Weather forecasts cannot help with these plans.

C2 Quick Lab

What Is the Weather Today?

Purpose

To determine the usefulness of different types of weather reports and forecasts

Materials & Equipment

- forecasts from several radio stations
- TV news weather reports
- forecasts from newspapers
- ***ScienceSource*** for Internet weather reports

Procedure

1. With a partner, choose one forecast from each source.
2. Using a checklist such as Table 7.1, compare the contents of the different forecasts.

Table 7.1 Comparison of Weather Reports

	Radio	TV	Newspaper	Internet
Number of days				
Temperature: High				
Temperature: Low				
Precipitation: Amount				
Precipitation: Type				
Wind Speed				
Wind Direction				
Wind Gusts				
Humidity				
Barometer Reading				

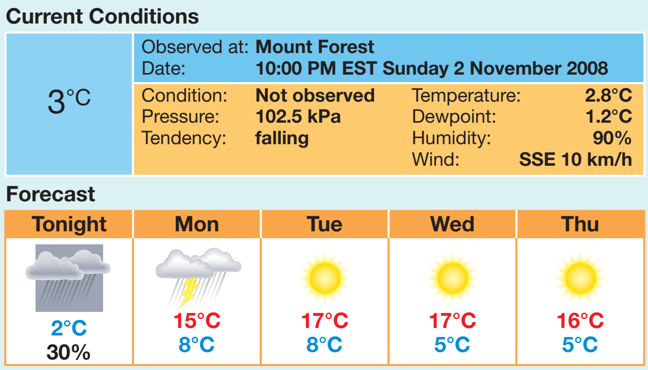


Figure 7.3 Local weather conditions can be predicted by meteorologists a few days in advance.

Questions

3. Which weather report is most useful in the following situations?
   - You are going to school.
   - You want to play soccer.
   - You want to go camping next weekend.
   - You are considering buying tickets to an outdoor concert.
   - You need to plant some trees.
   - You want to organize a car-wash fundraiser.
4. Why is one type of forecast more useful than another in the above situations? Which forecast is the most useful?
5. Weather forecasts typically extend about five days ahead. How would you plan an outdoor activity if you needed to pick a date a month in advance? A year in advance?
6. Describe the weather conditions that are typical for the season. Are today's predicted weather conditions typical for the season? Why or why not? Be prepared to share your analysis with the class.

Weather and Climate

Although weather and climate are related, they are not the same thing. Think of all the clothes you own. Your entire wardrobe is dictated by the climate in Ontario. Everything from shorts and T-shirts to a heavy parka deals with the range of climatic conditions we encounter over a year. The weather, however, dictated what you are wearing today.

Weather refers specifically to the environmental conditions that occur at a particular place at a particular time. These include temperature, air pressure, cloud cover, and precipitation. The morning weather forecast may predict sunny, warm conditions, while the afternoon forecast for the same area may call for increasing cloud cover overnight and the possibility of precipitation.

WORDS MATTER

The word "weather" started with the early root *wē*, which means to blow. *Wedram*, an early German word, meant wind or storm. *Wedram* became *weder* in early English.

Most people are familiar with what weather is and how it affects their daily lives. The effects of weather are immediate and obvious. If a severe snowstorm is forecast, you may decide to stay at home. If a weather forecast calls for rain, you may decide to take an umbrella or wear a raincoat when you go out.

Climate, and how it affects your life and the lives of other organisms, may not be as familiar to you. Knowing that your community gets an average of 75 mm of rain in June and the average June temperature is 19.3 °C is of little use when planning a June birthday party. These data are part of the climate of your area. **Climate** is the average weather conditions that occur in a region over a long period of time, usually a minimum of 30 years. The description of the climate of a region includes average monthly temperatures and precipitation, average wind speed and direction, and a variety of other data. Climate is studied by climatologists, who also understand meteorology.

WORDS MATTER

"Climate" originates from the Greek word *klima*, which means surface of Earth or region. The Romans changed the word to *clima*, which you can see in both "climate" and "acclimatize," which means to get used to new surroundings — to a new *clima*.

The climate of an area is affected by many factors. The four main factors are:

- latitude
- elevation
- the air masses that flow over the area
- the area's nearness to large bodies of water

During Reading

Thinking Literacy

Make a Text-to-Text Connection

As you read about weather and climate, think about other sources you use to get information about these two topics. How is information about weather and climate presented on television, on the Internet, or in newspapers?

Learning Checkpoint

1. In this section, weather and climate were compared using the analogy of a person's wardrobe. Think of another analogy to describe the difference between weather and climate.
2. Explain your analogy to a partner, and discuss in what ways the analogy works well and in what ways it is weak.
3. What is a weather forecast, and when could it be important to you?


(a) (b)

Figure 7.4 Wintertime in Canada. (a) In the north, people wear parkas for warmth. (b) Although southern Ontario also has snow and cold, the parkas that people wear are not as thick as those in the north.

How Climate Affects Your Life

Suggested Activity •
C4 Inquiry Activity on page 270

If you were planning to visit or move to another part of the world, you would want to have an idea of that region's climate. Perhaps you and your family immigrated to Canada from a country with a very different climate. You probably made some adjustments after you arrived. For example, if you came from a warmer climate, you may not have experienced snow before you arrived and did not understand the need for warm clothing and specialized footwear (boots, skates, skis), especially for outdoor winter activities (Figure 7.4(b)). The plants and animals you see around you here may also be different from what you are used to.

People in some parts of the world inaccurately associate Canada exclusively with a harsh winter climate (Figure 7.4). But in fact, all Canadians enjoy warm temperatures and sunshine for significant portions of the year (Figure 7.5).

The climate of a region determines the basic needs of people who live there. Clothing, agriculture, and housing are affected by the region's climate. Ontarians generally experience hot summers, cold winters, and more moderate temperatures in fall and spring. To deal with this, Ontarians equip themselves with a variety of clothing. Instead of local fresh fruits and vegetables, they rely on frozen, canned, stored, or imported produce during the winter and early spring. And they use different systems to heat, ventilate, and cool their buildings.


(a) (b)

Figure 7.5 The climate is warm to hot in Canada's summer. (a) People in Nunavut can wear light clothing. (b) The water is warm enough for swimming at Outlet Beach in southern Ontario but not in the north.

The Sun: Source of All Energy

Both weather and climate depend on the amount of energy in a region. Almost all the energy on Earth is initially **solar radiation** — transmitted as waves that radiate from the Sun. Life as we know it depends on solar radiation. Different regions on Earth's surface receive different amounts of solar radiation. In general, regions at or near the equator receive more solar radiation per square metre than regions closer to the poles do (Figure 7.6).

Some of the solar radiation that strikes Earth is absorbed by Earth's surface. This solar radiation is converted to thermal energy in everything it touches. **Thermal energy** is the total kinetic energy of the particles in a substance. A quantity of a substance at a high temperature has more thermal energy than the same quantity of that substance at a lower temperature. Heat flows from a substance at a high temperature to one at a lower temperature. A tiny amount of the solar radiation is converted to chemical energy through photosynthesis in plants.

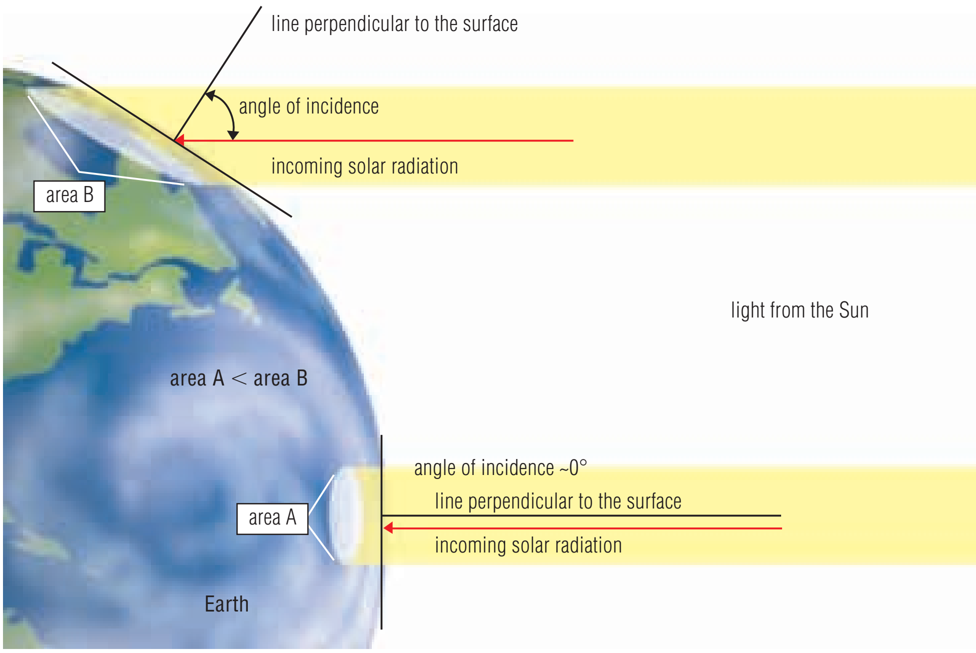


Figure 7.6 The angle of incidence of light from the Sun increases with distance from the equator. As a result, the same amount of solar radiation is spread out over a larger surface area at polar latitudes, such as area B, than at or near the equator, such as area A.

Earth's Biosphere

The climate of a region is affected not only by the amount of solar radiation it receives but also by interactions among components of Earth's biosphere. The **biosphere** is the relatively thin layer of Earth that has conditions suitable for supporting life. It is composed of all the living things on Earth and the physical environment that supports them. Other planets in our solar system do not appear capable of supporting life as we know it. Earth may be divided into four spheres for closer study (Table 7.2, Figure 7.7).

Table 7.2 The Spheres of Earth

Sphere	Explanation
Biosphere	bio = living, sphere = ball; the living layer around the planet; includes the atmosphere, lithosphere, and hydrosphere
Atmosphere	atmos = gas; the gas layer around the planet
Lithosphere	lithos = rock; the rock layer around the planet
Hydrosphere	hydro = water; the water layer around the planet

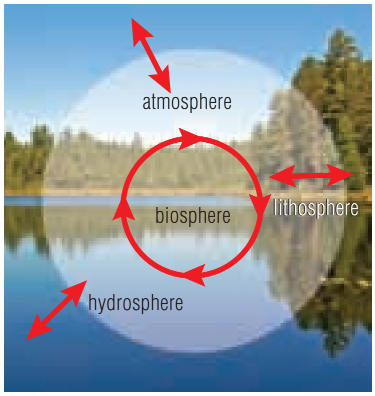


Figure 7.7 Earth's biosphere is home to all living things and the physical environment that supports them. All organisms live in the lower atmosphere, on the surface or just below the surface of the lithosphere, and in the hydrosphere.

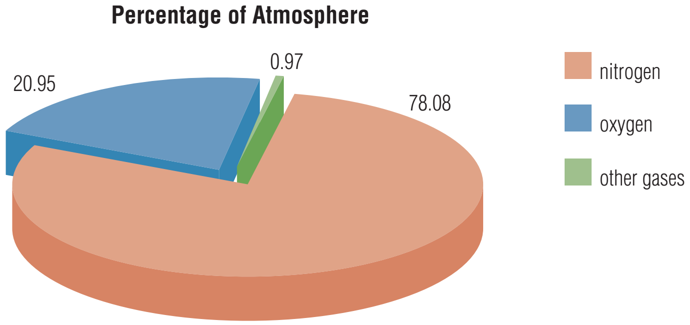


Figure 7.8 The main component of Earth's atmosphere is nitrogen gas. Because the amount of water vapour varies with temperature, it is not shown in this graph.

The Atmosphere

Air is the mixture of different gases found in Earth's atmosphere. The **atmosphere** is the layer of gases that extends outward about 300 km from the surface of Earth. The major gases found in this mixture are nitrogen and oxygen (Figure 7.8). Other gases found in trace amounts are argon, carbon dioxide, neon, helium, methane, and krypton. Water vapour is also a gas found in the atmosphere, but since levels of water vapour (humidity) can vary greatly, water vapour will be considered part of the hydrosphere in this book. Water vapour, oxygen, and carbon dioxide are essential for life.

In addition to these gases, the atmosphere also contains atmospheric dust, made up of abiotic (non-living) and biotic (living) particles. Examples of abiotic particles are soil particles and soot (sometimes called aerosols); examples of biotic particles are pollen and micro-organisms. Many of these particles are small (less than 0.66 mm in diameter) and solid. The amount of these particles in the air contributes to our air quality. Smog, a word combining "smoke" and "fog," occurs when soot particles combine with car exhaust in the air.

Just as the interior of Earth can be divided into the layers of core, mantle, and crust, the atmosphere can be subdivided into regions according to their distance from Earth's surface. These layers are described in terms of temperature, chemical composition, air movement, and density, which may differ from place to place. Figure 7.9 and Table 7.3 on the next page give information about these layers: the troposphere, stratosphere, mesosphere, and thermosphere.

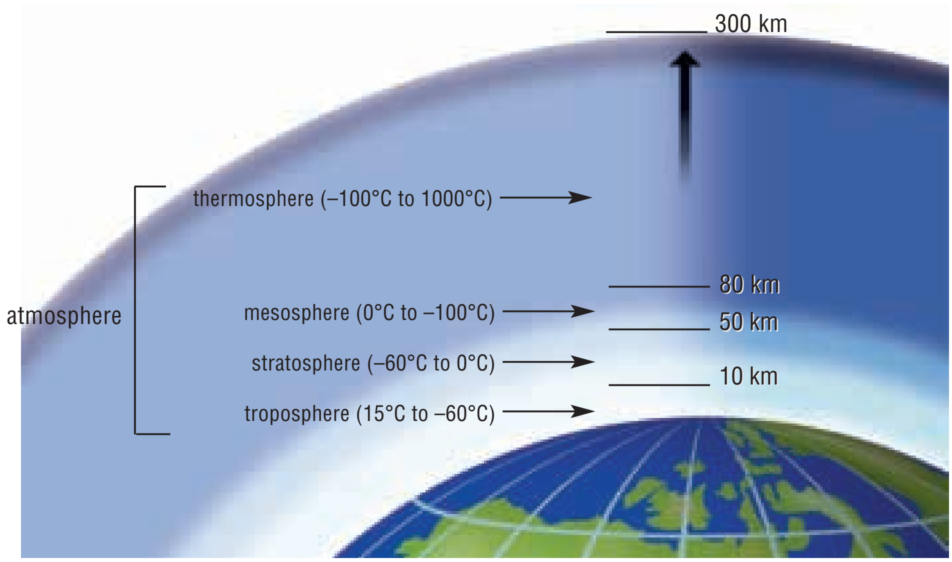


Figure 7.9 The layers of Earth's atmosphere do not have distinct boundaries but blend into one another. Values are the average altitudes for all of Earth as determined by the Centre of Atmospheric Science at the University of Cambridge, U.K.

Table 7.3 Summary of Earth's Atmospheric Layers

Layer	Average Altitude from Earth's Surface (km)	Temperature Range (°C)	Characteristics
Troposphere	0–10	20 to –60	• 80 percent of atmospheric gas by mass • can support life • contains most of the carbon dioxide and water vapour in the atmosphere • contains almost all of the atmospheric dust in the atmosphere • where weather takes place
Stratosphere	10–50	0 to –60	• contains most of the ozone gas in the atmosphere, which protects living organisms from damaging high-energy radiation • clumps of cells found but no other life • Air temperature increases with height as ozone gas absorbs ultraviolet solar radiation.
Mesosphere	50–80	0 to –100	• very little gas • Air is thin, and atmospheric pressure is low. • fewer oxygen molecules (O_2)
Thermosphere	80+	–100 to 1000	• very little gas • Gas particles are hot during the day and cold at night.

The Lithosphere

The **lithosphere** is the solid portion of Earth that floats on the semi-fluid portion of the mantle (Figure 7.10). The lithosphere is home to many micro-organisms, plants, and animals, including humans. It is the outer surface of Earth (its crust) plus the solid part of the upper mantle. It extends downward from Earth's surface and varies in thickness from as little as 5 km thick beneath parts of the oceans to as deep as 100 km beneath the continents. A few metres at the surface of the lithosphere are warmed by the incoming energy from the Sun. The rest is warmed mainly by the decay of radioactive elements in the lithosphere and mantle.

Movements in the lithosphere can affect climate. The science of plate tectonics describes how the different plates of Earth's lithosphere move over the mantle. When plates collide, they may push up mountains, although this can take many millions of years. The sides of mountains on which the wind blows receive most of the moisture from the clouds, while the leeward side can be dry (Figure 7.10). Also, most volcanoes occur where tectonic plates interact. Volcanic eruptions, such as the explosion of Mount St. Helens in Washington state in 1980, can spew millions of tonnes of ash high into the atmosphere, blocking the sun and cooling the global climate for a few years.

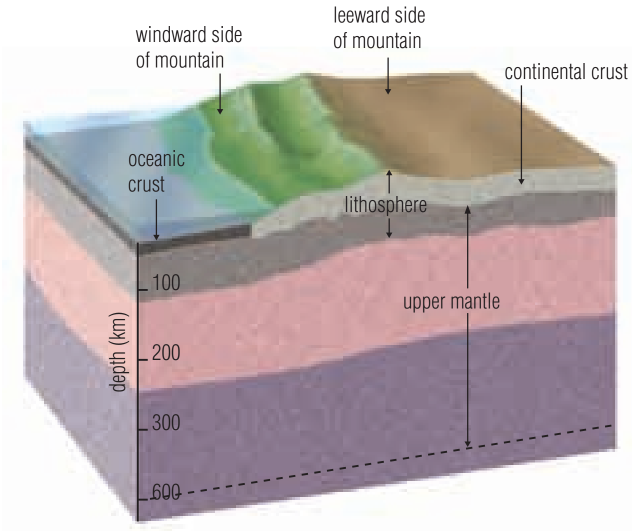


Figure 7.10 The lithosphere is the solid portion of Earth's crust and upper mantle.

The Hydrosphere

The **hydrosphere** includes all of the water on Earth. About 97 percent of this water is salt water in Earth's oceans. The other 3 percent is fresh water and includes liquid water, such as in groundwater, lakes, and streams, and frozen water, such as the ice in snow and glaciers.

Many different organisms, from whales to algae, live in the large water bodies of the hydrosphere. However, the vast majority of living organisms found in the lithosphere or atmosphere need water to survive and so also depend on the hydrosphere, even though they do not make their homes in it. The hydrosphere is warmed by incoming solar radiation.

During Reading — Thinking Literacy

Make a Connection to a Visual or Image

As you read about the biosphere, lithosphere, atmosphere, and hydrosphere, create an image or visual in your mind for each of these terms. Practise saying the term and naming your image to consolidate the concept or idea of each "sphere."

Interactions among the Biosphere's Components

Thinking about the atmosphere, lithosphere, and hydrosphere separately can help you understand the processes that occur on Earth. To get a better understanding of the systems of our planet, however, remember that these components continuously interact with one another. For example, water is present as water vapour in the atmosphere, where it plays a role in cloud formation and preciptation. It is also present in the soil and minerals of the lithosphere, where it erodes the rock and dissolves salts that plants can use as nutrients. Because these interactions are continuously changing, Earth is said to be dynamic.

Earth's Biomes

Although the biosphere provides environmental conditions that support life, these conditions are not the same everywhere on Earth. Thus, the types of life that can survive in different places are also not the same.

Take It Further

Choose a biome that interests you, and use Figure 7.11 to find out where it occurs in the world. Pick two or three of those places, and research the organisms that live there. Compare the organisms in these locations, and comment on how each is suited to live in that biome. Begin your research at ***ScienceSource***.

A **biome** is a large geographical region with a defined range of temperature and precipitation — its climate. Each biome is characterized by the plants and animals that are adapted to that climate. Figure 7.11 shows the land surface of Earth divided into 11 different terrestrial biomes. The oceans are considered a single biome — the marine biome — that covers about 70 percent of Earth.

Dividing Earth into biomes helps scientists study and understand how the biotic and abiotic components of each biome interact and how the biomes interact with each other. Biome divisions also make it easier for scientists to predict how different groups of organisms may be affected by changes in a region, such as a decrease in precipitation or an increase in summer temperatures.

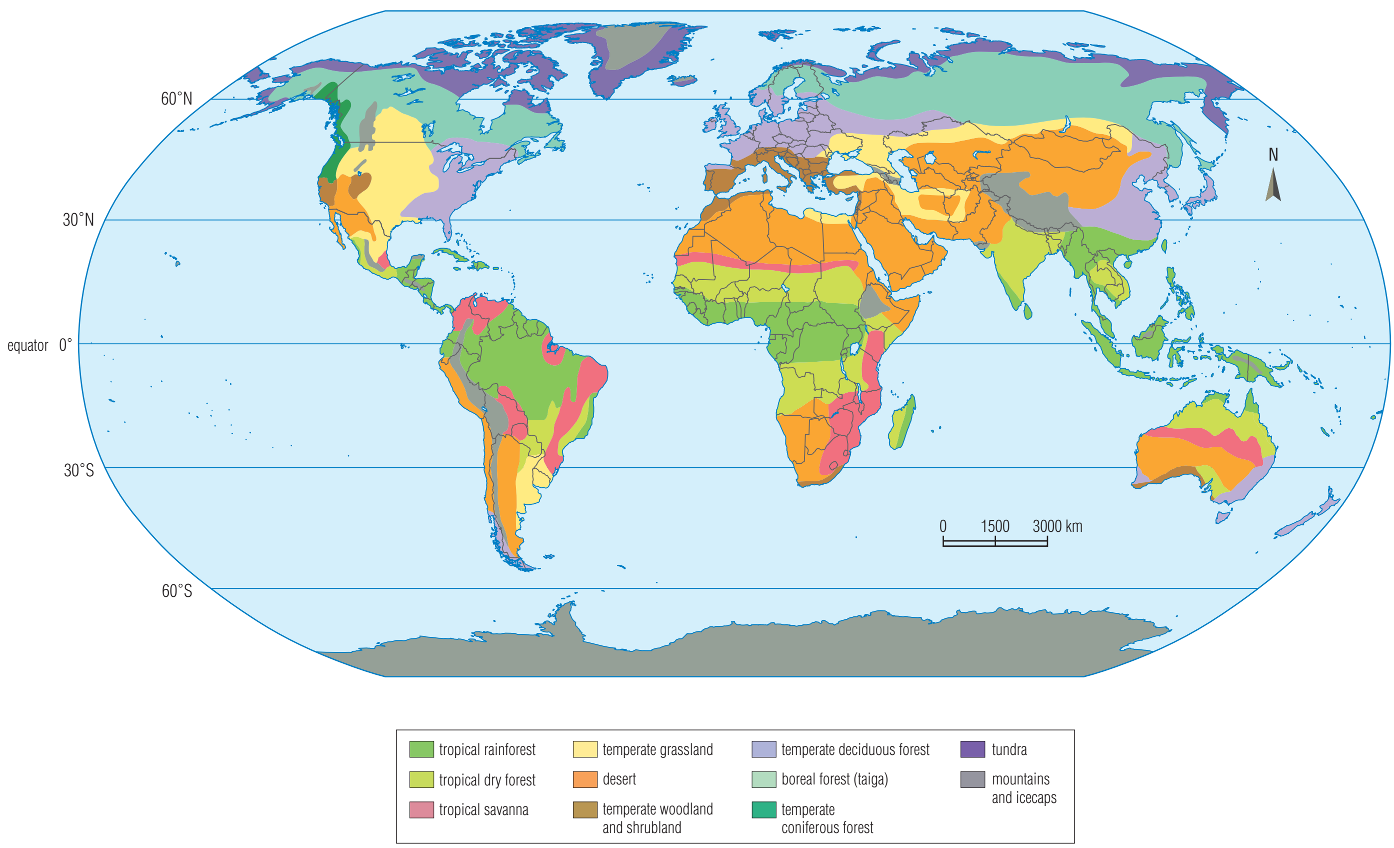


Figure 7.11 Earth's biomes reflect the climate (average temperature and amount of precipitation) in different regions.

Canadian Biomes and Climate

The six terrestrial biomes in Canada are tundra, boreal forest (also called taiga), temperate deciduous forest, temperate grassland, temperate coniferous forest, and mountain. Mountains show several different biomes as you climb, with tundra at the tops of the highest mountains. Table 7.4 shows the characteristics of each biome. Precipitation is measured in millimetres (mm) of liquid depth — the snow is melted before the measurement is taken. Note that Table 7.4 shows general trends only. Since climate conditions change gradually over the land, there is no distinct line between one biome and another. Many regions on Earth have characteristics of more than one biome.

Suggested Activity •
C5 Quick Lab on page 272

Table 7.4 Climatic Characteristics and Organisms of Canada's Terrestrial Biomes

	Climate				
Biome	**Average Annual Temperature (°C)**	**Precipitation (mm/y)**	**Description**	**Plants**	**Animals**
Tundra	–15 to 5	<200, mostly snow	short summer, 20–30 days	lichens, mosses, sedges, dwarf shrubs	arctic fox, caribou, musk oxen, polar bears, ptarmigan, mosquitoes
Boreal forest (taiga)	4 to 14	400–1000, much as snow	cool summers, cold winters	coniferous trees, lichens, grasses and sedges	woodpeckers, hawks, rodents, moose, bears, wolves, mosquitoes
Temperate deciduous forest	10 to 15	750–1500	well-defined summer and winter seasons	deciduous trees, shrubs, grasses, ferns, flowering plants	songbirds, hawks, rabbits, skunks, deer, black bears, timberwolves, raccoons, snakes, insects
Temperate grassland	4 to 10	250–600	well-defined summer and winter seasons	grasses, some flowering plants	hawks, snakes, rodents, buffalo, elk, coyotes, badgers
Temperate coniferous forest	10 to 20	800–1000	warm damp summers, mild wet winters	tall coniferous trees: Douglas fir, western red cedar	vultures, trumpeter swans, coyotes, black and grizzly bears, lynx
Mountains	depends on altitude	depends on altitude	depends on altitude	as you climb, small coniferous trees, then alpine flowering plants, mosses and lichens	boreal forest animals at lower altitudes; higher: ground squirrels, bighorn sheep, mountain goats, eagles

C3 *Just-in-Time Math*

Constructing a Climatograph

Climatographs show the average monthly temperatures and precipitation amounts on a single graph. The advantage of using a climatograph instead of a table of numerical data is that it is easier to interpret and compare the data (Figure 7.12).

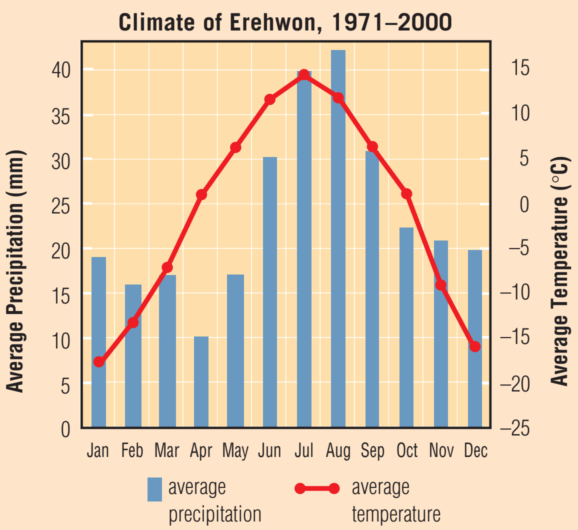


Figure 7.12 A sample climatograph

1. You can use graph paper or spreadsheet software to construct climatographs.
2. Study the information in Table 7.5.
3. Draw a graph outline with two vertical axes, one on each side of the graph. Label the horizontal axis with the months of the year.
4. Determine the range of the temperature data for the year. Label the vertical axis on the right side with this temperature range.
5. Plot the average monthly temperature data as a line graph.
6. Determine the range of the precipitation data for the year. Label the vertical axis on the left side with this precipitation range.
7. Plot the average monthly precipitation data as a bar graph.
8. Write a legend and a title for the climatograph. The title should include the location and the time the data was collected.

Table 7.5 Climate Data for Thunder Bay, ON, 1971–2000

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–14.8	–12.0	–5.5	2.9	9.5	14.0	17.6	16.6	11.0	5.0	–3.0	–11.6
Average monthly precipitation (mm)	31.0	25.0	42.0	42.0	67.0	86.0	89.0	88.0	88.0	61.0	56.0	38.0

C4 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE

- Interpreting data/information to identify patterns or relationships
- Communicating ideas, procedures, and results in a variety of forms

Toronto, Then and Now

Environment Canada provides climate data from its 2200 weather stations throughout the country. The global standard for climate data is 30 years, with the ending year as a decade year (e.g., 1971–2000). Because of this standard, you can easily compare climate data from cities around the world.

A weather station has been operating on Bloor Street in Toronto since 1840. *The Emigrants' Handbook*, published in 1864, included climate data from this site for 1840–1859. Nowadays, climate data for the same site can be obtained from Environment Canada. Constructing climatographs using the historical and recent climate data can help you compare people's living conditions now and 150 years ago.

C4 Inquiry Activity (continued)

Question

How has Toronto's climate changed in the last 150 years?

Materials & Equipment

- graph paper or spreadsheet software

Procedure

1. Predict your answer to the question.
2. Copy Tables 7.6 and 7.7 into your notebook.
3. Construct your two climatographs as described in "Constructing a Climatograph" on the previous page. Use two spreadsheet files, or construct your climatographs side by side on a sheet of graph paper.
4. When you determine the range of the average monthly temperature data over the year, select a range that accommodates both sets of data.
5. When you determine the range of the average monthly precipitation data, again select a range that will accommodate both sets of data.
6. Write a title for each climatograph.

Analyzing and Interpreting

7. Study each climatograph. Write a few sentences on each, describing the data, such as monthly data changes and if you think the temperature and precipitation are related.
8. Compare the two climatographs, and describe any differences you observe between them. Explain any differences.

Skill Practice

9. What are the advantages of using spreadsheet software over graphing by hand?

Forming Conclusions

10. What factors could have affected the climate between 1840 and now?
11. Would you feel confident making a statement about climate change in Toronto based on this information? If you answered "yes," why and what would the statement be? If you answered "no," why not?
12. Why would you construct climatographs for data averaged over a number of years instead of just an individual year?

Table 7.6 Climate Data for Toronto, ON, 1840–1859

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–4.6	–5.9	–1.1	5	10.7	16.2	19.5	18.9	14.4	7.3	2.5	–3.3
Average monthly precipitation (mm)	36.0	26.0	39.0	63.0	84.0	81.0	89.0	74.0	104.0	57.0	79.0	41.0

Table 7.7 Climate Data for Toronto, ON, 1971–2000

	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly temperature (°C)	–4.2	–3.2	1.3	7.6	14.2	19.2	22.2	21.3	17.0	10.6	4.8	–0.9
Average monthly precipitation (mm)	61.0	51.0	66.0	70.0	73.0	72.0	68.0	80.0	83.0	65.0	76.0	71.0

C5 *Quick Lab*

Your Biome and You

Purpose

To classify the climate of your local region and compare it with others in Ontario, Canada, and the world

Materials & Equipment

- books about biomes
- ***ScienceSource***

Procedure

1. Look at Figure 7.13, and determine where your community is on the map.
2. Determine the name of the biome where you live.
3. ***ScienceSource*** Use the Internet or books to locate some information that characterizes the biome you live in.
4. Organize the information you located into a fact sheet about the climate you live in.

Questions

5. Look at Figure 7.13, and describe the other biomes located in Ontario. How is your biome different from the others in the province?
6. Look at the world biome map (Figure 7.11), and describe any patterns you notice in the distribution of biomes around the world.
7. Write at least two ways your daily life is affected by the biome you live in.
8. Identify one biome you think is the most different from the one you live in. Explain your choice.
9. If you could pick the ideal biome to live in, what would it be and why?
10. Go to ***ScienceSource*** and find the Koppen climate map, the ecoregion map, and the horticulture zone map for Canada or Ontario. How does the information in these maps compare with the biome map? Can you think of uses for each map?

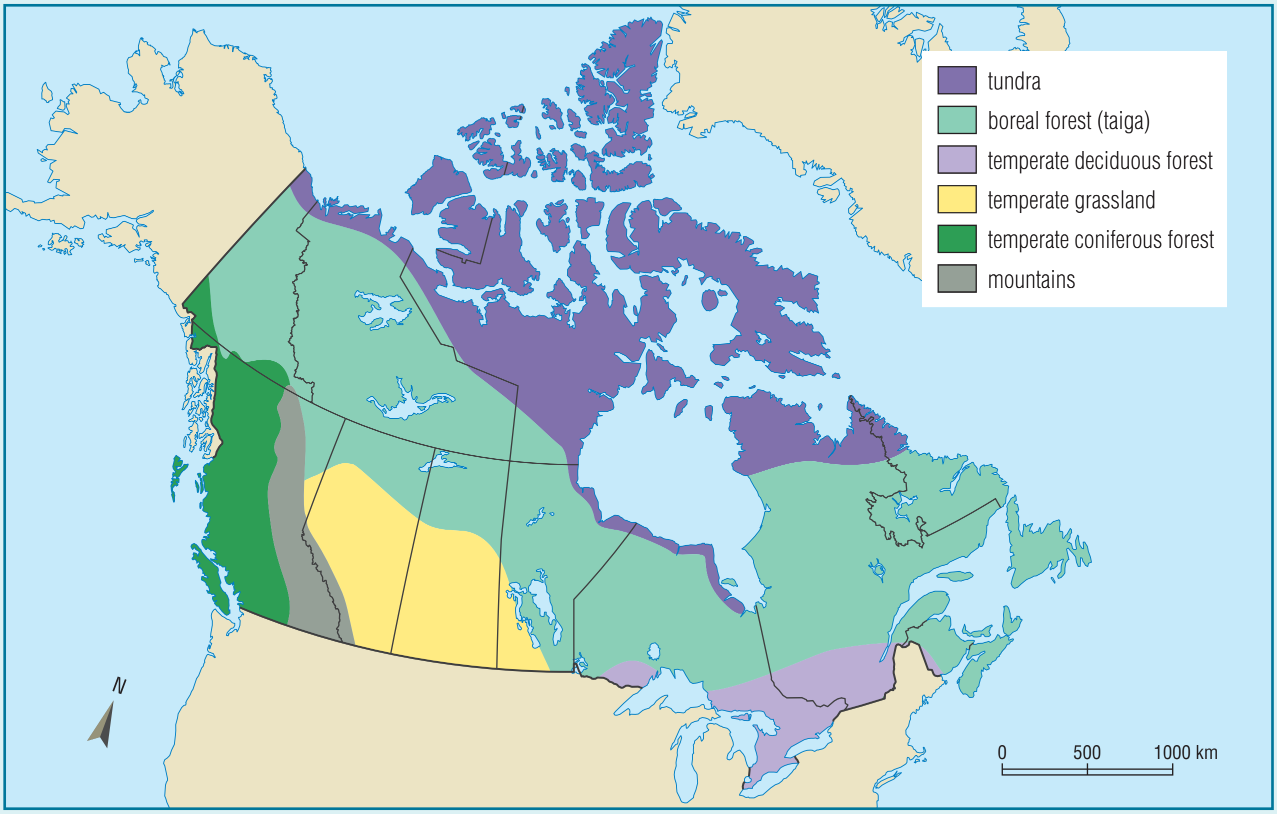


Figure 7.13 Canada can be divided into six biomes. Three of these biomes are found in Ontario.

7.1 CHECK and REFLECT

Key Concept Review

1. Define "weather" and "climate" in your own words.
2. Explain why the Sun is considered the source of almost all the energy on Earth.
3. List the interacting components of the biosphere, and briefly describe how they interact.
4. Look at the photographs, and list three words to describe the climate depicted in each.

Question 4

5. Describe one example of how climate affects people.
6. Make a list of the components you would find in Earth's atmosphere.
7. Describe two ways the lithosphere is warmed.
8. Create a pictorial representation of how the water in Earth's hydrosphere is classified.
9. State whether each of the following terms is related more to weather or to climate.
   (a) cloud cover
   (b) annual rainfall
   (c) chance of precipitation
   (d) average monthly temperature
10. Define the word "biome."
11. List two important facts about each part of the biosphere.
12. What is the difference between solar radiation and thermal energy?
13. List the six biomes in Canada. Briefly describe their climates and name one animal and one plant found in each.

Connect Your Understanding

14. Compare the similarities and differences between weather and climate, and explain how each affects your daily life.
15. Why is it important that Earth has a biosphere? Why is it important to study each component of the biosphere separately as well as consider them as a system?
16. Earth's biosphere, atmosphere, lithosphere, and hydrosphere are all interconnected. Identify one way these layers interact with each other.
17. Use the information in Table 7.4 on page 269 to make up three questions about biomes for a classmate to answer.
18. To be able to discuss a topic such as climate change, it is often important to learn some background information. Reflect upon this statement, and give your opinion about it. Support your opinion with evidence.

Reflection

19. What is one thing you learned in this section that you would like to find out more about?

For more questions, go to ***ScienceSource***.

7.2 Heat Transfer and the Natural Greenhouse Effect

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

- The natural greenhouse effect is a natural process that occurs in Earth's atmosphere and is essential to life.
- Earth's net radiation budget is the difference between the amount of incoming radiation from the Sun and the outgoing energy from Earth.
- The amount of energy reflected from Earth is affected by the albedo of the area.
- Thermal energy is transferred by radiation, conduction, and convection.
- The transfer of thermal energy on Earth affects winds and ocean currents.

Figure 7.15 The glass or plastic walls and roof of a greenhouse trap heat from the Sun.

Figure 7.14 Even though it is winter outside, this school bus has been sitting in the sunshine all day and is much hotter inside than outside.

Trapping Heat

After a lovely sunny day at the outdoor education centre, you return to your school bus and climb in (Figure 7.14). You are hit by a wall of heat and can hardly breathe! Stumbling back out of the bus, you get a couple of friends to help you. You all run onto the bus, open all the windows, and then put your heads out to breathe the cool air. You have just experienced how a greenhouse works.

You can find greenhouses all across Ontario. Some are in public gardens, such as Allan Gardens in downtown Toronto, where tropical plants thrive year-round, and the Niagara Parks Botanical Gardens (Figure 7.15). Some greenhouses are at garden centres, where they protect young plants from cold weather outside. Some are tiny greenhouses made by private gardeners from hoops and plastic, to give their plants a head start on the growing season.

Tomatoes, lettuce, and cucumbers are grown in commercial greenhouses (sometimes called hothouses) so we can buy Ontario-grown produce early in the season. Some greenhouse operators plant flower and vegetable seeds in greenhouses in late winter and sell the young plants in the spring. Municipalities and many gardeners prefer to buy young plants instead of seeds because they get the flowers or vegetables earlier in the season. Delicate or fragile ornamental plants are grown in greenhouses because they survive better than if grown outdoors.

Greenhouse operators rely on the sun to keep their greenhouses warm. Sunlight passes through the glass in the windows of the greenhouse (Figure 7.16). Some of the solar radiation reflects off the tables, ground, and plants inside and escapes back through the windows. Some of the solar radiation heats those tables, the ground, and the plants. These heat the air in the greenhouse. However, this air cannot escape so the greenhouse becomes warmer and warmer. While the glass lets the sunlight in, it does not let the warm air out.

Greenhouse operators often use temperature-controlled devices to open the greenhouse windows when the inside air becomes too hot, and close them again when it has cooled. When the day is cloudy, the operators use back-up heaters.

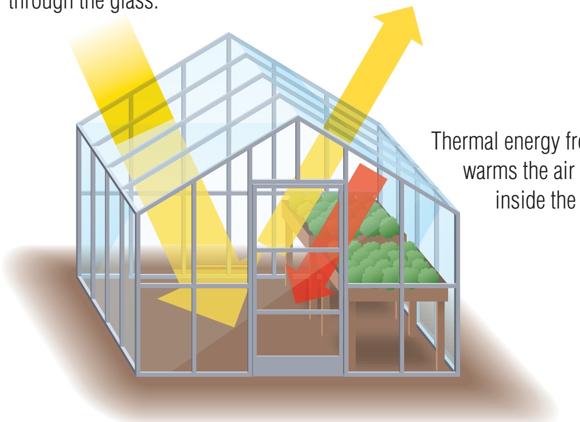


Figure 7.16 How a greenhouse works

C6 *Quick Lab*

Too Much Heat

You may have had experiences similar to those of the students getting on the school bus. Recall these situations, and look for patterns.

Materials & Equipment

- pencil and paper

Purpose

To discover why some places seem to be warmer than expected

Procedure

1. Form a group of four students.
2. In the middle of your sheet of paper, write "unexpectedly warm places" and circle the words.
3. Draw a line from the title to another place on the sheet and write "school bus parked in the sun." Add a sketch to illustrate this.
4. Discuss other times this has happened to you or a member of your group. Add these to the sheet of paper.

Questions

5. What do you notice about these warm places? What do they have in common?
6. Discuss how you think this concept is related to the study of climate.
7. Write a summary of your group's discussion in your science notebook.

Insolation and the Natural Greenhouse Effect

Although virtually all the energy on Earth comes from the Sun, different regions receive different amounts of solar radiation. **Insolation** is the amount of solar radiation received by a region of Earth's surface (see Figure 7.6). Insolation depends on latitude, which is the distance of any place on Earth from the equator, shown on a globe by a series of lines drawn around it parallel to the equator. The equator is at 0° latitude, and the North Pole is at 90° latitude. Toronto is at latitude 43°40' ("minutes") N (north of the equator). Insolation also depends on specific characteristics of the lithosphere, atmosphere, and hydrosphere in that region. Some of these characteristics can change from day to day.

As the insolation reaches Earth, some of it is scattered by collisions with water vapour, gas molecules, and dust in the atmosphere. Some of the scattered insolation returns to space, some is absorbed by the atmosphere, and some makes it to Earth's surface.

The Natural Greenhouse Effect

Suggested Activity •
C9 Inquiry Activity on page 287

Some of the solar radiation that is absorbed by Earth's surface is re-emitted into the atmosphere as infrared radiation (Figure 7.17). Most of this radiation is absorbed as thermal energy in the atmosphere by clouds and gases such as water vapour, carbon dioxide (CO_2), and methane (CH_4). Without the atmosphere, this thermal energy would escape into space, and Earth would be significantly cooler. The absorption of thermal energy by the atmosphere is known as the **natural greenhouse effect**. The natural greenhouse effect helps keep the temperature of our planet in the range that supports life. The average temperature at Earth's surface in 2007 was 14.7°C. Without the natural greenhouse effect, the average temperature on Earth would be about –20°C.

Water vapour, carbon dioxide, nitrous oxide, and methane are called **greenhouse gases**, gases that contribute to the natural greenhouse effect. Since so much water vapour is present in the atmosphere, it is the main contributor to the natural greenhouse effect. However, carbon dioxide, methane, and nitrous oxide also absorb significant amounts of thermal energy.

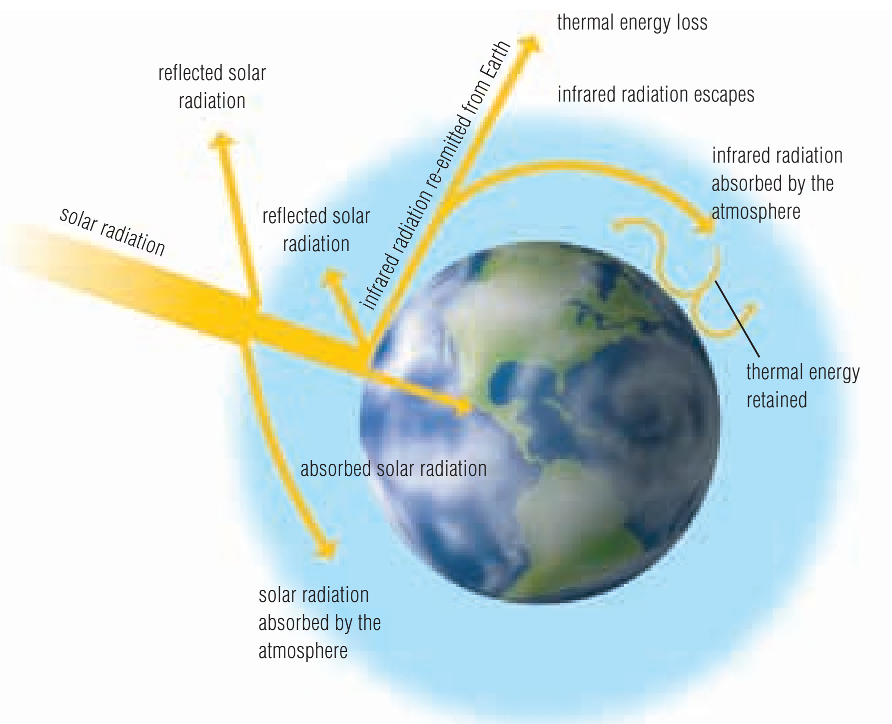


Figure 7.17 The natural greenhouse effect keeps Earth warm enough to support life by absorbing some of the infrared radiation re-emitted from Earth's surface.

The natural greenhouse effect has helped maintain Earth's climate for millions of years. While the climate has varied considerably over that time, its temperatures and precipitation amounts have always been in a range to support life on Earth.

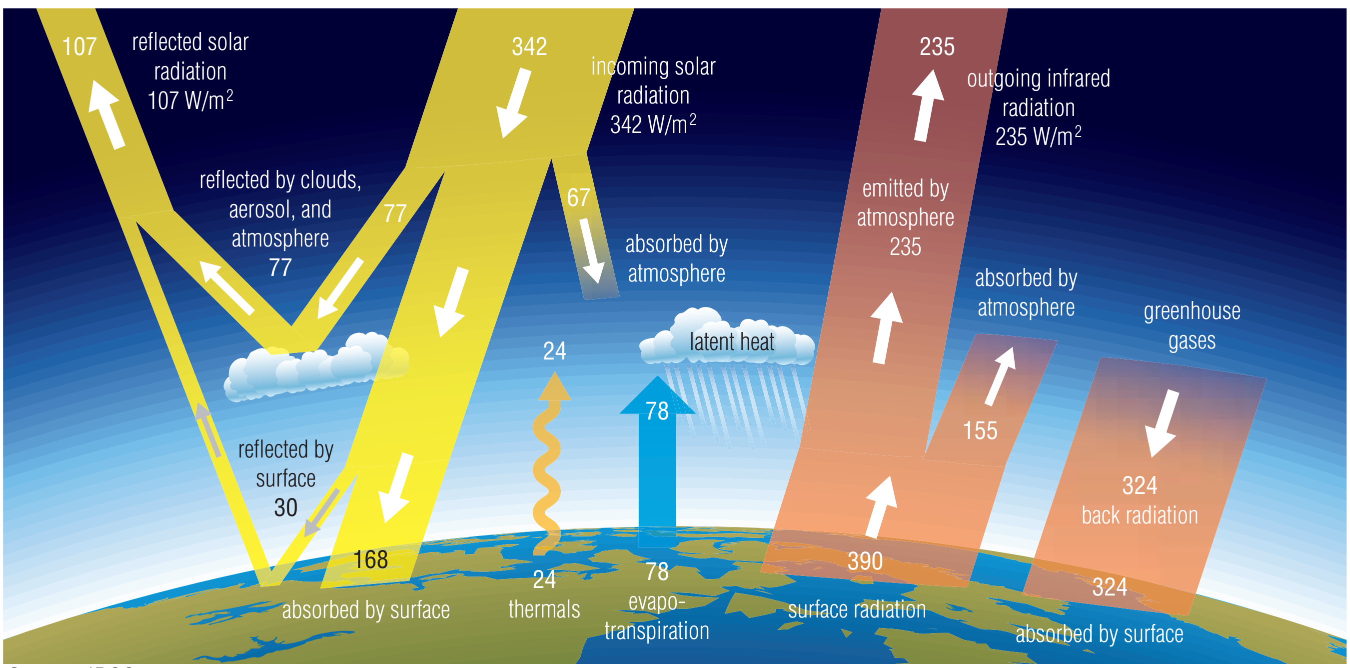
The Net Radiation Budget

Earth is a warm, habitable planet because Earth's surface and the atmosphere absorb incoming insolation. However, not all the incoming solar radiation is absorbed. Some is reflected out to space, and some is re-emitted as thermal energy by Earth's surface and atmosphere.

Figure 7.18 shows the relative contribution of different aspects of Earth's average **net radiation budget**, which is the difference between the amount of incoming radiation and the amount of outgoing radiation. Each square metre of the outer surface of Earth's atmosphere receives an annual average of 342 W of solar radiation. The W stands for watts, which are energy units per second. Of the 342 W/m^2, 31 percent is immediately reflected back into space by clouds, the atmosphere, and Earth's land surface. About 30 percent of the remaining solar radiation is absorbed by the atmosphere. The rest warms Earth's surface, which returns that heat to the atmosphere as infrared radiation, thermal energy, and water vapour. The atmosphere, in turn, emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface.

Almost all the energy absorbed by Earth's atmosphere, lithosphere, and hydrosphere is eventually radiated back into space as infrared radiation (Figure 7.18). Less than one percent of the incoming solar radiation is transformed by photosynthesis into chemical energy.

Figure 7.18 Earth's annual global net radiation budget. Incoming solar radiation is shown on the left side, and how the atmosphere emits the outgoing infrared radiation is shown on the right side. All numbers are in watts per square metre.



Source: IPCC

Balancing the Radiation Budget

On average, the amount of incoming radiation is equal to the outgoing radiation for all of planet Earth. In a word equation:

$$\begin{aligned}\text{net radiation budget} &= \text{incoming radiation} - \text{outgoing radiation}\\ &= \text{zero}\end{aligned}$$

If this balance were to change, then the average global temperature would either increase or decrease until the net radiation budget was balanced again. For example, if the amount of radiation re-emitted back into space decreased and the amount of incoming radiation remained the same, Earth's average global temperature would increase.

Although the net radiation budget is balanced for Earth as a whole, some regions on Earth have an unbalanced net radiation budget. Latitude is an important factor in predicting whether the net radiation budget of a region is out of balance. For example, polar regions tend to have less incoming radiation than outgoing radiation, and the tropics have more incoming radiation than outgoing.

Albedo

The amount of solar radiation that is reflected from Earth's surface depends on the characteristics of that surface. The **albedo** of a surface is the percent of the incoming solar radiation that it reflects. The albedo of our entire planet is about 30 percent. Light-coloured, shiny surfaces such as snow, ice, and sand reflect much more solar radiation — about 90 percent — than do darker, duller surfaces such as open water (about 10 percent), forests, and soils (Figure 7.19). Think about how bright it seems when you walk out of school after a fresh snowfall when every surface is covered with snow.

Suggested Activity •
C10 Inquiry Activity on page 288

Albedo varies with the seasons. Ontario usually has a higher albedo in winter than in the summer because of snowfall, frost, or dried grass. Albedo can affect a region's radiation budget because it can affect the temperature and rate of evaporation in that region.

During Reading — Thinking Literacy

Make a Text-to-World Connection

What concerns are there in North America and around the world about climate change and the greenhouse effect? How has this issue reached the public? How can we check to see which information is true?

Learning Checkpoint

1. Explain what happens to the solar radiation that reaches Earth.
2. What would the average temperature on Earth be without the natural greenhouse effect?
3. State whether the following surfaces would have a high or a low albedo.
   (a) a mirror
   (b) a lawn
   (c) a sidewalk
   (d) an asphalt driveway

Thermal Energy Transfer

Thermal energy transfer is the movement of thermal energy from an area of high temperature to an area of low temperature. Suppose you took a bicycle outdoors on a cold day. The temperature of the bicycle would fall to the same temperature as the air outside. If you then brought the bicycle back inside, the temperature of the bicycle would increase to the indoor temperature. In this example, thermal energy was transferred first from the bicycle to the outdoor air and then from the indoor air to the bicycle. Thermal energy transfer can occur by radiation, conduction, or convection.

(a)

(b)

Figure 7.19 (a) The Amazon jungle and (b) the Sahara Desert each receive about the same amount of solar radiation. However, the dark jungle has a low albedo and absorbs most of the solar radiation that hits it. The desert with its high albedo reflects most of the solar radiation into the atmosphere.

Radiation

Radiation is the emission of energy as waves. When radiant energy encounters particles of matter, it may be reflected or absorbed. Absorbed energy can increase the movement of the particles (their kinetic energy). An increase in kinetic energy increases the temperature of the matter.

Any substance at a higher temperature than its surroundings will emit radiant energy, usually as infrared radiation (Figure 7.20). For example, the Sun radiates energy in the form of electromagnetic waves (solar radiation). When this radiant energy reaches Earth, some of it is absorbed by matter such as land, water, or air. The absorbed radiant energy increases the kinetic energy of the molecules in the matter, and the temperature of the matter increases. The warmed matter then transfers some of its thermal energy to substances at lower temperatures or re-emits it as infrared radiation.

Conduction

Conduction is the transfer of thermal energy through direct contact between the particles of a substance, without moving the particles to a new location. Thermal energy transfer by conduction usually takes place in solids. Recall that particles in a solid all have a certain average kinetic energy. During conduction, particles with more kinetic energy transfer some of their energy to neighbouring particles with lower kinetic energy (Figure 7.20). This increases the kinetic energy of the neighbouring particles, which may, in turn, transfer energy to other neighbouring particles, increasing their kinetic energy. For example, in Figure 7.20, the barbecue is radiating energy to the solid metal pan. The particles of metal closest to the burner absorb some of this radiated energy and increase in kinetic energy. These particles can then transfer energy by conduction to neighbouring particles, causing an increase in temperature.

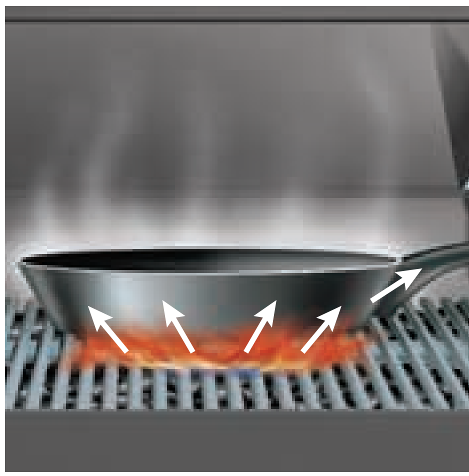


Figure 7.20 In this illustration, energy is radiated from the heat source and is absorbed by the lower surface of the pan. Thermal energy is then transferred to other parts of the pan (e.g., the handle) by conduction. Conduction transfers thermal energy from one particle to another through direct contact.

Convection

Figure 7.21 Convection transfers thermal energy through the movement of particles from one location to another.

Convection is the transfer of thermal energy through the movement of particles from one location to another. Thermal energy transfer by convection usually occurs in fluids, which are substances with no definite shape, such as gases and liquids. During convection, the movement of the particles forms a current, which is a flow, from one place to another in one direction. For example, when the water in the pot in Figure 7.21 absorbs energy from the barbecue, the water molecules increase in kinetic energy. The water molecules then begin to move apart from one another, causing the water to expand in volume. This expansion lowers the density, or mass per volume, of the water. The warmer, less dense water rises to the top, forming an upward convection current. When it contacts the cooler air at the surface, the water cools and contracts, which increases its density and forms a downward convection current.

Both water and air are fluids, but water has a higher heat capacity than air has. This means that it takes a lot of energy to increase the temperature of a mass of water. Also, when the mass of water cools down, large amounts of energy are released from the water. Water heats up and cools down slowly compared to other substances. Think about how, in summer, the sidewalk can feel much hotter than a puddle on the sidewalk does. Since Earth's surface is over 70 percent water, water has a large effect on Earth's climate. Therefore, regions closer to large bodies of water tend to experience more moderate weather conditions than regions farther from them. This feature is attractive to many people and is one reason why coastal cities tend to attract large populations.

Thermal Energy Transfer in the Atmosphere

Earth as a whole receives insolation from the Sun, but different parts of Earth receive different amounts. Since Earth's climate system is one interrelated whole, thermal energy is transferred throughout the atmosphere and hydrosphere.

The temperature of the atmosphere tends to increase in areas close to or at the equator. As the heated atmospheric gases gain energy and expand, the air becomes less dense and rises. In areas close to or at the poles, the temperature of the atmosphere tends to decrease. Here, the cooling atmospheric gases lose energy and contract and the air becomes denser and falls. If Earth were not spinning, there would be a continuous convection current between the polar and the equatorial regions (Figure 7.22).

Atmospheric pressure is the pressure exerted by the mass of air above any point on Earth's surface. Since warm air is less dense than cold air, warmer regions of the atmosphere generally exert less

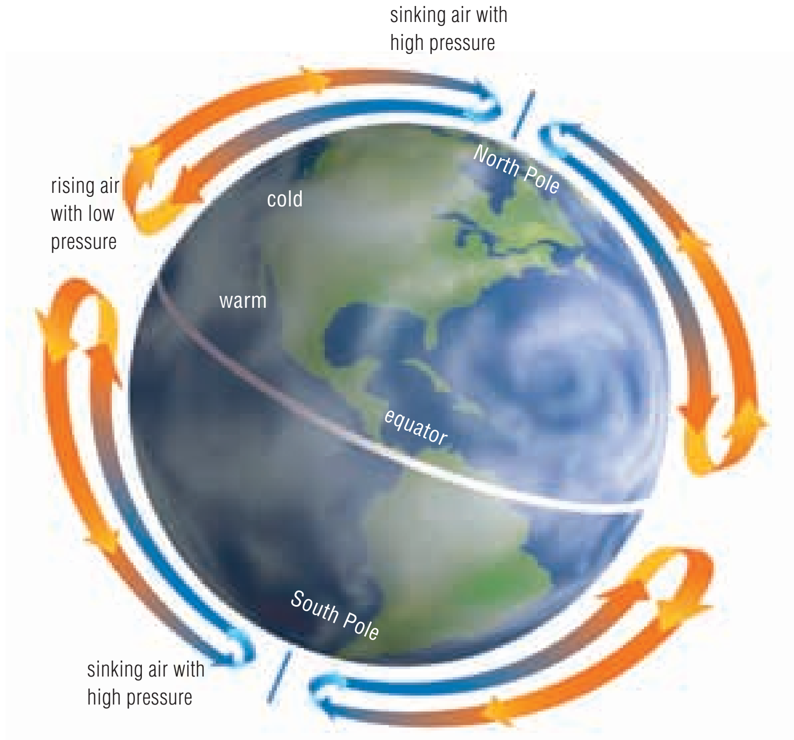


Figure 7.22 If Earth did not rotate, differences in thermal energy in the atmosphere would cause these convection currents.

atmospheric pressure than cooler regions. **Wind** is the movement of air from areas of high pressure to areas of low pressure. The rising and sinking masses of air in convection currents cause changes in atmospheric pressure, which cause wind.

The Coriolis Effect

The difference between the net radiation budget at the poles and at the equator tends to cause air to move directly north and south. However, since Earth is rotating on its axis, the winds are deflected either toward the right or toward the left. The **Coriolis effect** is the deflection of any object from a straight-line path by the rotation of Earth. The Coriolis effect causes moving air or wind to turn right in the northern hemisphere and left in the southern hemisphere.

To better visualize the Coriolis effect, imagine you are standing at the North Pole and you launch a rocket southward. Relative to space, your rocket travels south in a straight line from where you launched it. However, as the rocket travels, Earth rotates beneath it. Relative to the North Pole, the rocket is deflected westward, to the right. Similarly, if you launched a rocket from the South Pole toward the equator, Earth's rotation would again deflect the path of the rocket westward, which from the South Pole is to the left (Figure 7.23 on the next page).

Suggested Activity
C8 Quick Lab on page 286

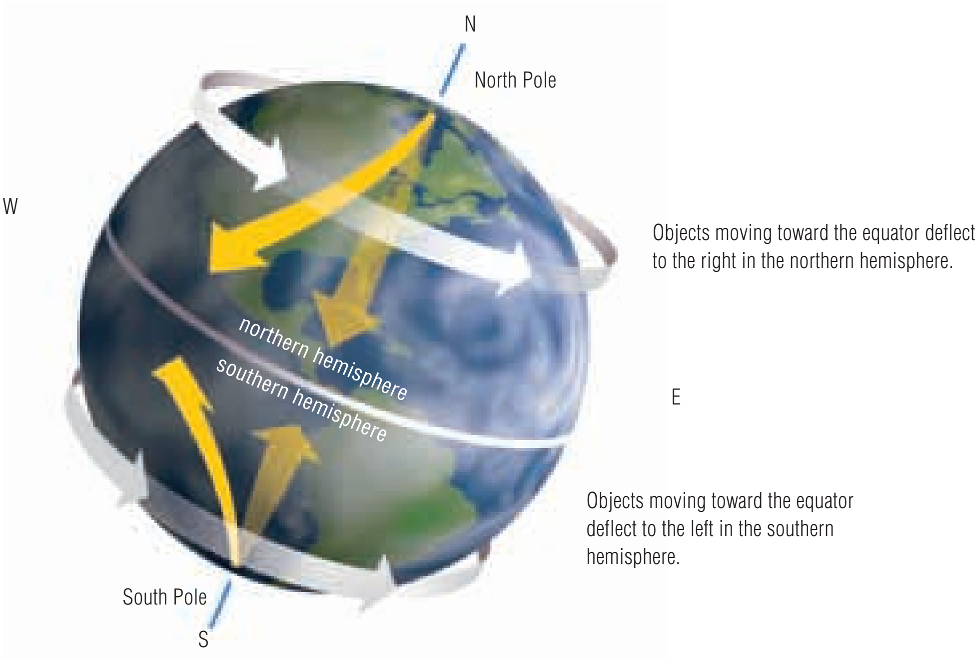


Figure 7.23 The white arrows show Earth's rotation. Because of the Coriolis effect, winds are deflected to the right in the northern hemisphere (pretend you are looking southward from the North Pole) and to the left in the southern hemisphere (looking northward from the South Pole). The winds in temperate regions of the northern hemisphere tend to circulate clockwise, while those in the temperate regions of the southern hemisphere tend to circulate counterclockwise.

Global Wind Patterns

The convection currents in the atmosphere and the Coriolis effect result in the global wind patterns (Figure 7.24). Global winds transfer thermal energy from areas of net radiation budget surplus to areas of net radiation budget deficit. If this did not occur, areas at or near the equator would grow very hot while the rest of Earth would become much colder.

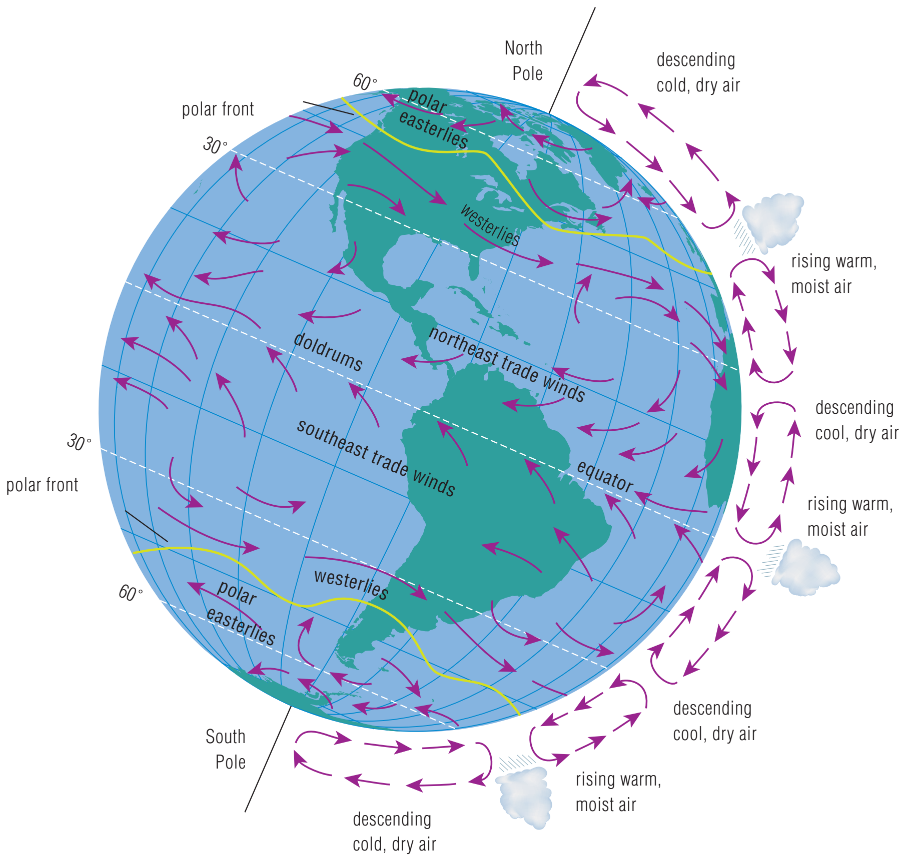


Figure 7.24 Global wind patterns are caused by the unequal heating of Earth's atmosphere and the deflection of winds by the Coriolis effect. The trade winds and polar easterlies tend to blow to the west. The doldrums are a region of very low winds in a band about the equator.

Ontario is subjected to the prevailing westerlies, which blow from west to east. They also occur at the same latitude in the southern hemisphere.

In regions near the equator, warm, rising air currents cause higher altitude winds that flow toward the poles. To replace the rising air, cooler surface air moves toward the equator from higher latitudes. This air movement is called the trade winds. The Coriolis effect makes the trade winds curve to the west, whether they are travelling to the equator from the south or north.

At latitudes of about 30°N and 30°S, some of the warm air from the equator is cooled enough to sink and move westward toward the equator. The rest of the warm air moves toward the poles and is pushed west by the Coriolis effect, which causes cold air to rush in, in a eastward direction. This gives rise to the westerly winds that prevail at latitudes between 30° and 60° in both directions from the equator. At the poles, sinking cold air is pushed westward, forming easterly winds.

Jet Streams

Local conditions such as the presence of continents or large bodies of water also affect wind patterns. Earth's surface and the density of the troposphere produce friction, which slows global winds. A jet stream is a band of fast-moving air in the stratosphere. Because of their high altitude, these winds are not subject to much friction and so are much faster than winds closer to Earth's surface.

Earth has several jet streams, which circle Earth at various latitudes (Figure 7.25). There are usually two or three jet streams in the northern and southern hemispheres. Like the surface winds, the convection currents in Earth's atmosphere also form the jet streams. Their speed and location vary with the amount of thermal energy in the atmosphere. During the cooler months, the jet streams tend to be closer to the equator and move more quickly.

Changes in the jet streams affect the formation of severe weather events such as squalls, storms, and cyclones. The movements of the jet streams, particularly those in polar regions, can also affect the movement of the air at lower levels of the atmosphere. Changes in the jet streams are therefore very important in predicting weather changes, so you are likely to hear them mentioned during weather forecasts.

During Reading

Make Connections Among Ideas

Draw a mind map to connect the terms and ideas on these pages. Use lines and labels to show the relationships among the Coriolis effect, wind patterns, the jet stream, and heat transfer.

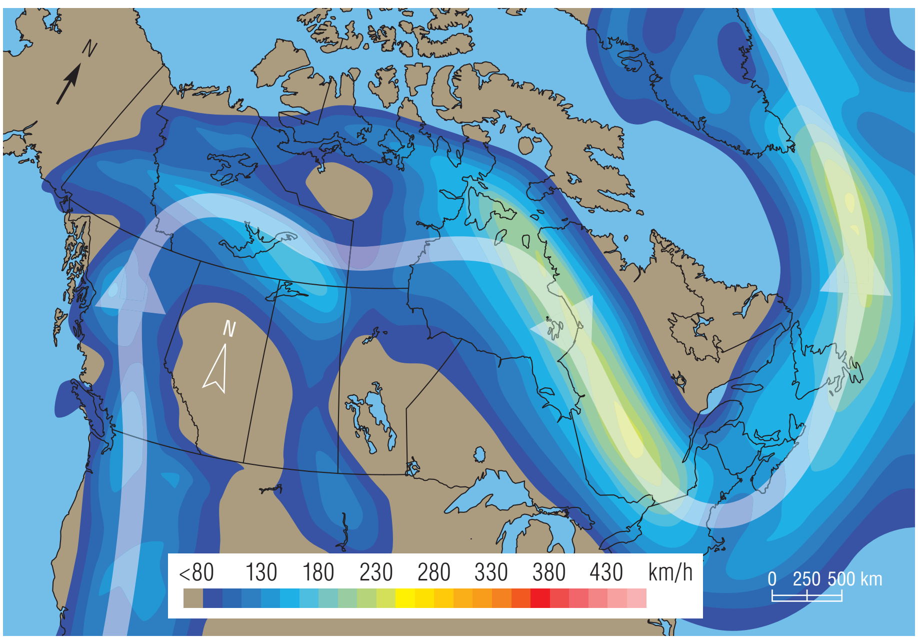


Figure 7.25 The jet stream across Canada on November 2, 2008

Thermal Energy Transfer in the Hydrosphere

The effect of water on the transfer of heat in the hydrosphere is very significant. Since water covers about 70 percent of Earth's surface and different forms of water can be found throughout Earth's biosphere, Earth's climate is influenced greatly by phase changes during the hydrologic cycle.

Recall what you know about the hydrologic cycle, also called the water cycle (Figure 7.26). At various stages in the hydrologic cycle, water molecules undergo changes in phase, from solid to liquid to vapour and back again. Whenever water changes phase, thermal energy is either released or absorbed. During a phase change, the temperature of the water remains the same even though the quantity of thermal energy increases or decreases. Thermal energy is released when water goes from liquid to solid. When liquid water changes to water vapour, thermal energy is absorbed. Through such changes of state, the hydrologic cycle transfers thermal energy through the biosphere.

Since water molecules undergo many phase changes during the hydrologic cycle, energy can be transferred in the biosphere without any changes in temperature of the water. This helps to keep the average temperature of Earth relatively stable.

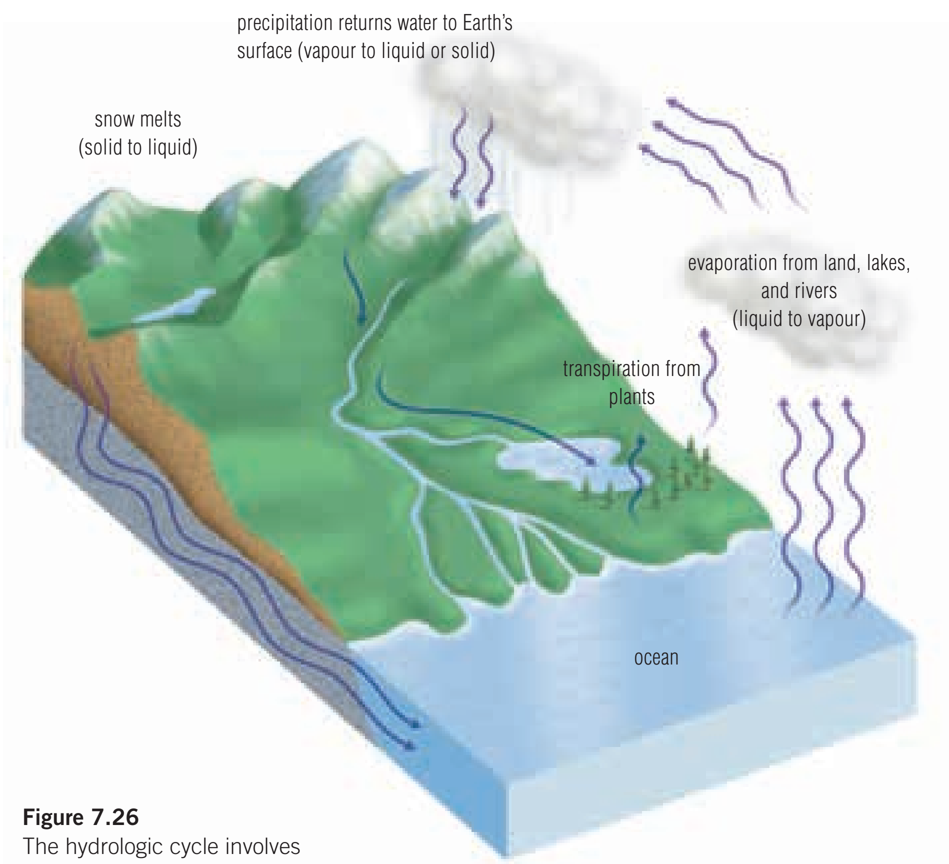


Figure 7.26
The hydrologic cycle involves many phase changes.

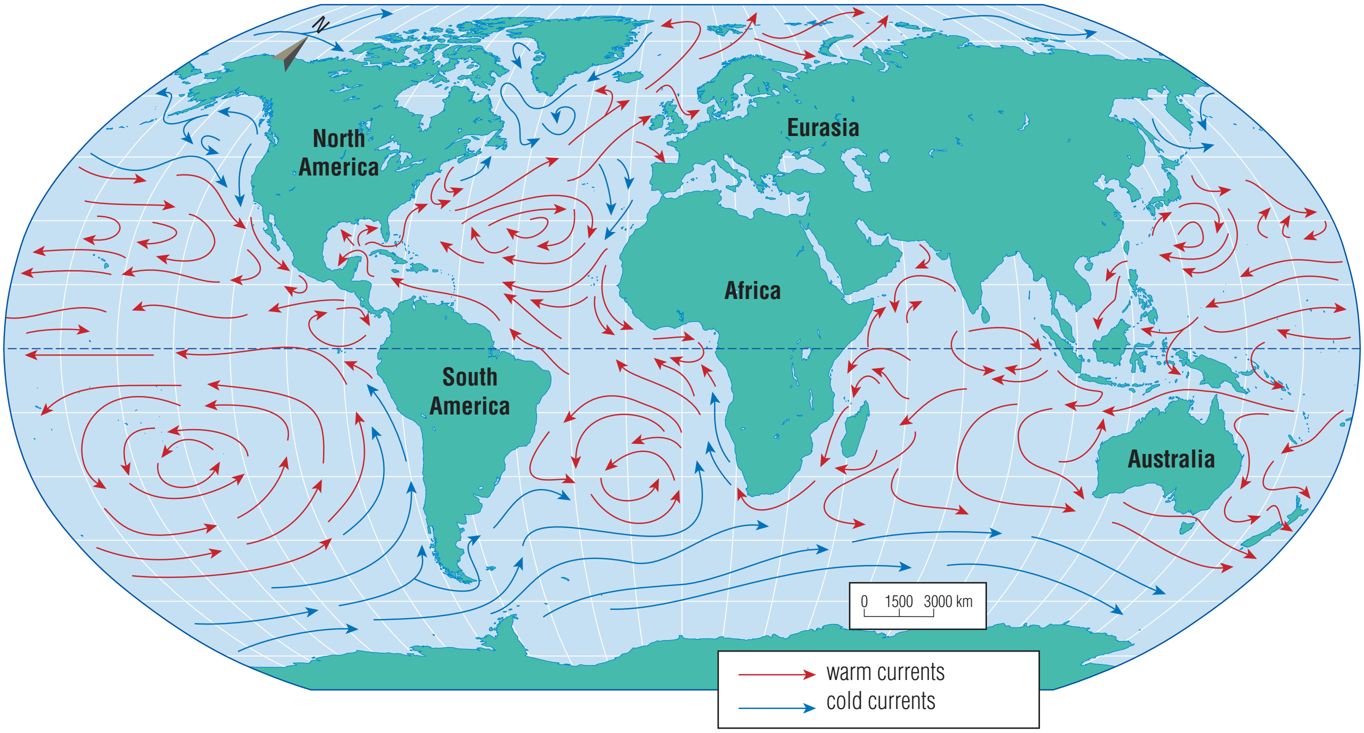


Figure 7.27 The surface ocean currents extend from the surface of the oceans to a depth of about 100 m and reflect the pattern of Earth's global winds.

Thermal Energy Transfer in the Oceans

Ocean currents are the main pathways for the transfer of thermal energy from the warmer latitudes near the equator to cooler areas near the poles. As the global winds blow on the ocean surface, they push on the water, driving the surface currents in the oceans. Figure 7.27 shows the major patterns of these currents. The warmer waters near the equator are driven by the trade winds between the equator and latitudes 30°N and 30°S. The winds change direction from westerly in the middle latitudes to easterly in the polar latitudes. They drive ocean currents that move warm water toward the poles in the mid-latitudes and cold water southward in higher latitudes.

As with global winds, the pattern of surface ocean currents is modified by the Coriolis effect. Currents in the northern hemisphere veer to the right. Currents in the southern hemisphere veer to the left. Earth's continents also affect the general pattern of the ocean's currents, however. The currents have to change direction when they encounter a large land mass. Some coastal regions, such as the east coast of the United States, experience a continuous current of warm water, whereas other regions, such as the east coast of Labrador, experience a continuous current of cold water.

Thermal energy is also transferred vertically through the oceans and other bodies of water, through convection currents. Just like the density of air, the density of water decreases when its temperature increases, so warm water tends to rise. Cooler water is denser, so it tends to sink. Deep ocean currents also carry water around the globe.

Take It Further

Jet streams influence air travel as well as weather. Find out how jet streams affect air travel, and write a short summary paragraph of your research. Compare your summary with that of a partner. If hearing a partner's summary gives you ideas for improving your summary, make the improvements now. Begin your research at ***ScienceSource***.

C7 STSE *Science, Technology, Society, and the Environment*

Who Owns the Arctic Ocean?

Canadians have always assumed that the Arctic Ocean between Canada and the North Pole was part of Canada. However, this view is not held by all countries. In the past, this issue has not seemed important, but climate change has brought the question of "who owns the Arctic Ocean" to the forefront.

Figure 7.28 Canadian Rangers are part-time military personnel who patrol the Arctic region and assist military, scientific, and search and rescue operations. Most of the 4500 Rangers are Inuit or First Nations people.

Geologists think that large amounts of Earth's undiscovered fossil fuels lie beneath the Arctic Ocean. Also, the loss of Arctic Ocean ice has led to ice-free summers in the Northwest Passage, now used by cargo and cruise ships.

In order to determine whether the "Canadian" part of the Arctic Ocean is geographically part of Canada, geologists such as Ruth Jackson of the Geological Survey of Canada are mapping the ocean floor to see how far the continental shelf extends outward from the land.

1. What do you think would be the consequences if scientists could not prove that the "Canadian" part of the Arctic Ocean is part of Canada? Do you think Canada should retain sovereignty over this area? Discuss this issue with a classmate.
2. Currently, the Canadian Rangers monitor the large land area of the Canadian Arctic. Go to ***ScienceSource*** to find out about the Canadian Rangers (Figure 7.28).

C8 *Quick Lab*

The Coriolis Effect

Purpose

To model the Coriolis effect

Materials & Equipment

- piece of cardboard at least 30 cm wide
- nail or large pin
- pen or marker

Procedure

1. Cut a circle at least 30 cm in diameter from a piece of cardboard. Put the nail or pin into the exact centre of the circle so that it spins freely.
2. Label the centre of the circle as the North Pole and the outer edge as the equator.
3. Draw a counterclockwise arrow on the circle at the edge, to indicate the direction of Earth's rotation.
4. To demonstrate the Coriolis effect, have a partner slowly rotate the circle as you draw a straight line from the North Pole to the equator.

Questions

5. Look at the line drawn on the cardboard circle. In which direction does the line twist?
6. What does the twisting line represent?
7. How does this activity model the Coriolis effect?
8. If you repeated this activity on the underside of the circle, in which direction would the lines twist?

C9 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE
- Conducting inquiries safely
- Processing and synthesizing data

Modelling a Greenhouse

Question

How does a model greenhouse show how greenhouses warm up and stay warm?

Materials & Equipment

- 2 thermometers or temperature probes
- one-hole stopper to fit bottle
- 2-L clear plastic bottle
- masking tape
- retort stand
- clamp
- reflector (heat) lamp with 200-W bulb
- timer or stopwatch
- graph paper, spreadsheet software, or graphing calculator

CAUTION: The lamp will be hot and bright. To avoid burn injury, do not touch the lamp. Do not look directly into the light.

Procedure

1. Carefully insert one thermometer or temperature probe into the one-hole stopper. Fit the stopper assembly snugly into the top of the empty 2-L bottle. The bulb of the thermometer should be as far down into the bottle as possible.
2. Secure the stopper in place with tape. Tape the bottle to the table to prevent it from falling over.
3. Attach the second thermometer to the retort stand with the clamp. Make sure that the bulb of the thermometer is at about the same height as the one inside the bottle. Position the stand and thermometer near the bottle.
4. Position the heat lamp so it is at an equal distance from both thermometers. Your model should look like Figure 7.29. Do not turn on the lamp yet.
5. Create a data table to record the temperature inside and outside the bottle every minute for at least 15 min.
6. Record the starting temperatures, then turn on the lamp. Record the temperatures every minute.
7. When the temperatures stop rising, continue to monitor and record them for another 3–5 min.
8. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

9. Graph your results. Choose a method to distinguish the temperatures inside the bottle from those outside. Explain your method in the legend.
10. Compare the temperature changes inside and outside the bottle. Explain any observed differences.

Skill Practice

11. Why was it important to have both thermometers the same distance from the lamp?

Forming Conclusions

12. Explain why the temperature eventually stopped rising inside the bottle, even with the lamp still on.
13. Was the bottle a good model of the natural greenhouse effect in the atmosphere? How did it help you understand the natural greenhouse effect better? What are the limits of this model?
14. How useful is this model in showing you how a greenhouse works?

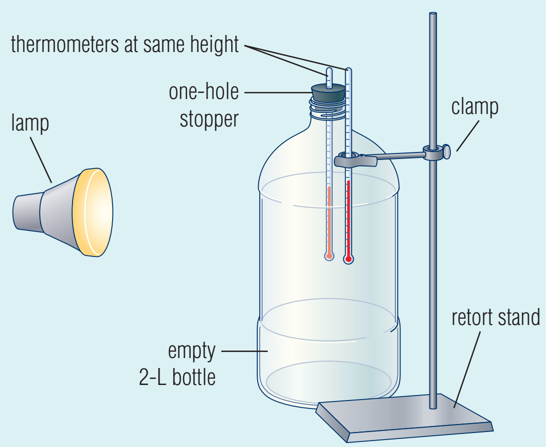


Figure 7.29 The completed model

C10 *Inquiry Activity* Skills Reference 2

SKILLS YOU WILL USE
- Observing and recording observations
- Evaluating whether data supports or refutes hypothesis

Modelling Albedo in the Biosphere

Question

When two samples with different albedos are exposed to equal amounts of radiation, how will that affect the temperatures above and below the sample surfaces?

Materials & Equipment

- 3 paper baking cups
- white sugar
- green-dyed sugar
- graph paper, spreadsheet software or graphing calculator
- 5 thermometers or temperature probes
- retort stand
- 5 clamps
- reflector lamp with a 200-W bulb
- timer or stopwatch

CAUTION:
To avoid burn injury, do not touch the light bulb.
Do not look directly into the light.
Never eat anything in a science lab.

Hypothesis

Create a hypothesis that relates the albedo of white sugar and green sugar to the change in temperature above and below the surface of the sugar samples.

Procedure

1. Fill one baking cup with white sugar and another with green sugar. Fill both cups close to the top, and flatten off the surface of the sugar. Leave the third baking cup empty as a control.
2. You will measure the temperatures of the sugar samples and of the air just above the sugar samples every 2 min for 10 min. You will also measure the temperature inside the control cup at the same times. Using graph paper or spreadsheet software, create a data table to record these data. If you are using a graphing calculator, open the appropriate application to collect or enter temperature data.
3. Place the bulb of one thermometer or temperature probe just under the surface of each sugar sample. Place two more thermometers or probes with their bulbs just above the surface of each sugar sample. Place the last thermometer or probe inside the empty baking cup so that it is not touching any surface. Secure all the thermometers to the retort stand with clamps. Record the initial temperature of each thermometer.
4. Place the lamp about 30 cm above the containers. Set the timer to zero.
5. Turn on the lamp, and start the timer. Record the thermometer readings every 2 min for 10 min with the light on. After 10 min, carefully turn off the lamp.
6. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

7. Using your data, draw graph(s) of the temperature versus time. Your graph(s) should include temperatures above and below each sugar sample and in the control for each time point.
8. Describe the temperature changes above and below the surfaces of the white sugar and green sugar and in the control. Outline any differences among the samples and the control.
9. According to your graph(s), over which sugar sample did the air temperature change more when the light was on? Relate this to the albedos of the two sugar samples.

Skill Practice

10. Why did you need to determine the temperature of the air in the empty baking cup?

Forming Conclusions

11. How effectively do the different sugar samples represent surfaces with different albedos?
12. How do the temperature readings you recorded answer the initial question?
13. Do the data you collected support or refute your hypothesis? Explain.
14. What are the implications of the results of this experiment with respect to the loss of ice shelves in the Arctic?

7.2 CHECK and REFLECT

Key Concept Review

1. Explain what is meant by the term "the natural greenhouse effect."

2. Study the word "insolation," and explain why it stands for incoming solar radiation.

3. Why is it important that some of the insolation hitting Earth returns to space?

4. Draw the following diagram in your notebook, give it a title, and label it.

Question 4

5. What is thermal energy? What is another name for the absorption of thermal energy by the atmosphere?

6. Define "conduction," "convection," and "radiation," and draw a sketch of each to illustrate their mechanisms of heat transfer.

7. Explain how the Coriolis effect influences the direction of wind in the northern hemisphere.

8. Describe how thermal energy is transferred in the hydrosphere.

Connect Your Understanding

9. Why is the natural greenhouse effect necessary to life on Earth?

10. Explain what would happen to Earth without the natural greenhouse effect.

11. Discuss the scenarios that could occur if Earth's net radiation budget became unbalanced.

12. State whether each of the following is an example of conduction, convection, and/or radiation. Explain if you think there is more than one possibility.
    (a) You are cooking, and the handle of the spoon you are using to stir the soup starts to feel hot.
    (b) A pail of hot water is added to a child's inflatable pool. After a while, the pool is warm.
    (c) You go to the park, and when you sit on a metal bench, it is hot.
    (d) You are standing near a barbecue, and you feel the heat on your face.

13. Why are coastal cities attractive to many people seeking a moderate climate?

Reflection

14. Think back to the story on page 274 about how greenhouses trap heat. Did learning about how a greenhouse works enhance your understanding of the natural greenhouse effect? Explain your answer.

15. What is one thing you learned about the natural greenhouse effect that you would like to learn more about?

16. Describe the most interesting thing you found about Earth's net radiation budget.

17. Recall an earlier time you learned about conduction, convection, and radiation. How have you added to this knowledge in this section?

For more questions, go to ***ScienceSource***.

Investigating CAREERS in Science

Great CANADIANS in Science Sheila Watt-Cloutier

Over thousands of years, the Inuit peoples of the Arctic have developed skills and knowledge that allow them to live in the Arctic climate (Figure 7.30). However, climate change may mean the end of a way of life for these communities. Sheila Watt-Cloutier is doing everything she can to make sure this doesn't happen (Figure 7.31).

Watt-Cloutier has been politically active since 1995. In her role as chair of the Inuit Circumpolar Council from 1995 to 2001, she represented 155 000 Inuit in Russia, Alaska, Greenland, and Canada.

In 2005, Watt-Cloutier joined with Inuit hunters and elders from communities across Canada and Alaska to file a complaint to the Inter-American Commission on Human Rights based on the results of the Arctic Climate Impact Assessment. The complaint stated that loss of sea ice may make the Inuit hunting culture impossible to maintain and alleged that the cause of this loss was greenhouse gas emissions from the United States.

In a 2006 *Globe and Mail* article, Watt-Cloutier said, "Until now, there has been no human connection with climate change—just bureaucracies. Few grasp it until they hear the stories. Climate change affects every facet of Inuit life. We have a right to life, health, security, land use, subsistence, and culture. These issues are the real politics of climate change."

Figure 7.31 Sheila Watt-Cloutier

Figure 7.30 Many Inuit fish from kayaks in the summer. Warmer water in the Arctic Ocean may drive away the fish that prefer colder water.

Watt-Cloutier was born in Kuujjuaq, Nunavik (northern Quebec). She lived a traditional life for her first 10 years until she was sent away to school in Nova Scotia and Manitoba. She studied counselling, education, and human development at McGill University. Since then, she has worked tirelessly to improve education and life for the Inuit communities.

Throughout her career, Watt-Cloutier's work has been recognized as outstanding. Among the many awards she has received are a National Aboriginal Achievement Award, Officer of the Order of Canada, and the Rachel Carson Prize. She has also received honorary doctorates from various universities across Canada.

For Watt-Cloutier, the issues of climate change are real, immediate, and threatening to her community's way of life. She has made it her life's work to bring these issues to the public's attention.

Questions

1. How does learning about the threat to Inuit culture affect your thinking about climate change?
2. Go to ***ScienceSource*** and find out what Sheila Watt-Cloutier is doing now. What would you like to ask her about her work?

Science in My FUTURE Environmental Educators

In order for environmental issues such as climate change to be well understood by the public, people need to be educated about them. Many people who are concerned about these issues become environmental educators.

Provincial and national parks and outdoor education centres are often mandated to include environmental stewardship and conservation in their programs. At these parks and centres, people learn about these issues while enjoying the natural surroundings. They also learn that some natural surroundings could be threatened by inaction, both governmental and personal, regarding environmental issues (Figure 7.32).

Some environmental educators are authors and journalists who write newspaper and magazine articles or books on the environment. Reading these articles and books helps the general public keep up to date on the issue. Other environmental educators make documentary films and TV shows.

As people learn more about the environment, they use their knowledge in making personal decisions about household management, transportation, and even whom to vote for in elections.

Other environmental educators enjoy working specifically with students. Maggie Ballantyne has found a way to do this as an EcoSchools student leadership facilitator (Figure 7.33).

Figure 7.32 When people are exposed to the beauty of nature, they are more likely to want to protect it.

Figure 7.33 As a facilitator, Maggie Ballantyne helps students achieve environmental goals.

EcoSchools is a K–12 Environmental Education program that stresses waste reduction, energy conservation, schoolground greening, and ecological literacy. Ballantyne works with secondary school students, teaching them how to bring about change in their own schools using the EcoSchools model.

Students interested in bringing the EcoSchools program to their own schools have an ally in Maggie Ballantyne. She sets up "EcoTeams" to begin the process, conducts audits of the schools, and works with the teams on projects to help remediate climate change and other environmental problems.

If you want to become an environmental educator, a diploma or a degree in environmental science will help. As well, practise your communication skills! Students often work at provincial parks during their summer breaks, learning environmental education on the job.

Questions

1. Why might it be necessary for the public to be educated about environmental issues?
2. Why might it be an advantage to find a job that supports your interests? Go to ***ScienceSource*** to explore job possibilities.

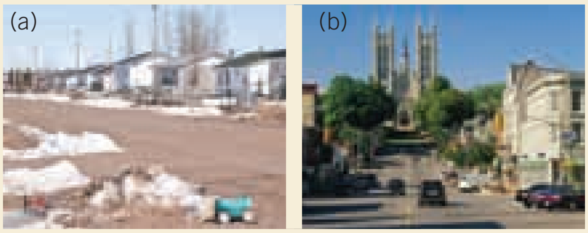
7 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

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

Key Concept Review

1. What is the biosphere? *k*
2. (a) How does climate differ from weather? *k*
   (b) Use an analogy to illustrate the difference between climate and weather. *c*
3. Describe the climate of each region shown below. Describe how life in one region would differ from life in the other. *k*



Question 3 (a) Moosonee, Ontario; (b) Guelph, Ontario

4. Describe what happens to the insolation received by Earth. *k*
5. How does cloud cover influence the amount of insolation that reaches Earth's surface? *k*
6. (a) Why does the temperature of the thermosphere vary from −100 °C to + 1000 °C each day? *k*
   (b) What terrestrial biome shows a similar type of temperature fluctuation? *k*
7. How does the net radiation of a region change with its latitude? *k*
8. In a brief descriptive paragraph, distinguish between the hydrosphere, lithosphere, and atmosphere. *c*
9. Explain the relationship between the troposphere and the survival of humans. *k*
10. What is atmospheric dust, and where is it found? *k*
11. What three gases in Earth's atmosphere are most important in supporting life? *k*
12. What two sources of energy warm the lithosphere? Identify which one is more significant. *k*
13. What states of water are found in the biosphere, and where are they located? *k*
14. List six terrestrial biomes found in Canada. Describe each in your own words. *k*
15. Why are there no clear boundaries between biomes? *k*
16. Explain why the albedo of an area can change with the seasons. *k*
17. Explain how thermal energy is transferred when you take your backpack from inside your home to the outdoors during a cold winter day. *a*
18. Use this figure to explain the Coriolis effect. *t*

Question 18

19. What are the trade winds, and where do they occur? *k*
20. What are jet streams? *k*

21. Define the term "natural greenhouse effect" in your own words. k

22. Write a one-sentence, catchy slogan to describe the natural greenhouse effect. c

23. Explain the idea of a net radiation budget. c

24. What happens to the solar radiation that reaches Earth's surface but is not reflected back into space? k

25. How does latitude affect the net radiation budget of a region? k

Connect Your Understanding

26. Draw a cartoon to depict one aspect of heat transfer presented in this chapter. c

27. It is difficult to include water vapour in a chart or table of the composition of Earth's atmosphere. Why is this? t

28. A large island, surrounded by ocean, has two cities at the same latitude. One city is situated on the west coast, and the other on the east coast. Cold ocean currents travel along the west coast of the island, and warm ocean currents travel along the east coast. Predict which city would have the warmer average annual temperature. Explain your answer. t

29. Create a model of a biome that is within a 50-km radius of your school. Include the lithosphere, hydrosphere, atmosphere, and the organisms that live there. a

30. Draw a word web to illustrate your understanding of the natural greenhouse effect. c

31. What do you think would happen if conditions on Earth suddenly changed so that much less heat was reflected back into space than is the case now? t

32. Why is it important for the net radiation budget of Earth to be in balance? k

33. Organize the information about incoming and outgoing solar radiation in a graphic organizer that makes sense to you. t

34. How do you think classifying biomes adds to information about climate? c

Reflection

35. If the climate of your region became warmer, how would that affect your way of life? Share this with a group of classmates. c

36. Describe the climate of the region you live in. If you could change one thing about that climate, what would it be and why? List potential impacts of that change. c

37. Think about when you have encountered the term "greenhouse effect." What is your reaction to the term? Why do you think this is? a

38. Describe how your lifestyle reflects the climate in which you live. a

39. If you had to move to a region with a different climate than yours, what types of changes do you think would be the easiest and hardest for you to make? c

After Reading

Thinking Literacy

Reflect and Evaluate

List the various types of connections that you made as you read this chapter. How did making connections help you to understand and learn the terms and ideas from this chapter?

Write a brief paragraph explaining which "making connections" strategy helped you the most. Exchange paragraphs with a partner to find out whether you chose the same or a different strategy.

Unit Task Link

As you do research for your unit task, consider any severe weather events in the last 12 to 18 months. Have any of these events brought new concerns to the forefront? Have they affected locations that have not been affected before? Are the effects different from those in the past? Clip newspaper articles, bookmark Web pages, or make notes to add to your portfolio for the Unit Task.

Home Quit

8 Earth's climate system is influenced by human activity.

Oil refineries, like this one, process crude oil to make gasoline, natural gas, and furnace oil. As we use fossil fuels in our cars and homes, we add greenhouse gases to the atmosphere.

Skills You Will Use

In this chapter, you will:

- use a model to illustrate the natural greenhouse effect and modify the model to explain the anthropogenic greenhouse effect
- analyze sources of scientific data for evidence of climate change
- investigate a popular climate change hypothesis
- research the influence of ocean currents on heat transfer and precipitation patterns
- compare different perspectives on climate change

Concepts You Will Learn

In this chapter, you will:

- distinguish the natural greenhouse effect from the anthropogenic greenhouse effect
- describe the human causes of climate change in Canada
- describe the sources and sinks of greenhouse gases
- describe the causes and effects of the anthropogenic greenhouse effect
- identify and describe indicators of global climate change

Why It Is Important

Earth's climate system has worked well over time but is increasingly influenced by human activity. It is important to explore the consequences of human activities so that we may make informed decisions.

Before Reading

Thinking Literacy

Understanding by Asking Questions

Good readers are like expert scientists. They carry on a dialogue in their heads, often asking questions about what they read. What does this word mean? Do I agree with this opinion? Where is the evidence?

As you read section 8.1, turn the subheadings into questions that begin with "who," "what," "when," "where," "why," "how," or "what does it mean."

Key Terms

• anthropogenic greenhouse effect • carbon sink
• carbon source • climate change • economic system
• fossil fuels • global warming • global warming potential
• persistence • positive feedback loop
• runaway positive feedback loop • salinity

8.1 The Anthropogenic Greenhouse Effect

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

- The concentrations of carbon dioxide, nitrous oxide, and methane in the atmosphere are increasing.
- The anthropogenic greenhouse effect is the enhancement of the natural greenhouse effect due to human activities.
- Human activities, such as deforestation, combustion of fossil fuels, and industrial emissions, lead to increased concentrations of greenhouse gases and the anthropogenic greenhouse effect.
- Carbon sources and carbon sinks affect greenhouse gas emissions.
- The increase in greenhouse gas emissions has led to global warming, which is causing climate change.
- Since human activities are causing increases in greenhouse gas emissions, humans are contributing to climate change.

Figure 8.1 A “core sample” from a tree trunk is being removed from the core borer. You can find out the age of a tree and of the local growing conditions (such as availability of moisture) by examining the number and thickness of its rings.

History in a Tree Trunk

Recording growth is one way to document change. You may have a record of your own growth in the form of a growth chart that documents your height and weight since you were a baby. People often document their children’s growth on a wall or door frame (Figure 8.2).

The growth of a tree is documented in the widths of its rings (Figure 8.1). If you have ever seen the cross-section of a tree trunk, you have seen history. You may have participated in an outdoor or environmental education program where you counted the rings on a tree stump or a core sample to determine the tree’s age.

You may have wondered why some rings were thicker than others. One tree ring is formed every year, during the summer when the tree grows. Thicker rings mean the tree grew in better conditions — enough precipitation and appropriate temperatures. Thin rings mean poorer conditions: drought, or higher or lower temperatures than usual. By comparing the rings, scientists can determine the weather conditions over the life of the tree (Figure 8.3). Since some trees live for hundreds of years, the rings provide long-term climate data.

Figure 8.2 Recording a child’s growth

Figure 8.3 Life was good for this tree in its first and last few years but was more difficult in between.

C11 Quick Lab

Climate and Tree Growth

For every year of its growth, a tree produces a single ring of new wood in its trunk. The width of each growth ring is affected by the average temperature and moisture conditions during that year.

Since trees can live many years, tree rings can be used to identify changes in the climatic conditions of a local area over long spans of time. In order to see the growth rings, scientists drill out core samples that extend from the centre of the tree (the pith) to the outer bark.

Sometimes, scientists are presented with data that need to be interpreted. When looking at the thickness of rings on tree bark, scientists have to decide what constitutes "narrower" and "thicker."

Purpose

To determine how tree rings are used to identify climate conditions

Materials & Equipment

- pen and paper
- ruler

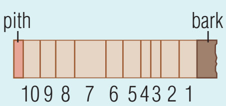


Figure 8.4

Procedure

1. Look at Figure 8.4. The tree in this sample is 10 years old because there are 10 rings between the bark and the pith. Look at the thickness of each ring, and judge it to be "narrower" or "wider."
2. Create a chart with the following column headings: Sample, Age, Good Conditions, Poor Conditions, and Notes.
3. Look at the drawings of core samples taken at different times from four different trees growing in the same area (Figure 8.5). Determine the age of each tree, and record it in your chart.
4. For each core sample, interpret the time periods when each tree experienced good conditions and when each experienced poor conditions. Record your interpretations in your chart.

Questions

5. Write a descriptive sentence or two about each sample tree based on your data.
6. Compare your interpretations with those of a classmate. How do they compare?
7. Why would scientists studying climate change find the data from core samples useful?
8. What are the advantages and limitations of this technique?

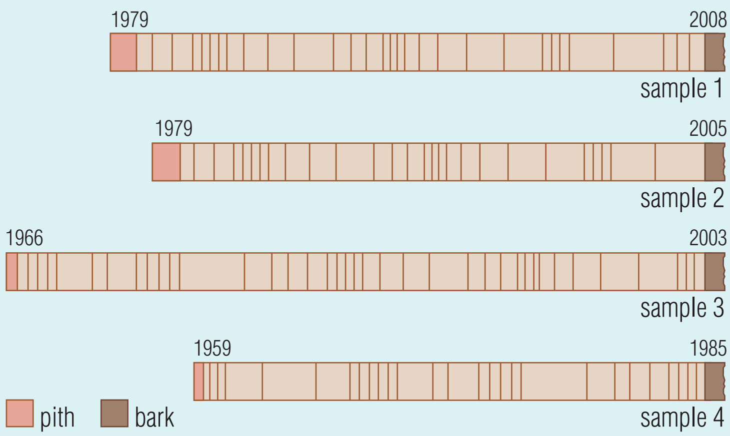


Figure 8.5

Greenhouse Gases

In section 7.1, you found out that the natural greenhouse effect keeps our planet warm by absorbing some of the infrared radiation from Earth's surface. The natural greenhouse effect is due mainly to the presence in our atmosphere of water vapour, with other naturally occurring greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, also playing a role. However, these gases are also produced by human activities, such as industry, electricity generation, transportation, and agriculture (Figure 8.6).

Figure 8.6 Modern agricultural practices produce greenhouse gases: carbon dioxide comes from tractors and equipment; methane comes from livestock manure and cattle; and nitrous oxide comes from fertilizer usage, crops, and manure. Carbon dioxide is taken up by crop plants.

The four main greenhouse gases are water vapour, carbon dioxide, methane, and nitrous oxide. Table 8.1 gives the global warming potential of three of these gases. **Global warming potential** is a measure of the ability of a gas to trap thermal energy in the atmosphere over a specified time. Water vapour is not included in the global warming potential classification because its concentration varies with temperature. Climatologists have given carbon dioxide a rating of 1, and other greenhouse gases are rated relative to carbon dioxide. The persistence of each gas is also given. **Persistence** is the length of time the gas remains in the atmosphere. Gases that persist longer can absorb thermal energy over a longer period of time. Persistence of carbon dioxide is not defined because it depends on the amount emitted and carbon dioxide has a variety of sinks.

Table 8.1 Global Warming Potential of Three Main Greenhouse Gases

Gas	Global Warming Potential over 100 years	Persistence (years)
carbon dioxide (CO_2)	1	–
methane (CH_4)	25	12
nitrous oxide (N_2O)	298	114

History of Greenhouse Gas Research

The discovery that different gases absorbed infrared radiation differently dates back to the work of the Irish scientist John Tyndall in 1861. In 1896, Swedish Nobel Prize winner Svante Arrhenius calculated that the world would warm between 5°C and 6°C if atmospheric carbon dioxide levels doubled.

In the first half of the 20th century, climatologists noticed that the average global temperature was rising slowly. They measured the concentrations of different gases in the atmosphere and found that the carbon dioxide and methane levels were increasing. However, they had no earlier data to give them a full history of these gases until they read the journals of Antarctic and Greenland explorers. The climatologists discovered that a good source of data was under the explorers' feet, in the continental glacier in Greenland, a glacier that had been there for hundreds of thousands of years.

Greenland Ice Core Project

Some of the best data on greenhouse gas concentrations in the atmosphere come from the Greenland Ice Core Project (GRIP), which operated on Greenland's huge continental glacier. Glaciers are made of snow that turned to ice under the pressure of later snowfalls. Each year's snowfall is recorded as a distinct layer. From 1989 to 1992, a 3029-m-long ice core was drilled vertically and removed from the continental glacier. At its deepest, the ice layer is thought to be 200 000 years old, while the ice layer at the surface was formed the previous winter. The pieces of the ice core were dated, labelled, and stored frozen.

Ancient ice can be read like a history book. It contains tiny bubbles, which have preserved the atmosphere's gases at the time that particular ice was formed. Scientists can slice out a layer of the core, melt it, and analyze the gas concentrations in the bubbles (Figure 8.7).

The ice core data show that the concentration of CO_2 in the atmosphere fluctuated between 180 ppm and 300 ppm during the glacial and interglacial periods (over 10 000 years ago). The abbreviation ppm means parts per million, or 0.0001 percent. Then, for the last 10 000 years, CO_2 concentrations remained stable around 280 ppm. Around 1750, about the same time the Industrial Revolution started, CO_2 concentrations began to increase rapidly from 280 ppm to the present level of 385 ppm (Figure 8.8(a) on the next page).

Figure 8.7 Like boring into a tree trunk to get a sample of its rings, scientists have bored vertically into the continental glaciers on Greenland and Antarctica. The ice layers can be dated, just like tree rings.

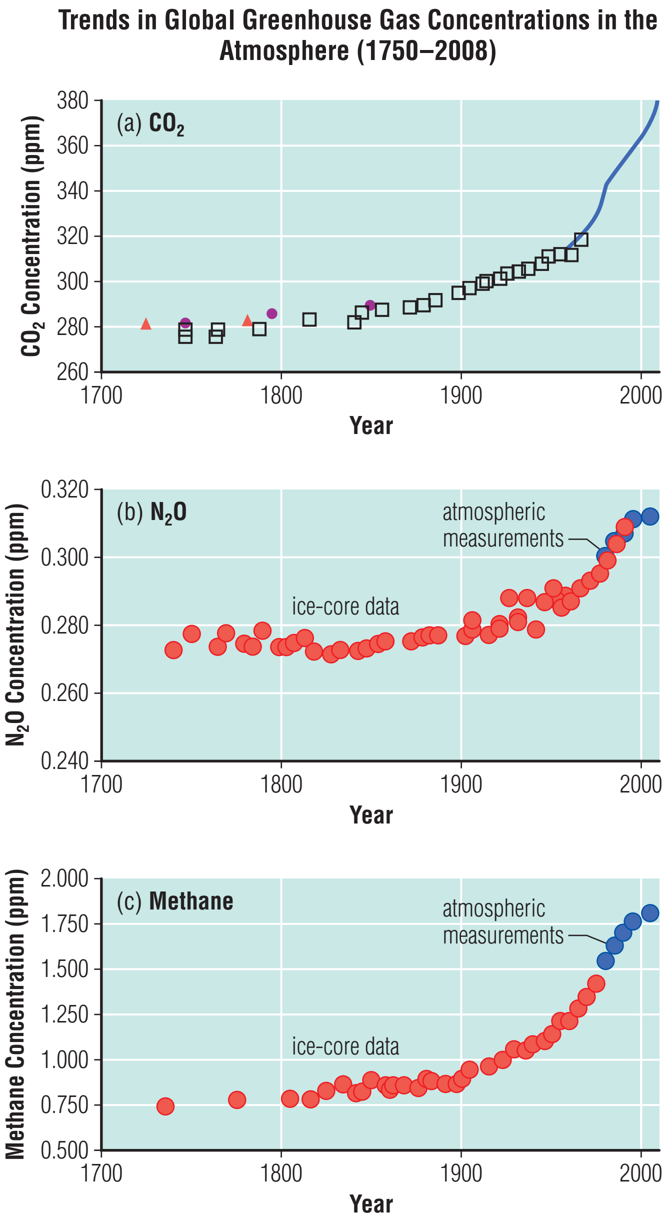


Figure 8.8 Global changes in (a) carbon dioxide, (b) nitrous oxide, and (c) methane concentrations since the mid-1700s. Carbon dioxide data were collected from three sets of ice core data (triangles, squares, and circles) and directly measured from the atmosphere (blue line).

Greenhouse Gas Concentrations

The data from ice-core samples from Greenland and Antarctica, as well as atmospheric data collected over the last few decades, have led climatologists to conclude that the concentrations of greenhouse gases in the atmosphere have increased since the 1700s (Figure 8.8).

Scientists have conclusively shown that the increase in greenhouse gas levels is a direct result of changes in human activity. Before the Industrial Revolution, humans depended on manual labour, animal energy, wind power, and water power to do work and to produce goods. During the Industrial Revolution, the focus shifted rapidly to coal-fired steam engines and the mass production of goods. Human society became more and more dependent on the consumption of fossil fuels. As a result, more and more greenhouse gases were emitted from the machinery and the new coal-fired trains.

Since greenhouse gases absorb heat, changes in their atmospheric concentrations can unbalance the net radiation budget of Earth. Increased greenhouse gas concentrations mean that less thermal energy is released back into space, and as a result, the average temperature at Earth's surface increases. Chapter 7 introduced the natural greenhouse effect, which keeps Earth at a liveable average temperature. However, the additional greenhouse gas emissions are causing the **anthropogenic greenhouse effect**, which is the enhancement of the natural greenhouse effect due to human activities.

WORDS MATTER

The words "anthropology" and "generate" can help you figure out the meaning of "anthropogenic." "Anthropo" comes from a Greek word meaning human being, and "gen" comes from a Latin word meaning to produce.

Sources of Greenhouse Gases

Table 8.2 summarizes the sources of the major greenhouse gases from human activities. The most significant greenhouse gas is carbon dioxide, so most discussions about the anthropogenic greenhouse effect focus on it. Any process that releases carbon dioxide to the atmosphere is called a **carbon source**. Burning fossil fuels and the respiration of organisms are both carbon sources, since they both release carbon dioxide to the atmosphere.

Fossil fuels — coal, oil, and natural gas — formed underground from the remains of once-living organisms. Because organisms are made up of carbon, hydrogen, and oxygen, fossil fuels are carbon compounds called hydrocarbons.

Table 8.2 Sources of Greenhouse Gases from Human Activities

Greenhouse Gases	Sources
carbon dioxide (CO_2)	• burning coal, oil, gasoline, and natural gas • cement making • deforestation
methane (CH_4)	• coal mining • production of petroleum products • natural gas leaks • rice paddies, landfills, cattle
nitrous oxide (N_2O)	• burning coal, oil, gasoline, and natural gas • fertilizer

People have used coal for over 4000 years. They discovered that coal, a shiny black rock, burned much longer than wood did. Also, burning coal produces much more heat than burning the same volume of wood. Although oil has been used for almost as long as coal, it only became popular when scientists invented gasoline, which is produced when oil is "refined." Gasoline powers many motors, from transport trucks to lawnmowers. About 5 trillion litres of oil (including gasoline, home heating oil, motor oil, fuel oil, and diesel fuel) were used around the world in 2006.

While these fossil fuels are in the ground, their carbon content is undisturbed. As they are extracted from the ground, they release a small amount of methane and carbon dioxide gases into the atmosphere (Figure 8.9 on the next page). When fossil fuels are burned to produce energy, large amounts of carbon dioxide and nitrous oxide are released. Thus, fossil fuels are a carbon source. For each litre of gasoline used in a car, 2.3 kg of carbon dioxide is released into the atmosphere.

Increasing Greenhouse Gas Emissions

Beginning in the late 1700s, the population of North America grew rapidly. European people settled in the forests and started to clear the land of trees to provide timber for fuel and construction and to prepare land for agriculture (Figure 8.10 on the next page). Before the settlers arrived, over 90 percent of southern Ontario was covered with trees. Today, only about 38 percent of that land is forested.

During Reading

Thinking Literacy

Asking Questions: Why and How

As you read about greenhouse gases and examine the chart of sources of greenhouse gases, ask yourself WHY we are producing these significant amounts and HOW we can change our way of living to reduce them.

Suggested Activity •
C12 Inquiry Activity on page 306


Figure 8.9 In 1851, the world's first oil company was formed in Oil Springs, near Petrolia, Ontario. An early "pump jack" is shown on the left, with a modern one on the right.

Forests play an important role in removing carbon dioxide from the air through the process of photosynthesis. Photosynthesis is a **carbon sink**, which is any process that takes carbon dioxide from the atmosphere and stores it — for example in the ground or trapped in the structure of plants. The loss of forest cover in North and South America over the last two centuries has reduced the size of Earth's carbon sink and therefore decreased the amount of carbon dioxide being removed from the atmosphere. Loss of forests continues today around the world.

Another important carbon sink occurs when large amounts of atmospheric carbon dioxide dissolve in Earth's oceans and lakes and are removed from the atmosphere.

If the release of carbon dioxide to the atmosphere by carbon sources is equal to the amount of carbon dioxide removed from the atmosphere by carbon sinks, the concentration of this greenhouse gas in the atmosphere remains stable. However, the balance between carbon sinks and carbon sources has shifted since the Industrial Revolution, causing the levels of carbon dioxide in our atmosphere to increase around the world. According to scientists at the Carbon Dioxide Information Analysis Center in the United States, the concentration of carbon dioxide gas in the atmosphere has increased by 38 percent over the last 200 years.

Learning Checkpoint

1. What do thicker tree rings mean?
2. Name three greenhouse gases and give one human activity that produces each one.
3. When did climatologists notice that the average global temperature was rising?
4. Where do scientists find the gas samples to analyze in ancient ice?
5. When did people start using coal?

Figure 8.10 In the late 1800s, lumber companies were still taking huge, old-growth trees from northern Ontario forests. The stripped land was rocky, which made it of little use to farmers.

Greenhouse Gases, Global Warming, and Climate Change

Climate scientists have concluded that the increased emissions of greenhouse gases by human activity have influenced the global climate. The anthropogenic greenhouse effect is a change in Earth's net radiation budget caused by the increase in human-generated greenhouse gases. Temperature data collected from around the world show that the global average temperature increased by approximately 0.74°C between 1880 and 2008 (Figure 8.11). This time span was also the period when changes in human activity, such as the invention of the internal combustion engine, and its use in cars, trucks, and other vehicles, increased the amount of greenhouse gases emitted to the atmosphere. The eight warmest years of this period have all occurred since 1998.

Combined with the natural greenhouse effect, the anthropogenic greenhouse effect has led to **global warming**, the observed increase in Earth's average annual temperature. Global warming is leading to **climate change**, the significant long-term change in expected climate patterns. Climate change means that more than just temperature is changing; so are the number and severity of storms, the strength of winds, and the amounts of precipitation, contributing to both floods and droughts (Figure 8.12 on the next page). In general, the world is experiencing more extreme conditions.

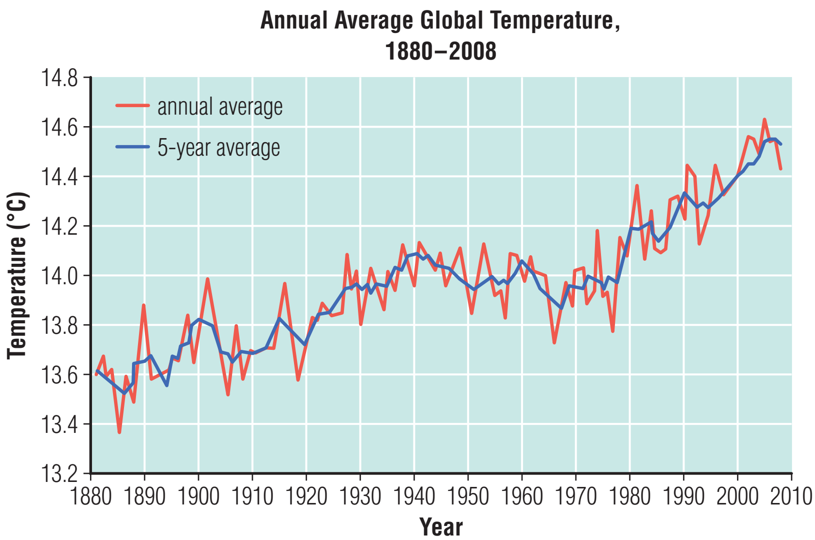


Figure 8.11 The average global temperature has increased substantially since 1980. The graph shows little sign of levelling off.

(a)

(b)

Figure 8.12 Both (a) flooding and (b) drought result from changes in average precipitation.

A Global Problem

Global warming has been detected in all regions of Earth by international organizations that collect and share weather and climate information. Environment Canada is one such organization, as are the meteorological services in most other countries. An important international organization of this type is the Intergovernmental Panel on Climate Change (IPCC), a group of the world's leading climate scientists from many countries brought together by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). The scientists volunteer their time to review and assess scientific research on climate change. The IPCC has linked global warming to the increase in the amount of greenhouse gases in the atmosphere.

The IPCC reports that if we continue to produce high levels of greenhouse gases and decrease the number of carbon sinks, global warming will continue and Earth's climate will change even more rapidly than it is now. The need for immediate and decisive action has been championed by notable media figures including politicians, scientists, musicians, and actors. In 2007, Al Gore, the former vice-president of the United States, and the IPCC were joint recipients of the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."

Canada's 2004 Greenhouse Gas Emissions by Sector

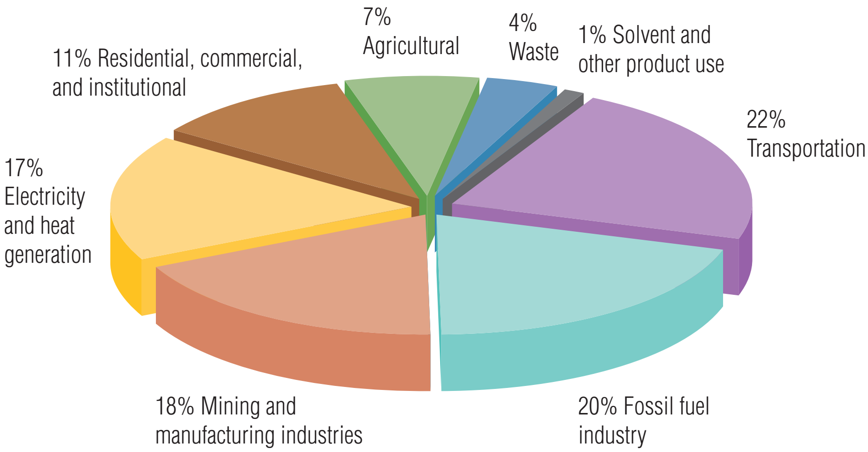


Figure 8.13 Human activities that produce greenhouse gas emissions

Source: A. Weaver, *Keeping Our Cool*, Viking Canada, 2008.

Human Activities Contribute to Climate Change

Both natural processes and human activities can affect carbon sources, carbon sinks, and the anthropogenic greenhouse effect. For example, if a forest fire is started, whether by lightning or people camping, the forest is no longer a carbon sink. Instead, the burning forest releases carbon dioxide into the atmosphere, becoming a carbon source.

Human activities, such as the production of electrical energy or the use of fossil fuels, release large amounts of carbon dioxide into the atmosphere. Some of the largest demands for energy come from industries (to produce goods) and individuals (to light, clean, heat and cool homes, cook food, and operate cars). Figure 8.13 shows which human activities add greenhouse gases to the atmosphere.

It is easy to conclude that large industries and electricity generation are a main cause of the problem, but lifestyle choices also contribute greenhouse gas emissions. Consider the amount of garbage generated by your household or school. Garbage in landfill sites is compressed to minimize the space it needs, then it is covered with soil. Anaerobic bacteria, which do not need oxygen, break down the garbage. This process adds methane, a greenhouse gas, to the atmosphere.

As well, North Americans purchase many "disposable" products, such as paper cups and plastic food trays. It takes energy to manufacture these products, and they take up space in landfill sites after being used just once. North Americans and Europeans use and consume more now than we did even a few decades ago. We also consume more than people in many other countries, especially developing countries, do.

Consider also the amount of electricity you use at home or the number of lights left on in office buildings at night. Think about how far trucks must travel to deliver the goods we want. These are just some examples of the many ways we contribute to greenhouse gas emissions and hence to climate change.

Take It Further

The life cycle of disposable items is so short, and so many of these products are manufactured, that they affect greenhouse gases emissions more than non-disposable items. Find out about how they are manufactured and identify one way you can cut down on your use of disposable products. Begin your research at ***ScienceSource.***

C12 *Inquiry Activity* Skills Reference 2

SKILLS YOU WILL USE
- Planning for safe practices in investigations
- Observing and recording observations

Modelling the Natural and Anthropogenic Greenhouse Effects

Models can help you understand difficult concepts. This model first represents the natural greenhouse effect and can then be changed to represent the anthropogenic greenhouse effect.

Question

How does the model help to explain the natural and anthropogenic greenhouse effects?

Materials & Equipment

- beaker
- water
- hot plate
- thermometer
- aluminum foil
- retort stand and clamp
- stopwatch or timer
- beaker tongs

CAUTION: Be careful when using the hot plate. Do not turn it higher than necessary.

Procedure

1. Place a beaker full of water on a hot plate.
2. Cut two pieces of aluminum foil large enough to cover the beaker's top. Make a small hole in the middle of each piece, and slide the aluminum foil pieces onto the thermometer. You may need to wrap small pieces of aluminum foil below each square so the squares do not fall down.
3. Using a retort stand and clamp, position the thermometer so its bulb is in the middle of the water in the beaker. Make sure the aluminum foil squares are below the clamp but not resting on the beaker (Figure 8.14).
4. Turn the hot plate on to medium.
5. Record the temperature of the water every minute until the temperature does not change any more. Record this information as "Scenario 1."
6. Move the lower piece of aluminum foil down to make a loose lid over the beaker. Repeat step 5, and record this information as "Scenario 2."
7. Move the top piece of aluminum foil down, and make a tighter lid over the beaker. Repeat step 5, and record this information as "Scenario 3."
8. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

9. What were the highest temperatures reached in each scenario?
10. Why were the temperatures different in each case?

Skill Practice

11. When working with a partner, how can you efficiently make the most accurate temperature readings?

Forming Conclusions

12. In this model, Scenario 1 represents a state of equilibrium between the Sun and Earth if Earth had no natural greenhouse effect. Scenario 2 models the equilibrium with the natural greenhouse effect present. Scenario 3 models the consequences of the anthropogenic greenhouse effect. Describe how this model helps to represent these scenarios.
13. What are the strengths and weaknesses of this model?

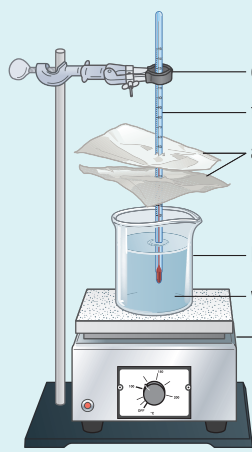


Figure 8.14 Step 3

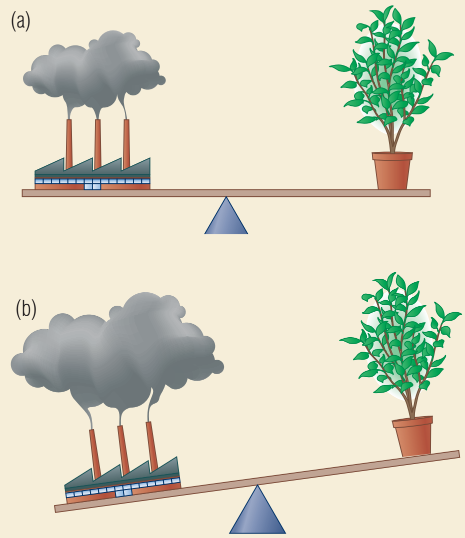
8.1 CHECK and REFLECT

Key Concept Review

1. Describe the process of using growth rings on trees to derive information about climate.
2. Why is water vapour, a greenhouse gas, not included in the global warming potential information?
3. What is the Greenland Ice Core Project? What type of information do scientists find when they analyze the ice cores?
4. What is global warming potential?
5. List three greenhouse gases. Describe how the atmospheric concentration of these gases has changed over the last 200 years.
6. Define "carbon source" and "carbon sink." Give two examples of each.
7. Define the term "anthropogenic greenhouse effect." Why is it important to distinguish it from the term "natural greenhouse effect"?
8. List three human activities that contribute to climate change.

Connect Your Understanding

9. Compare the type of data derived from tree growth rings to that derived from the Greenland Ice Core Project.
10. What evidence have scientists cited as the reason for their conclusion that human activity is a major cause of the increase in Earth's observed global warming?
11. Describe the relationship between the anthropogenic greenhouse effect and climate change.
12. Is it possible that climate change could occur in only one part of the world? Explain.
13. Many trees are cut down for lumber and paper products. Describe in words and/or diagrams how the forest's role as a carbon sink or carbon source is affected.
14. In the illustration, the smokestacks represent carbon sources and the plants represent carbon sinks. Describe the two scenarios represented by diagram (a) and diagram (b).



Question 14

15. Why might the terms "natural greenhouse effect" and "anthropogenic greenhouse effect" be useful even though they are caused by the same gases?
16. People's lifestyles have changed a great deal since the Industrial Revolution. Describe some of these changes and their impact on society and on the environment.
17. What types of lifestyle change do you think would be most difficult for people to make in order to reduce greenhouse gas emissions? Explain your answer.

Reflection

18. What changes in your own life would you undertake to reduce your greenhouse gas emissions?
19. What is the most troubling thing you learned in this section? What is the most positive thing?

For more questions, go to ***ScienceSource***.

8.2 Physical Effects of Climate Change

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

- Climate-change effects in the atmosphere include increasing frequency and severity of heat waves, droughts, and storms.
- Climate-change effects in the hydrosphere include melting ice, warming ocean temperatures, and changing ocean currents.
- Climate-change effects on wildlife include range shifts and threatened species.

Figure 8.15 It is fun to play games, but it is very tempting to play them late into the night.

Lifestyle Choices

We sometimes use the phrase "too much of a good thing" to explain how something that starts off good can have negative consequences. You may use the phrase if you stayed up very late to play video games one evening, only to wake up the next morning with a headache (Figure 8.15). Playing the game was very enjoyable, but by enjoying it for too long, you had trouble waking up and find that your head hurts from lack of sleep. This could be serious if you have an early morning exam.

Figure 8.16 It is not easy to decide which shampoo to buy!

Sometimes we don't even realize that some of the choices we indulge in could be harmful. Our society gives us the ability to choose from a lot of different consumer items. Think about something simple: washing your hair. What is involved in washing your hair? Shampoo and hot water. But what else is involved? Electricity to heat the water. A sewage system to take the water away after you've finished with it. Energy to dry your hair and to wash and dry the towel. Energy to make the shampoo. Petroleum products to make the shampoo bottle and transport it to the store. And on and on. While washing your hair is a good thing, people can sometimes wash their hair too often and end up damaging both the environment and their hair!

You go to the store to buy shampoo, and you see shelves and shelves of it — many different brands and several varieties of each brand (Figure 8.16). Add to this the choice of store you go to: the drugstore, supermarket, or corner store. Many modern stores are so huge that they are located away from residential areas. People often have to drive or take a bus to get there.

In Chapter 7, you learned that the natural greenhouse effect was essential to maintaining habitable conditions on Earth. Now, however, scientists agree that human activities are adding greenhouse gases to the natural greenhouse effect — our activities are becoming too much of a good thing for Earth.

C13 *Quick Lab*

The Price of Choice

When communities were smaller, local general stores sold almost everything people needed, from boots to groceries. Some small communities still have a general store. Compare a general store (Figures 8.17 and 8.18) with a superstore (Figure 8.16).

Purpose

To discuss the implications of lifestyle choices

Materials & Equipment

- paper and pencil
- store flyers

Procedure

1. By yourself, make a list of the types of products you use to wash and style your hair. For example, you may use shampoo, conditioner, and hairspray.

Figure 8.17 The only store in Holstein, Ontario, is the General Store and Post Office.

2. Beside each type of product, write the names of all the different brands you have used, seen advertised, or seen in a store.
3. Join with three classmates, and compare your lists. Make a master list. Then, check the flyers to find other brands and products advertised.

Questions

4. Why do you think there is so much choice with this type of product?
5. What are advantages and disadvantages of having this much choice?
6. Think of ways in which having this much choice can affect greenhouse gas emissions.

Figure 8.18 The shampoo section in the Holstein General Store. Note the boots on the shelf above.

WORDS MATTER

You have probably heard the word "evidence" on TV police shows, referring to things and events that help people form conclusions. Evidence is also used in science to mean the results of an investigation that either proves or disproves a hypothesis. The Latin root, *evidens*, means obvious.

Collecting Evidence on Climate Change

The increases in global average temperatures and in greenhouse gas levels are evidence that Earth is currently undergoing climate change. Scientists' observations suggest that effects of these increases are the changes observed throughout Earth's biosphere.

Effects of Climate Change in the Atmosphere

Heat Waves

Earth has always experienced severe weather events, but they are becoming more frequent, more widespread, and more severe than in the past. When a heat wave occurs in Toronto, its Public Health Department issues an "Extreme Heat Alert." This means that a hot, humid, often smoggy air mass is in the area. The heat and smog may cause the deaths of elderly or ill people. The "Heat Alert" puts several city regulations into action. City pools are kept open longer, and some air-conditioned public buildings are kept open as cooling centres.

In the summer of 2008–2009, parts of southeastern Australia suffered 10 days in a row with temperatures above 40°C (Figure 8.19). Air conditioners were turned on high, resulting in an increased use of electricity and therefore the release of more greenhouse gases. More than 40 people died of the heat. Combined with a drought that had lasted for several years, the dry heat caused a series of wildfires that burned hundreds of houses and killed at least 200 people.

Warming conditions are not restricted to the atmosphere. As the air becomes warmer, the soil, lakes, and rivers also warm up. The borders of climatic zones can shift. In Canada's north, areas of permafrost — permanently frozen soil — are thawing much more in the summer than they used to. As a result, the soil becomes looser and house foundations are no longer safe (Figure 8.20). Trees can tilt or even fall over.

Figure 8.19 Australia has suffered extreme heat, as shown by the beach conditions sign here.

Figure 8.20 The permafrost is melting below this house, making it unstable. No one can live in it now.

Drought

Droughts are most severe when they affect regions near deserts. Until recently, many of these regions had seasonal rains that provided the water needed to grow crops and keep animals. Ethiopia had experienced a severe drought over the past few years. No seasonal rain had fallen, crops have dried up, and animals have died, leaving the people with inadequate food (Figure 8.21). In Canada, severe droughts occasionally affect the Prairies as they did particularly in the 1930s.

Figure 8.21 When drought hit this African grassland, it soon became a desert.

Wildfires

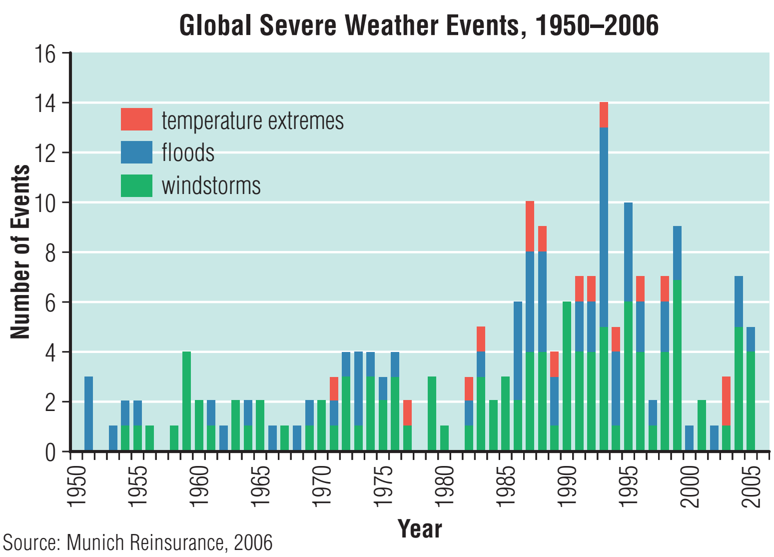
When the weather is hot and dry for a long time, the trees may become so dry that they lose their leaves. The probability of wildfires increases. Southern California and Australia experience many such fires as their climates become dryer.

While the frequency of wildfires is low around the world compared with other natural disasters such as drought, it is increasing. Wildfires usually occur in summer. During summer in Canada, the Canadian Wildland Fire Information System publishes fire weather and fire behaviour maps daily. The service also keeps historical data. If you go camping, you may be familiar with the restrictions on open fires in provincial parks.

Storms

Many regions on Earth, including Canada, have experienced severe weather-related disasters in the past, such as the crippling ice storm that hit Ontario and Quebec in 1998 (Figure 8.22), record rainfall in Toronto and southern Ontario in the summer of 2008, and tornados through southern Ontario. Changes in the frequency and severity of storms are one potential effect of the rapid increase in average global temperature and the movement of energy throughout the world (Figure 8.23).

Figure 8.22 The ice storm of 1998 in eastern Ontario toppled trees, cut electricity, and caused 44 deaths.



Source: Munich Reinsurance, 2006

Figure 8.23 The number of global climate-related disasters, by event, from 1950 to 2006

Floods

When the air temperature warms rapidly in spring, the snow can melt too quickly for the rivers and streams to handle the run-off. These "seasonal" floods damage homes and cropland and are becoming more frequent.

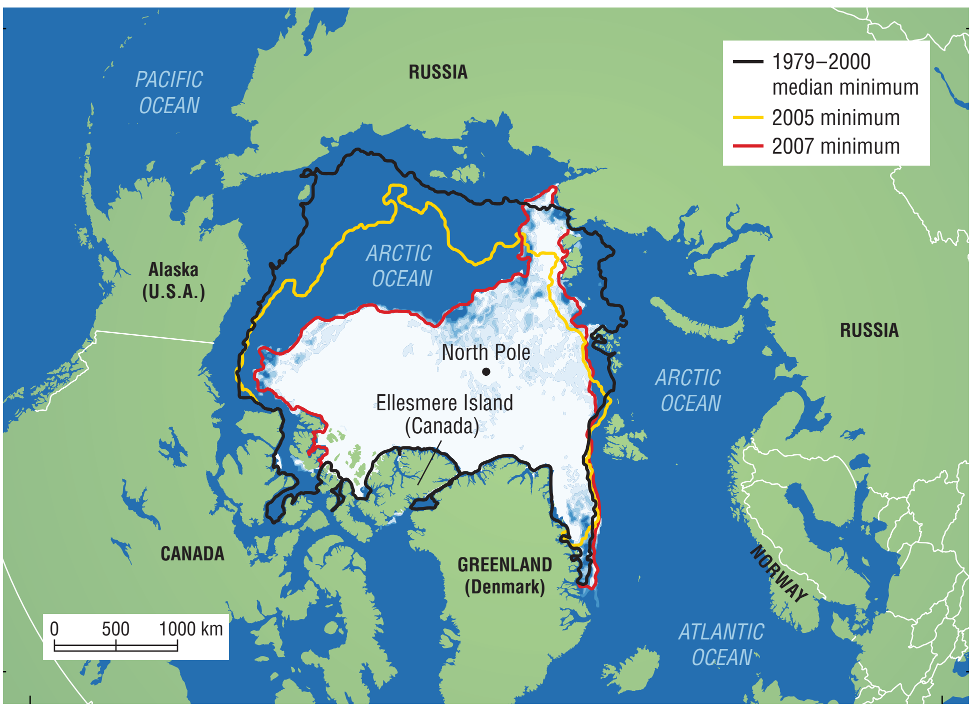
Effects of Climate Change in the Hydrosphere

Melting Ice

As the average global temperature increases, Earth's ice — both sea ice and glacier ice — is melting. This has consequences for more than just the Arctic and Antarctic regions. Melting ice can affect Earth by:

- flooding land that is currently just above sea level
- changing habitats of shoreline plants, animals, and micro-organisms
- causing the loss of property
- changing geographic coastlines and shapes of continental coasts
- reducing the amount of fresh water available to communities

In the Arctic Ocean, the amount of sea ice in the summer has decreased substantially (Figure 8.24). In the 1800s, Arctic explorers could not find the Northwest Passage because it was blocked with ice, even in midsummer. Now, it is easy to sail between Canada's northern islands in summer, even without using an icebreaker.



Source: NASA

Figure 8.24 Each summer, more of the ice cover on the Arctic Ocean is melting. This map shows the mean ice cover in the summers between 1979 and 2007.

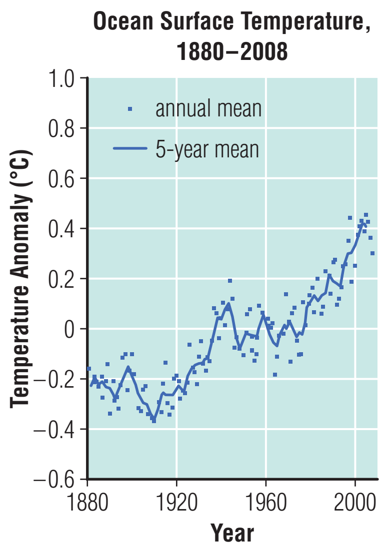
The average level of the world's oceans has increased by about 20 cm over the past century. There are three causes of this: as water warms, it expands; glaciers on land have retreated; and more recently, the Greenland and Antarctic continental glaciers have been melting.

Ocean Warming

The most obvious effects of rising global temperatures have so far been on land. The impact of rising temperatures on oceans is less obvious because water warms up more slowly. Think about walking barefoot on a summer day: the sidewalk is much hotter than the damp grass. As well, convection currents in the oceans mix the cold and warm water. Over the past century, the average ocean temperature has increased by about 0.6°C, a little less than the increase in air temperature over the same period (Figure 8.25).

We should be concerned about warming oceans for a number of reasons.

- As the water warms, it expands, so warmer oceans mean higher sea levels, causing loss of coastal land.
- Warmer water absorbs less carbon dioxide (just as cold pop retains more carbon dioxide than warm pop does), so it is less effective as a carbon sink.
- Warmer water is not as ideal a habitat for plankton growth. Phytoplankton undergo photosynthesis and therefore are an important carbon sink (Figure 8.26). Warmer oceans mean less phytoplankton, less carbon dioxide absorbed, and therefore an increase in greenhouse gas emissions.
- Warmer water produces more intense hurricanes, which damage land and harm people. Hurricanes are also beneficial in that they transfer heat from the warm tropical oceans to colder climates.



Source: World Resources Institute

Figure 8.25 The average global annual temperature of the surface layers of the ocean has been rising over the past century.

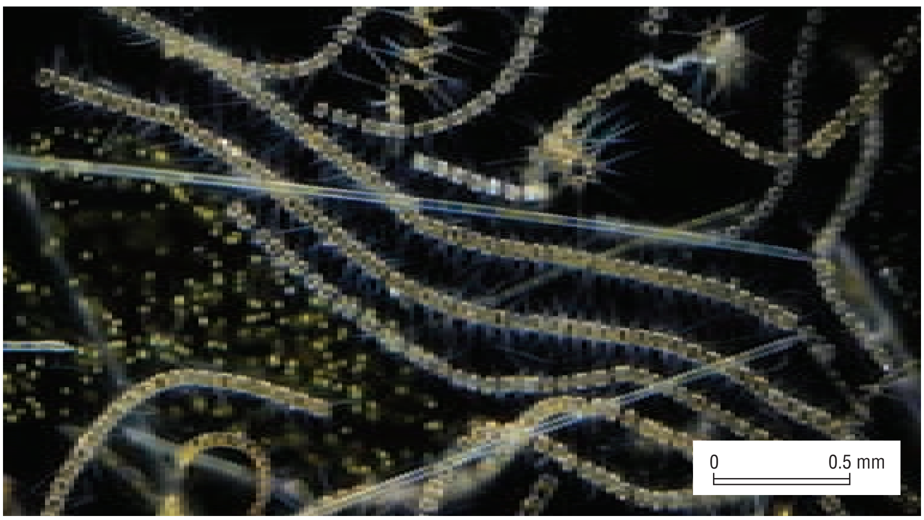


Figure 8.26 Marine phytoplankton. These tiny algae are the primary producers in the ocean and thus the base of almost all marine food webs.

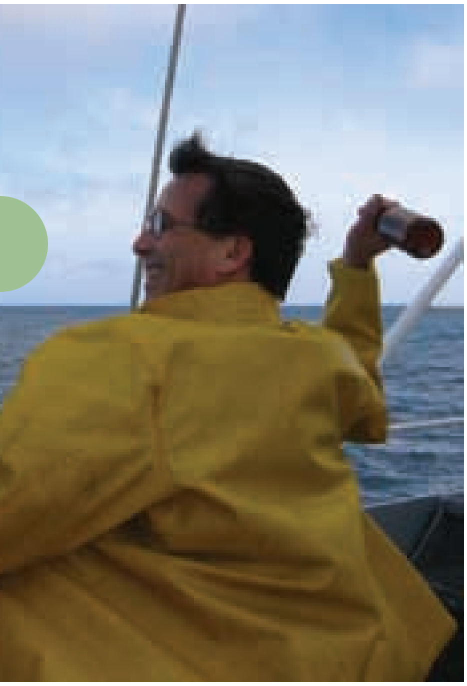


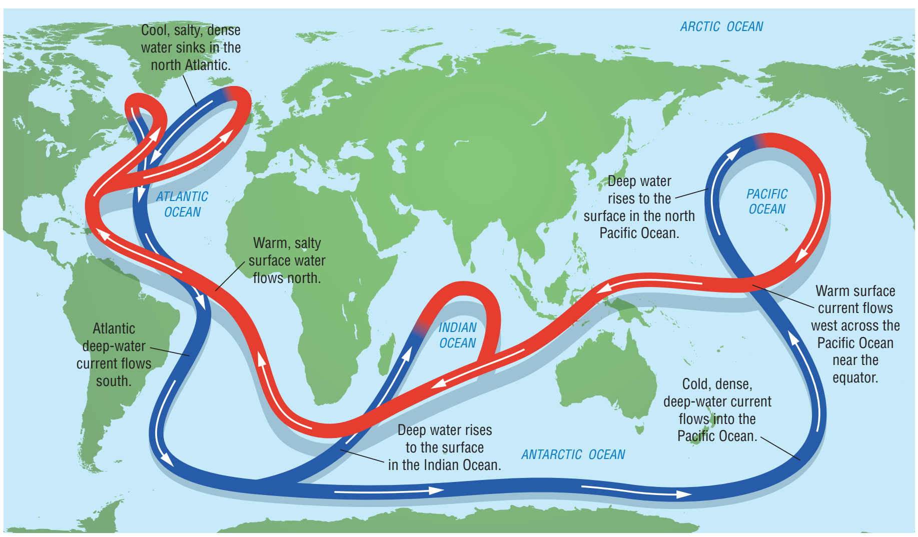
Figure 8.27 Drift Bottle Project leader Eddy Carmack throws another bottle into the ocean.

Ocean Currents

Oceans act as Earth's heating and cooling circulation system. As the temperature of Arctic water increases, it can lead to more extreme weather around the planet. According to Eddy Carmack, a Canadian expert on ocean currents, the melting of the Arctic ice could affect ocean currents around the world as well as lead to droughts and hurricanes. Some of his research on ocean currents involves "messages in bottles." He has tossed more than 4000 of these bottles overboard at research stops at various points in the Arctic and down the Pacific coast of North America (Figure 8.27). The message includes the date and location of the toss, along with his address. More than 150 messages have been returned from as far away as Norway, France, and Brazil. The bottles took about two years to reach these destinations.

Melting ice and warming oceans can change the flow of the ocean currents. Ice is frozen fresh water, so as the sea ice, icebergs, and glaciers melt, they add fresh water to the oceans. This dilutes the **salinity**, or salt content, of the sea water just as melting ice cubes dilute a drink. Fresh water is less dense (lighter) than salt water, so it remains on the surface.

As the salinity in the surface waters of the oceans declines, the mechanisms that drive the currents are affected (Figure 8.28). At present, at the surface of the North Atlantic, the dense, salty water sinks, pushing the currents through the deeper parts of the world's oceans. But melting sea ice and continental glaciers add fresh water to the oceans. This makes the surface water less salty, which affects the mechanisms that drive the ocean currents. Over the next century, the North Atlantic deep-water current could slow down to about half its present speed, disrupting the global ocean current system. This shows how one change can lead to another.



Source: Dorling Kindersley

Figure 8.28 The slowing down of ocean currents

Learning Checkpoint

1. How does the melting of permafrost affect trees?
2. Who publishes information about wildfires in Canada?
3. Give two ways that melting ice can affect Earth's climate.
4. How does warming water affect plankton?
5. What effects of climate change alter the flow of the ocean?

During Reading

Thinking Literacy

A Hypothesis Is a Type of Question

A hypothesis is essentially the combination of a question and a prediction. As you read about the climate change effects on wildlife, create a hypothesis following the pattern "If _____ continues, then _____ will happen." What evidence might help prove that your hypothesis is correct?

Effects of Climate Change on Wildlife

Warming climates and oceans and melting sea ice are affecting Earth's organisms. The ranges (home territories) of some animals and plants are shifting, and some organisms are threatened with extinction. Other organisms may actually benefit from climate change and increase in numbers.

The decline in fish stocks such as Pacific salmon may be related to increasing ocean temperatures. These salmon are adapted to a narrow range of cold temperatures while in the ocean. If ocean temperatures in the North Pacific rise above this range, salmon will not be able to survive unless they swim farther north.

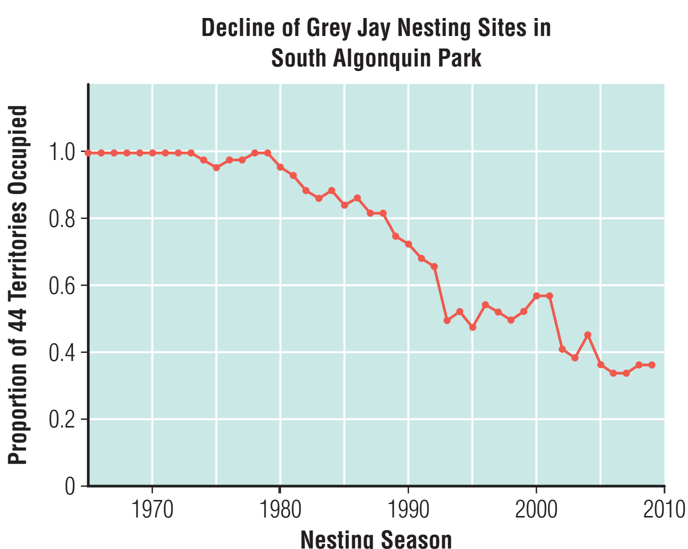
You may have heard about the plight of polar bears now that the Arctic sea ice melts earlier in the spring. Polar bears normally walk on the ice to hunt seals, because seals swim too quickly for the bears to catch them in open water. However, when the seals come up to a hole in the ice to breathe, the bears can capture them. Less ice means poorer hunting, and polar bears are going hungry.

Figure 8.29 Grey jays are no longer nesting at what was the southern edge of their range 40 years ago.

Range Shifts

Grey jays, commonly seen in northern Ontario, are very curious birds (Figure 8.29). They often approach people, especially if the people have food. Dan Strickland, a naturalist in Algonquin Park, has studied them for many years. Grey jays hoard enormous amounts of food for winter and they nest in late winter, with snow still on the ground. They feed their young with the hoarded food.

Strickland discovered that fewer birds nest in the southern part of their range now, as compared with 1965. This means that the southern edge of the grey jays' range has moved northward over the past four decades (Figure 8.30). Higher temperatures during breeding or the previous fall cause the hoarded food to rot, and the nestlings starve. Farther north, conditions are still suitable for grey jays to breed successfully.



Source: Dan Strickland

Figure 8.30 Before about 1980, many grey jays nested in south Algonquin park. Since then, the number of nesting birds has declined in this area. However, new nesting sites have been found at the northern edge of the range.

Figure 8.31 An adult blacklegged tick on a human arm

Similarly, the ranges of many other animals have moved northward. Opossums are now common, and mockingbirds now breed in southern Ontario. Both were formerly confined to the United States. Blacklegged ticks, which can carry Lyme disease, are now established on the north shores of Lakes Erie and Ontario and are also slowly moving northward (Figure 8.31).

Using satellite data and historical records, scientists have found that wildflowers in the northern hemisphere now bloom an average of 26 days earlier than they did 100 years ago. As well, many plants are dying along the southern edge of their ranges as the ranges shift northward.

Threatened Species

Figure 8.32 The 3-cm-long blue poison arrow frog from Suriname, South America, is threatened.

The changing climate may force many organisms to adapt or migrate, or they may become extinct. According to the IPCC, between 40 percent and 70 percent of all species are at risk of extinction if the global average temperature increases by only 3.3°C. Already, more than 35 percent of frogs, toads, and salamanders are threatened with extinction due to climate change (Figure 8.32). These animals' habitats are changing so quickly that the animals are unable to adapt. In 2008, the International Union for the Conservation of Nature began to identify the species most vulnerable to the negative impacts of climate change.

Corals are ancient animals related to jellyfish. They secrete skeletons that remain long after the animals have died. These skeletons build up for thousands of years, forming coral reefs (Figure 8.33). Earth has already lost about 20 percent of its coral reefs due to warmer water, sedimentation, and storm damage (Figure 8.34). If the carbon dioxide emissions continue to increase, most of the remaining reefs will be lost.

Figure 8.33 Coral reefs are the largest structures on Earth of biological origin.

Figure 8.34 When all the animals die in a coral reef, the skeletons remain. This is a "bleached" (dead) coral reef.

The oceans absorb about a quarter of the carbon dioxide emitted into the atmosphere from human activities. Over the past 25 years, the acidity of the surface seawater has increased at the same rate as the increase in atmospheric carbon dioxide. As the oceans dissolve more carbon dioxide, the water will become more acidic. Just as vinegar dissolves the calcium deposits in a coffeepot, increased acidity in the ocean can damage the calcified shells of aquatic species such as clams, snails, and sponges.

Scientists predict that ocean acidification will kill most coral reefs within four decades if atmospheric carbon dioxide levels continue to increase. This increase could also lead to changes in commercial fish stocks, seriously harming the fishing industry and adding to the global hunger problem.

Take It **Further**

Read about the research done by Eddy Carmack (ocean currents), Dan Strickland (wildlife), Derek Mueller (Arctic ice shelves), Andrew Weaver (member of the IPCC), or another Canadian scientist. Prepare a short summary to update a classmate who read about a different scientist. Begin your research at ***ScienceSource.***

Organisms That Benefit from Climate Change

Some organisms may find their environments improved as the climate changes. The numbers of several species of free-living jellyfish have increased up to 100 times in many coastal areas of the oceans. Large jellyfish that live off the coast of Japan can completely fill fishing nets (Figure 8.35). Enterprising fishers now dry and salt them to sell for snacks! Other jellyfish have very toxic stingers and can even kill humans (Figure 8.36). These jellyfish were formerly found only off the Australian coast; now they appear to live worldwide.

Suggested Activity
C14 Design a Lab on page 318

Figure 8.35 The giant Namura's jellyfish can be up to 6 m across and weigh 220 kg.

Figure 8.36 Box jellyfish are now found around the world. The "bell" is about 10–15 cm in diameter, and the tentacles up to 1.5 m long.

C14 Design a Lab

Skills Reference 2

SKILLS YOU WILL USE
- Gathering, organizing, and recording relevant data from inquiries
- Evaluating reliability of data and information

Test Your Hypothesis

In Chapter 7 and this one, you have read about and performed activities to learn about climate change. Now, it is time for you to test a hypothesis related to the cause-and-effect relationships in this complex discipline. You will find historical data available from sources at ***ScienceSource***.

Question

How can I test a cause-and-effect relationship with respect to climate change?

Design and Conduct Your Investigation

1. Review the information presented in the first two chapters of this unit. Skim the chapters, and make a list of questions that you have about the information in the chapters.
2. Review your list of questions, and put a "*" beside those you think you can test. Reword each question as a hypothesis. Suggestions include:
   - If the combustion of fossil fuels increases, then global temperatures will increase.
   - If the average annual atmospheric temperature increases, then intensity of cyclones and hurricanes will increase.
   - If the concentration of atmospheric CO_2 increases, then average annual global temperatures will increase.
   - If the human population increases, then greenhouse gas emissions will increase.
3. Discuss the possibilities with a partner or a small group (Figure 8.37). Draw a chart similar to Table 8.3 to help you make your decisions.

Table 8.3 Decision Chart

Hypothesis to be investigated	
Types of data to be collected	
Possible sources of data	

4. Present a one-page proposal for your teacher's consideration.
5. Conduct the investigation approved by your teacher.
6. Report on the investigation in the form of a formal lab report.

Figure 8.37 Whether you work in a group or with a partner, remember that teamwork makes the job easier.

8.2 CHECK and REFLECT

Key Concept Review

1. What is evidence? How do scientists define evidence?
2. Give an example of how extreme heat affects people in Ontario and in another part of the world.
3. Describe how drought has affected a local area, using specific examples.
4. State how increases in the occurrence of each of the following can be a consequence of climate change.
   (a) heat waves
   (b) droughts
   (c) wildfires
   (d) melting ice
5. How can the increasing severity of storms be attributed to climate change?
6. List five consequences that melting ice can have on Earth.
7. Describe four reasons that warming ocean temperatures might be of concern.
8. Describe how one scientist, Eddy Carmack, has studied changing ocean currents.
9. Why does fresh water tend to float on salty water?
10. Give one example of an Ontario animal species whose range has shifted. What is the evidence?
11. Why do changes in climate threaten species?
12. How do increasing levels of dissolved carbon dioxide in ocean water threaten shelled creatures such as snails and clams?

Connect Your Understanding

13. Describe several effects of climate change in Earth's atmosphere, and describe which one you feel has the most severe effects on your local area.
14. The trees in this photo are crooked because they are growing in thawing permafrost. Explain how this is related to some of the evidence of climate change described in this section.

Question 14

15. Why is the Northwest Passage important to consider when studying climate change?
16. What is the connection between melting ice, warming ocean temperatures, and ocean currents?
17. The effects of climate change on wildlife will affect humans, too. Give an example of this, and describe the consequences.

Reflection

18. Climate change is a big issue with many potential effects. People who take active roles in fighting global warming often focus their energy on one specific aspect of the issue, such as educating people about the plight of polar bears or warning of the potential spread of disease. Why do you think this happens? What aspect of climate change would you focus your energy on? Why?

For more questions, go to ***ScienceSource***.

8.3 Social and Economic Effects of Climate Change

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

- The economic and social effects of climate change are beginning to affect human society.
- These effects include the ways in which businesses operate and society functions.
- Changes to Earth's climate are having many negative and a few positive effects.
- Human activities may cause runaway positive feedback loops in some effects, and the consequences may worsen.
- People have different views about the causes, degree, and severity of climate change.

Figure 8.38 A market stall in Yemen. In the front are bins of beans and lentils.

The World Is a Marketplace

Marketplaces are colourful, full of people busy selling and buying food and other goods. Anywhere you go in the world, you will find markets — farmers markets, craft markets, flea markets, souks (Arabian), and bazaars (India) (Figures 8.38, 8.39, and 8.40). These markets show us that everyone on Earth buys and sells things, even though people live in different societies. We are all part of the global economy.

Figure 8.39 The Byward Market in Ottawa is particularly busy on Saturdays, when the farmers bring in their produce.

Figure 8.40 Not just food is sold in markets, as shown in this market in India.

C15 *Quick Lab*

Climate Change and Societies

The different societies on Earth are affected in different ways by climate change. A good way of seeing this is to look at how different societies are affected by severe weather events.

Purpose

To assess some severe weather events affected by climate change and reflect upon how they affect the societies involved

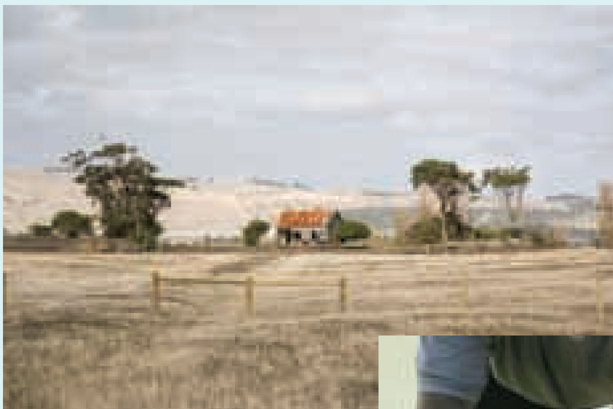
Procedure

1. Examine each photograph, and describe the severe weather event pictured (Figure 8.41).
2. Write down how you think each event is related to climate change.
3. Discuss your ideas with a partner, and then be prepared to share them with the class.

Questions

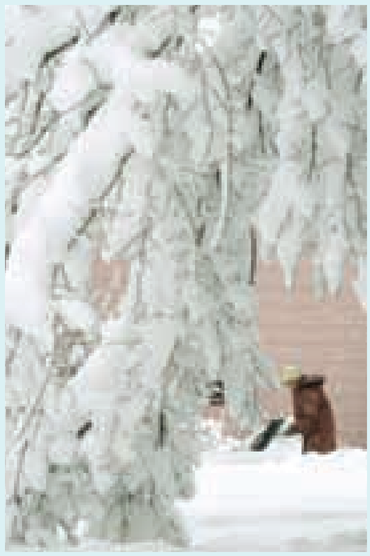
4. For each picture, write down how you think the severe weather event may affect the day-to-day lives of the local society.
5. Which picture do you feel depicts the most negative event? Why?
6. Choose two photographs and compare the two events, listing similarities and differences.

(c)



(a)

(b)



(d)

Figure 8.41 Climate change can cause severe weather events. (a) Dry weather stops grass growing (although it is still alive). (b) Heat waves can cause people such as this football player to suffer heat exhaustion. (c) Hurricanes can cause serious damage. (d) Owen Sound, Ontario, seems to get more and more snow each winter.

Effects of Climate Change on Economic Systems

WORDS MATTER

"Economy" has the same root as "ecology" does — the Greek word *oikos*, meaning house. *Oikonomia* means household management. In this section, we are talking about the world's economy — the wealth, resources, and household management of the entire world.

An **economic system** is the organized way in which a country or region sets up activities related to how goods and services are produced, distributed, and consumed. For a country such as Canada to continue to function well, citizens need to actively participate in the economy by earning and spending money. You are already participating in Canada's economy. However, climate change is affecting some of the economic and social functioning in Canada and in the rest of the world.

Production and Distribution of Goods

As humans, we rely on a system of production and distribution of goods to get what we need. This reliance has changed over the generations. Some people grow some of their own food (vegetables and fruit) and make some of their own household goods and clothing. However, society has shifted from people doing things for themselves to much greater specialization. Since the Industrial Revolution, society has found it much more efficient to mass-produce goods.

Production of goods requires natural resources for raw materials, and it needs energy to run the machinery involved and to transport the raw materials from their sources. Distribution of goods often requires manufacturing of other goods (packaging, shipping containers, trucks, etc.) to ensure their safe delivery (Figure 8.42). Fossil fuels can be used in every phase of production, as well as in moving the goods from one place to another.

Figure 8.42 Transport trucks load and unload goods at warehouses. At large retailers' warehouses, you may see 20 or more trucks lined up.

Traditionally, industries consider a number of factors when deciding on manufacturing techniques and the location of the factory. Generally, they try to minimize manufacturing costs in order to maximize profits. Labour costs and transportation costs are two main expenses. Recently, people have become aware of the environmental impact of transporting raw materials and goods. Often, the raw materials have to travel long distances in order to be turned into the products society wants. Then, the products are transported huge distances to stores. These two journeys increase both the cost of the product and its impact on the environment. This happens frequently because labour costs are lower in developing countries than in North America. Therefore, even though the businesses spend more money on fuel, the savings in labour offset this cost.

Consumers concerned about climate change are now considering the environmental costs of the goods they buy as well as the financial costs. A consumer may choose to buy used furniture instead of new, which reduces the need to produce new goods. Some people shop locally for furniture and other goods as well as food. This avoids transportation of raw materials and products.

Food Production

Much of Ontario's food is grown and produced on specialized farms. In 1956, the census reported over 140 000 farms in Ontario; by 2006, that number had dropped to about 57 000. Recently, food production has become a topic of conversation with respect to climate change. Some people prefer to eat locally produced food in order to minimize the use of fossil fuels to ship food long distances. Although we can get a large proportion of our food from Ontario sources, items such as coffee, bananas, and oranges have to be transported. Some foods can be grown in greenhouses, but fossil fuels are needed to heat greenhouses in winter.

Learning Checkpoint

1. What does the word "economy" mean?
2. Define "economic system" in your own words. Explain how you participate in it.
3. Write two or three sentences summarizing the relationship between an economic system and climate change.
4. Describe the terms "production," "distribution," and "consumption" with respect to goods.
5. How do fuel costs and labour costs affect manufacturing decisions?

During Reading

Thinking Literacy

Asking Questions of the Author

As you read, consider what the author has included and omitted. What questions would you ask the author about how information is chosen and why it is included?

Effects of Climate Change on Societies

A society is a group of people who have a distinctive way of life and economic system. Although Earth's climate system is one interconnected whole, different societies have different impacts on it. People who live in the industrialized or "developed" world enjoy a higher standard of living than those living in the "developing" world but have a greater impact on Earth.

The G8 (Group of Eight) is a group of government representatives from Canada, France, Germany, Italy, Japan, the United Kingdom, the United States, and Russia (Figure 8.43). Residents of the G8 countries enjoy some of the highest standards of living in the world. These countries also use more energy per capita (per person) than those who live elsewhere. Each person who lives in a G8 country is responsible for more greenhouse gas emissions than a person in most other countries. It also means that we each contribute more to climate change. Table 8.4 on the next page shows the per capita amounts of greenhouse gases emitted by selected countries.

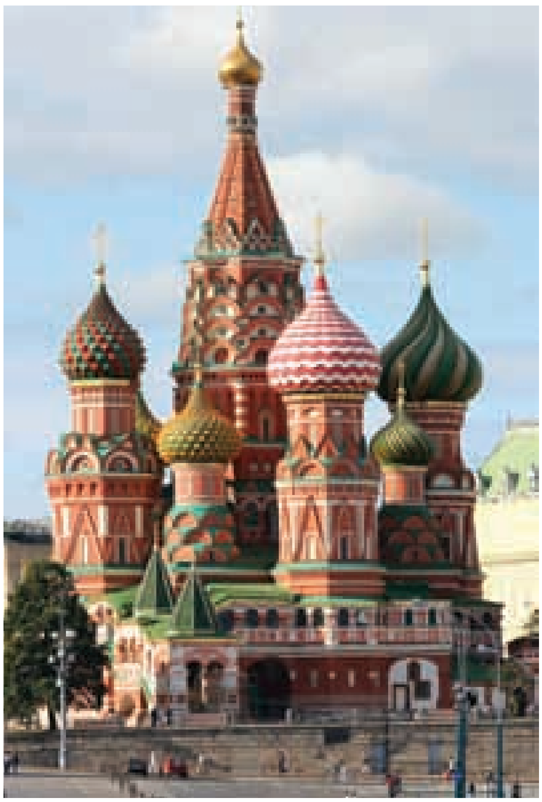


Figure 8.43 St. Basil's Church in Moscow's Red Square. Moscow is the capital of Russia, a G8 country.

Figure 8.44 Afghanistan is a developing country.

Suggested Activity
C18 Decision-Making Analysis on page 329

Table 8.4 Per Capita Greenhouse Gas Emissions in 2005 in Selected Countries

Country[1]	Per Capita CO_2 Emissions[2] (Tonnes)	Rank of Country	Percent Increase from 1990[3]
Kuwait	26.0	1	160.9
United Arab Emirates	25.6	2	20.2
United States	20.2	3	5.8
Australia	17.4	4	10.9
Canada	16.9	5	9.9
Netherlands	11.0	12	3.8
Russian Federation	10.6	15	(30.9)
Japan	9.6	19	9.2
United Kingdom	9.5	22	(6.4)
South Africa	7.8	32	(2.2)
France	6.1	40	(7.8)
Jamaica	4.0	56	29.3
Argentina	3.7	58	15.0
China	2.7	71	26.2
Egypt	1.9	77	16.9
Brazil	1.9	78	32.8
India	1.0	96	36.3
Philippines	1.0	98	43.4
Pakistan	0.7	102	26.6
Bangladesh	0.2	117	63.2
Sudan	0.2	126	(16.6)
Afghanistan	0.0	144	(77.7)

1. Countries were ranked in a list of 146 countries.
2. Carbon dioxide emissions from land use and burning forests and crop residues are not included.
3. The numbers in parentheses are decreases in emissions.

Source: World Resources Institute

People who live in developing countries — for example, Afghanistan — tend to be most vulnerable to the effects of climate change for several reasons (Figure 8.44). Many of the poorest societies, such as those in sub-Saharan Africa, already experience extreme climate conditions. As droughts continue, farmland south of the Sahara Desert dries up and becomes a desert.

On the other hand, people in developed countries are more able to deal with severe conditions (Figure 8.45). For example, in Europe and North America, our homes can usually withstand bad weather. This may not be the case in developing countries. Table 8.5 outlines some of the possible impacts of climate change on people throughout the world.

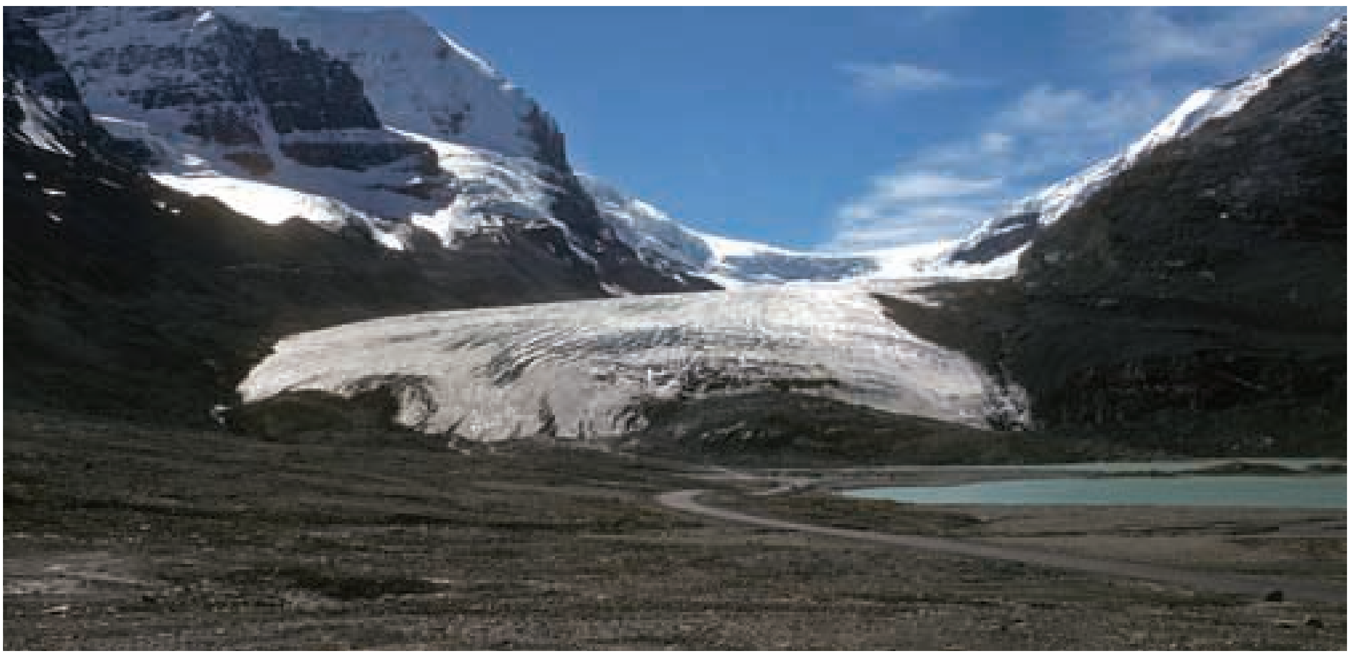
Table 8.5 Societal Impacts of Climate Change

Category	Description
Food	• Global warming could make it harder to grow crops in tropical countries. • A reduction in crop yield would lead to widespread food shortages in developing countries and rising food prices in developed countries.
Drinkable water	• Drought will make it even more difficult to obtain water in drier climates. • Shrinking glaciers will limit the supply of fresh water to Southeast Asia and western South America. • Flooding could contaminate the freshwater supplies of low-lying areas.
Infrastructure breakdown (equipment, buildings, and roads)	• Severe weather events can damage the infrastructure for energy distribution, communication, and transportation.
Disease	• Tropical diseases such as malaria could spread as climates become warmer.
Population displacement	• If land is flooded or becomes desert, people will be forced to move in order to meet their basic needs. This could result in conflicts.

Source: IPCC

(a)

(b)



(c)

Figure 8.45 Changes to Canada's climate can mean (a) crops lost to drought and (b) worse storms.
(c) Since 1850, the Athabasca Glacier in Alberta has lost 1.7 km of its length, half its depth, and two-thirds of its volume.

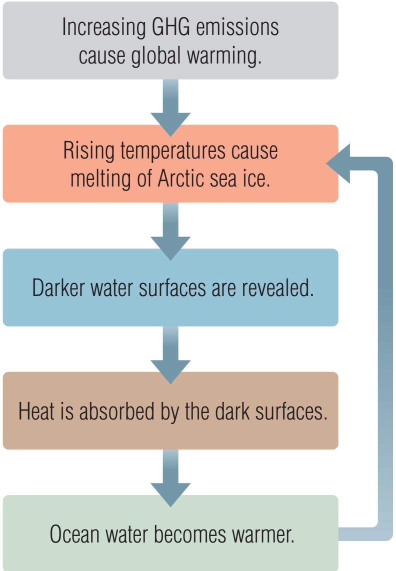
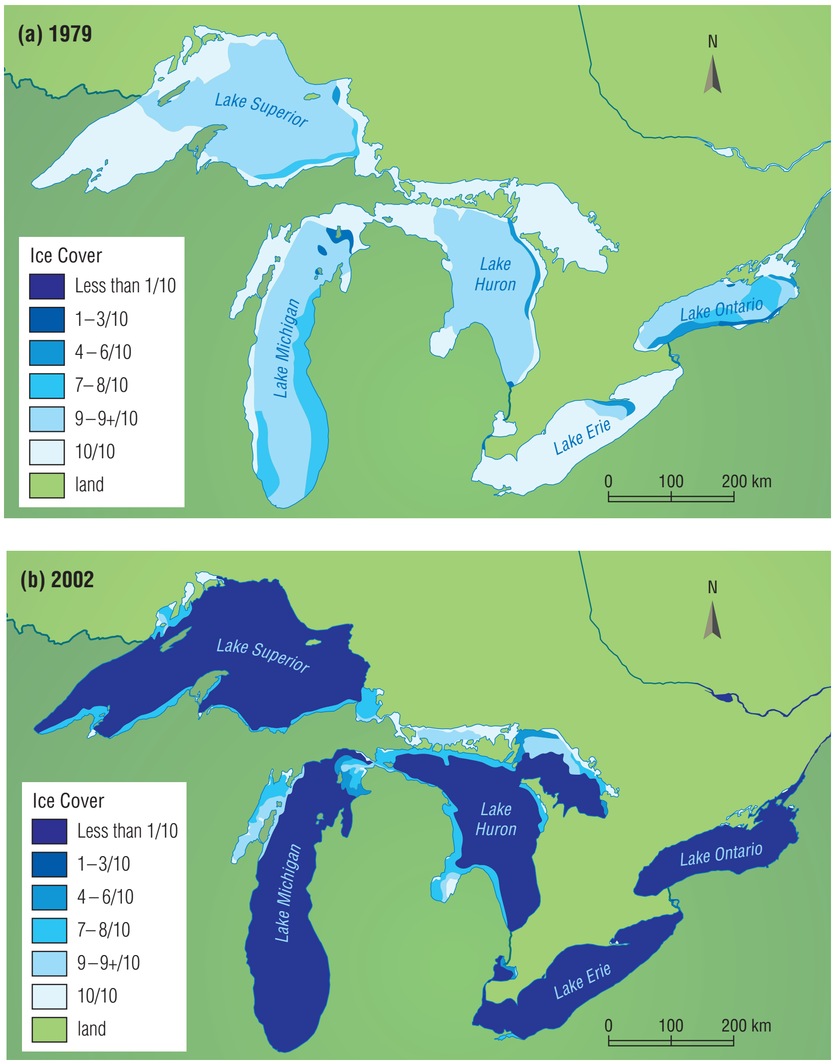


Figure 8.46 Positive feedback loop of melting ice. GHG stands for greenhouse gas.

Global Consequences

When we consider the global consequences of the physical effects of climate change, it is clear that even small changes can have serious impacts. You may have noticed that some of the physical consequences of rising global temperature show a **positive feedback loop**, a sequence of events that cycles back to one of the earlier events in the sequence and enhances the outcome. "Positive" in this instance refers to the type of feedback loop, not to the consequences, which may be quite negative. The positive feedback loop shown in Figure 8.46 means that a small rise in global temperature can trigger a process that actually increases the speed of warming. Such events include the following:

- A wildfire destroys a forest, which no longer acts as a carbon sink, so more of the atmospheric carbon dioxide in that area can become a greenhouse gas. This results in an increase in the greenhouse effect, which creates even hotter, drier conditions, which can cause more wildfires.



Source: Canadian Ice Service

Figure 8.47 The ice cover has diminished dramatically on the Great Lakes in winter: (a) 1979, (b) 2002. Since less solar radiation is now being reflected by Great Lakes ice, Ontario's winters have become warmer but snowier.

- Ice and snow have a high albedo. They reflect about 90 percent of the solar radiation that strikes them. As the snow and ice melt, they reveal darker-coloured surfaces (open water, soil) that absorb about 90 percent of the solar radiation, reflecting only 10 percent. When ice on a lake or an ocean melts, it reveals water, which absorbs solar radiation and warms up much more quickly than the ice did. This extra heat melts more ice, revealing more open water, which warms up and melts still more ice. After the ice has melted, much more solar radiation is absorbed, which increases the temperature of the water and the atmosphere above it (Figure 8.47 on the previous page).

Some environmentalists, concerned that these positive feedback loops will speed up the effects of global warming, have coined the term **runaway positive feedback loops**, in which the sequence of events appears to speed up with each cycle.

Take It ***Further***

Each person's impact on Earth is different. To calculate your own impact on Earth, you can determine the amount of carbon your lifestyle choices contribute. Use an online carbon calculator to determine how your choices compare to those of others. Discuss your results with a small group, highlighting similarities and differences. Begin your research at ***ScienceSource.***

Positive Effects of Climate Change

Not all the projected effects of climate change are negative. Ontario is a major farming province, with over 82 000 farmers and 5.5 million hectares under cultivation. Much of southern Ontario as well as areas in northern Ontario (e.g., New Liskeard, Massey) have rich farmland. As climate change brings warmer temperatures, the length of the growing season will increase, and farmers will be able to increase crop yields and grow crops that require more heat.

As the sea ice on the Arctic Ocean melts, the Northwest Passage shipping route will be open water every summer. Sailing through the Arctic islands will substantially shorten the shipping distance from Europe to China and Japan, reducing the cost of transporting goods Cruise ships can sail farther north than before, so tourists can follow in the wake of Arctic explorers such as Henry Hudson and John Franklin.

C16 STSE *Science, Technology, Society, and the Environment*

Reducing Climate Change Impacts at School

You spend many waking hours every weekday, 10 months per year, at school. An important part of society, school is where students can learn about issues such as climate change. It is also a place to learn to take action on climate change.

1. Pick one technology used at your school that you think can be changed so that your school will make less of an impact on the environment. Consider things such as light bulbs or computer monitors.
2. Summarize the costs and benefits of making the change.
3. Make a list of the key people who would be affected by the change, and make sure to address their concerns in your summary.
4. Present this information in one page that could be sent to members of your student or school council.

C17 *Skill Builder Activity*

Evaluating Evidence

Many people use evidence in their work. When you are not feeling well, you go to a doctor, who may collect evidence on the state of your health, starting with simple tests such as listening to your heartbeat and measuring your blood pressure. She may order further tests if the results from the initial tests are not conclusive.

Police also collect evidence at crime scenes and accident scenes. They use all of the evidence, called the "body of evidence," to help them determine whom to arrest or who was at fault in the accident.

In school, your teachers collect evidence of your learning. You participate in class, submit projects, perform labs and activities, and write tests and quizzes (Figure 8.48). Your teacher looks at this body of evidence to determine your grade.

Procedure

1. Look at the marks of the two students recorded in Table 8.6.
2. Put yourself in the role of the teacher. Use this evidence to determine a report card grade and comment.
3. Determine the grade you would record for each student.
4. Join with a partner, and compare the methods you each used and the grades you each determined for each student.
5. Discuss questions 6–9 with your partner.
6. Did you agree on the grades for each student? Why or why not?
7. Are the grades you each determined appropriate for each student?
8. How confident are each of you in your decision about the grade and comment?
9. What other information would you like to know about each student in order to grade him or her more reliably?

Table 8.6 Student Marks in Science 10

Description	Student A	Student B
Quiz 1 (/10)	7	5
Quiz 2 (/10)	7	9
Quiz 3 (/10)	6	2
Quiz 4 (/10)	8	10
Quiz 5 (/10)	7	7
Unit Test (/100)	73	66
Lab 1 (/10)	7	4
Lab 2 (/10)	8	9
Unit Task	B	B+

Figure 8.48 Students writing a test

DI Key Activity

C18 Decision-Making Analysis

Skills Reference 4

SKILLS YOU WILL USE

- Evaluating reliability of data and information
- Communicating ideas, procedures, and results in a variety of forms

Where Do You Stand?

Issue

Climate change, like every issue, has many interpretations. There is a very strong consensus among scientists on most of the evidence. However, scientists, governments, environmental groups, and the general public can have different opinions about how serious the issue is, how dire the consequences may be, and how much can be done about it.

Background Information

It is a fact that the Earth's average annual temperature has increased over the last century. Evidence from data such as fossil records and ice cores shows how Earth's climate has undergone many changes in the past, both before and since humans existed. However, some people argue that today's global warming could just be part of a natural climate cycle that occurs over thousands of years. They believe that until such cycles are fully described, the human contribution to global warming remains debatable.

The issue of climate change has prompted a great deal of discussion. The IPCC stated in 2007: "Warming of the climate system is unequivocal, as is now evident from

- observations of increases in global average air and ocean temperatures,
- widespread melting of snow and ice, and
- rising global average sea level."

Climate change skeptics, on the other hand, make three main points.

- We do not understand Earth's climate well enough to make predictions about the future.
- The global climate is getting warmer but not because of human activities.
- The global climate is getting warmer, but this will create greater benefits than costs.

Each group has access to the same evidence — the evidence (effects) described in this chapter — but has come to different conclusions.

When you looked at the students' marks in the previous activity, you may have determined that a student should pass but were unsure about the exact grade. When you evaluate the evidence on climate change, can you decide where you stand on this issue? Where would you rank the seriousness of the issue in terms of the other issues facing us? What do you think you can or should do about the issue? What is your obligation to future generations? What roles do the reports from the media and government play in forming your opinion?

Analyze and Evaluate

1. Go to ***ScienceSource*** to begin your search for information.
2. Look for a variety of different views about climate change. Make a fact sheet on three groups of people with different views. Identify the qualifications and potential bias of the group/person.
3. Using a ranking system of 1–5, with 1 = mildly serious to 5 = extremely serious, rank each group/person's views on
   - how serious is climate change?
   - how dire are the consequences?
4. State how each group/person views what can and should be done about it.
5. Think about what you know about climate change, and add your own views to the fact sheet.
6. How do you think your view has been shaped by media, government views, and this unit?
7. Discuss your views as a class. Do you hold similar or different views? What evidence do you agree on? Where do your views differ?

Skill Practice

8. What evidence are you using to support the way you filled out your fact sheet?

8.3 CHECK and REFLECT

Key Concept Review

1. How is “society” defined?
2. Using Table 8.4 on page 324 explain why the top five countries are in those positions.
3. State key differences between the way people acquire goods now and how they acquired goods before the Industrial Revolution.
4. Explain why businesses may manufacture their goods great distances from where they plan to sell their goods.
5. List the G8 countries, and locate them on a map of the world. What trends do you notice?

Connect Your Understanding

6. How is climate change likely to affect the worldwide availability of drinkable water?
7. Why do citizens of the G8 countries have so much influence on climate change?
8. Scan Table 8.4 on page 324 for countries you have heard about in the media. Describe the reports about these countries.
9. Compare the evidence described in this section by presenting it in a graphic organizer of your choice.
10. Explain why positive feedback loops are of special concern when considering climate change.
11. Study Figure 8.46 on page 326, which shows a positive feedback loop. How do you think positive feedback loops become runaway positive feedback loops?
12. Why will citizens of G8 countries be better able to cope with the effects and impacts of climate change?
13. Identify each fruit shown, and determine the possible country of origin of each. How does being able to assemble fruit such as this affect climate change?

Question 13

14. What implications would “eating locally” have on you and your family?
15. Compare the fast-food hamburger dinner and the salmon dinner shown below and their possible impacts on climate change.

Question 15

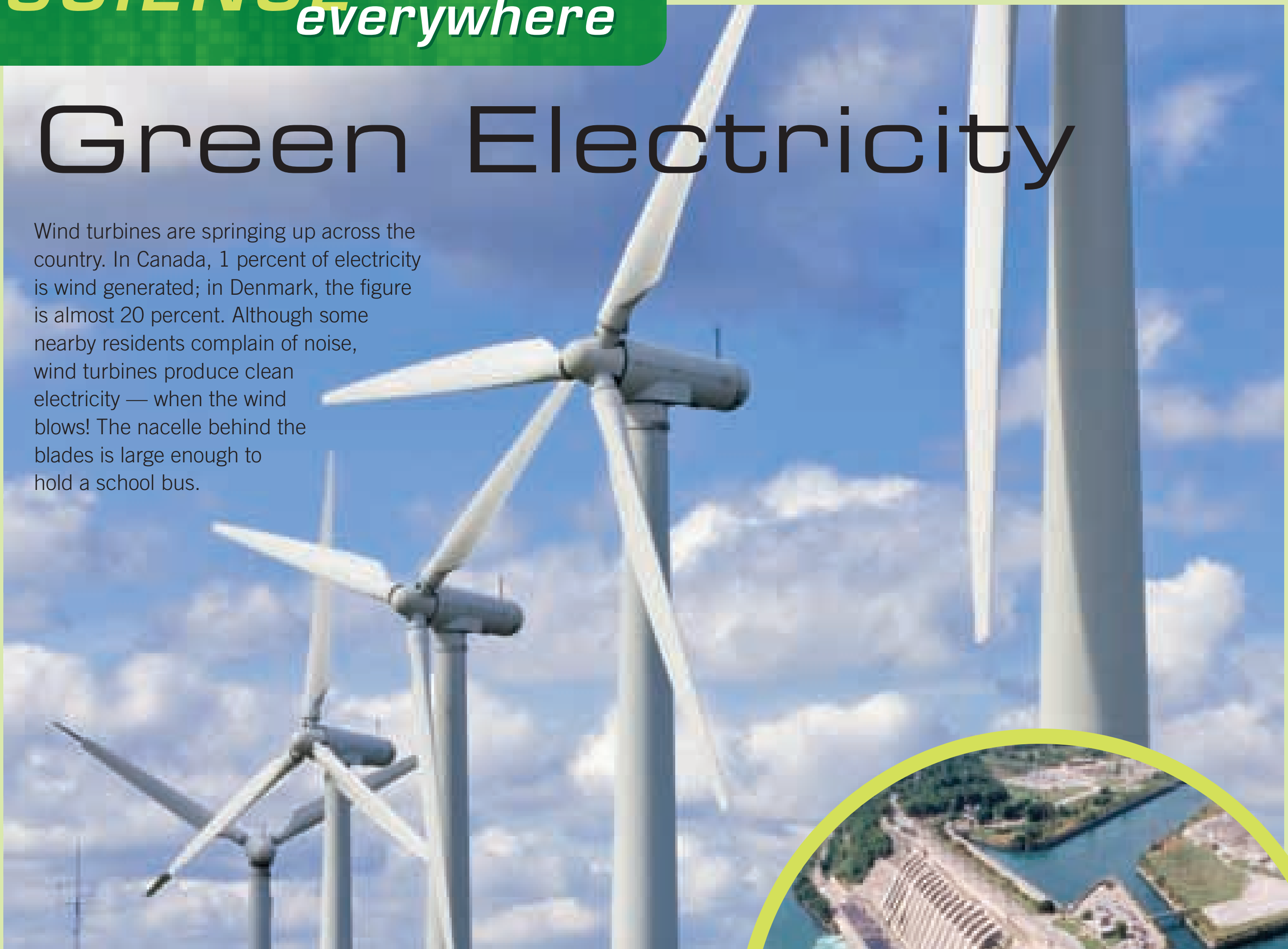
Reflection

16. Why is it important to understand other views on climate change even though there is broad scientific consensus that climate change is happening and that human activity is causing it?

For more questions, go to ***ScienceSource***.

SCIENCE everywhere

Green Electricity



Wind turbines are springing up across the country. In Canada, 1 percent of electricity is wind generated; in Denmark, the figure is almost 20 percent. Although some nearby residents complain of noise, wind turbines produce clean electricity — when the wind blows! The nacelle behind the blades is large enough to hold a school bus.

People have long used the power of falling water. The Sir Adam Beck Hydroelectric Power Stations at Niagara Falls have converted that power into electricity since 1922. As long as the designers take the local environment into account when damming or diverting rivers, hydroelectric power is one of the cleanest sources of electricity. None of the generators shown on this page produces greenhouse gases while generating electricity.

Use the Sun to light up the night! Solar cells can (a) power a small garden light or (b) provide enough electricity for a small city. The use of solar cells, also called photovoltaic cells, is doubling every two years around the world.

People also use solar panels, which are different from solar cells, to heat water and their homes.

8 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

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

Key Concept Review

1. Describe how greenhouse gases can affect Earth's net radiation budget. k

2. Why did the level of greenhouse gas emissions begin to increase during the Industrial Revolution? k

3. Explain the steam engine's role in the Industrial Revolution.

4. Describe some severe weather events that have affected (a) Ontario and (b) the rest of Canada. k

5. Describe how greenhouse gas emissions are being affected in each photograph below. k


(a)


(b)


(c)


(d)

Question 5

6. Define the terms "carbon source" and "carbon sink" with respect to greenhouse gases. Give examples of each. k

7. Describe one similarity and one difference between the natural greenhouse effect and the anthropogenic greenhouse effect. k

8. (a) What have scientists concluded about atmospheric concentrations of greenhouse gases from Greenland and Antarctic ice core data? k
   (b) Does tree ring data support this conclusion? k
   (c) Which set of data is more complete? Explain. k

9. Mockingbirds are becoming more common in southwestern Ontario than a decade ago. Explain why this is happening. k

10. Explain why the use of fossil fuels has increased over the past century. k

11. Describe one method that scientists use to measure changes in the concentration of greenhouse gases over time. k

12. List the sources of human-generated nitrous oxide emissions. k

13. Describe the IPCC and its role in assessing climate change. k

14. Describe two ways in which climate change may affect biomes. k

15. Create a Venn diagram to show the similarities and differences between the natural greenhouse effect and the anthropogenic greenhouse effect. t

16. How is albedo related to climate change? a

17. Explain "positive feedback" as related to climate change, and give an example. k

Connect Your Understanding

18. Why do most discussions about climate change focus on carbon dioxide?

19. What does the burning of fossil fuels have in common with the process of respiration?

20. List three different ways scientists have gathered evidence related to climate change, and describe the evidence you find the most persuasive.

21. Why is it important to have an organization such as the IPCC when attempting to understand climate change issues?

22. Climate change will affect different parts of the world in different ways. Why should people who live in parts of the world that expect the least negative effects be as concerned as those who live in parts of the world that expect the most negative effects?

23. Study the following figure, and comment on how confident you are about IPCC reports.

Question 23 The preparation of all IPCC reports follows strict procedures. Expert contributors from around the world reflect a range of views, expertise, and geographical representation. Before publication, IPCC reports are reviewed by governments and experts.

24. Think of your typical day, and list three ways you participate in Canada's economy.

25. Choose one effect of climate change, and depict it visually. Use arrows, key words, and colour to make your points clearer.

26. What do you think are the obligations of people who live in G8 countries to those who live in the developing world?

27. How could a shift in consumer demand affect the production and distribution of goods?

28. Many celebrities have embraced the climate change issue. What are the pros and cons of this phenomenon? Explain.

29. Why is it important for you and every citizen to understand the science of climate change?

Reflection

30. What is the most concerning thing you have learned about climate change in this chapter? Explain.

31. How has the information you have learned about climate change affected your thinking? your actions?

32. What is the most surprising thing you have learned about climate change in this chapter?

After Reading

Reflect and Evaluate

Why is it important, especially for a scientist, to ask questions? Consider places in the text where you asked questions. List the questions you asked and the answers you found or still need to discover. How do these questions move you forward in your thinking?

Write down three purposes for asking questions as you read. Share and compare your purposes with other members of a small group.

Unit Task Link

As you prepare for your unit task, gather research that has been published in the last 12 to 18 months. How does the evidence from the new research compare with what is presented in this chapter? Does it substantiate or question what you read here? Has evidence been gathered in a new or innovative way? Add the new evidence and your notes about it to your portfolio.

Home Quit

9 Local, national, and international governments are taking action on climate change.

People who live near the ocean build seawalls to prevent the sea from damaging their houses. As sea level rises because of climate change, those people will have to build higher seawalls or move inland.

Skills You Will Use

In this chapter, you will:

- use appropriate terminology related to climate change to communicate your ideas and opinions
- compare different perspectives on how climate change may affect Earth

Concepts You Will Learn

In this chapter, you will:

- analyze positive and negative effects of climate change on humans and natural systems
- assess the effectiveness of some current individual, regional, national, and international initiatives that address the issue of climate change and propose a course of action related to one of those initiatives

Why It Is Important

To deal with climate change, we must learn to adapt to the changes that have already occurred and to prepare for more changes in the future. We have to learn to anticipate potential future impacts and reduce or adapt to them. As part of an educated public, you can help to ensure that governments act appropriately on each issue.

Before Writing

Thinking Literacy

Gathering Information for Writing

Good writers often spend many more hours researching information than they do writing. Choose two subtopics from section 9.1, and estimate the type and amount of research that was done to prepare for writing.

Key Terms

- carbon footprint • carbon offsets
- carbon tax • confidence level • emissions trading
- Kyoto Protocol • mitigation • sequestered
- sustainable development

9.1 The Future of Climate Change

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

- Scientists study climate change using computer models.
- The international community is taking action against climate change.
- Canada has a role to play and a responsibility to take action.

Figure 9.1 School is one place in which you plan your future.

Predicting the Future

What do you see when you think about your future? When you look back over your life so far, you can remember things that happened and the lessons you learned from them. Your past gives you clues about what might happen in your future. Your life right now — in the present — includes studying climate change in a grade 10 classroom (Figure 9.1).

Most young people try to predict what they will do "when they grow up" (Figure 9.2). You may already know what type of job you would like, or you may still be open to possibilities. Some of today's jobs, in fields such as information technology and ecotourism, did not exist a generation ago. Your choices for your future will depend on what you have learned in your past plus what interests you in your future.

Trying to predict the future is not limited to young people wondering what it will be like when they grow up. Politicians, economists, and scientists also try to predict the future. They also use past and present information to help with their predictions. Politicians want to know the future because governments that cannot maintain stability, predictability, and prosperity for their voters do not tend to stay in power. Most people want to feel confident about the future even if they can't predict it.

Climate scientists use computer models to predict the future climate. What their models tell them is troubling. As a result, governments are starting to pay attention to climate change.

Figure 9.2 From a young age, humans consider their future role in society.

C19 *Quick Lab*

What Is the Likelihood?

Predicting the future is difficult. The farther into the future you try to look, the harder it is to make accurate predictions. To make the best prediction possible, you need to look at evidence from the past and present. The more reliable your past evidence, the better the prediction you can make.

Purpose

To analyze past evidence in a variety of situations in order to make accurate predictions

Materials & Equipment

- pencil and paper

Procedure

1. Choose three situations from the following list, and write them in your notebook.
   - The Toronto Maple Leafs will win the Stanley Cup this year (Figure 9.3).
   - You will score 70 percent or better on your next science test.
   - A cure for cancer will be found in your lifetime.
   - The price of gasoline will be higher by this time next year.
   - You will watch TV at some point in the next 24 h.
   - The current Canadian government will be re-elected in the next federal election.
2. Decide what evidence you would consider to make a prediction about each of the three situations.
3. Rate your prediction from 0 to 10, with 0 = would never happen and 10 = 100 percent confident it will happen.

Figure 9.3 The Toronto Maple Leafs won the Stanley Cup in 1967.

Questions

4. Which predictions are you most confident about and why?
5. What predictions are you least confident about and why?
6. Did you rank anything 0 or 10? Explain your reasoning.
7. What factor does time play in predictions? Think about why many polls are taken leading up to an election, or why we can get short- and long-range weather forecasts. Is anything ever 100% certain?

Modelling to Predict Future Climates

Earth's climate is a complex system, so changes in any part of the system affect the whole system. This complexity makes it difficult to predict the effects of changes. This is why climate scientists use computer models to examine and understand many different scenarios and to predict what might happen in the future.

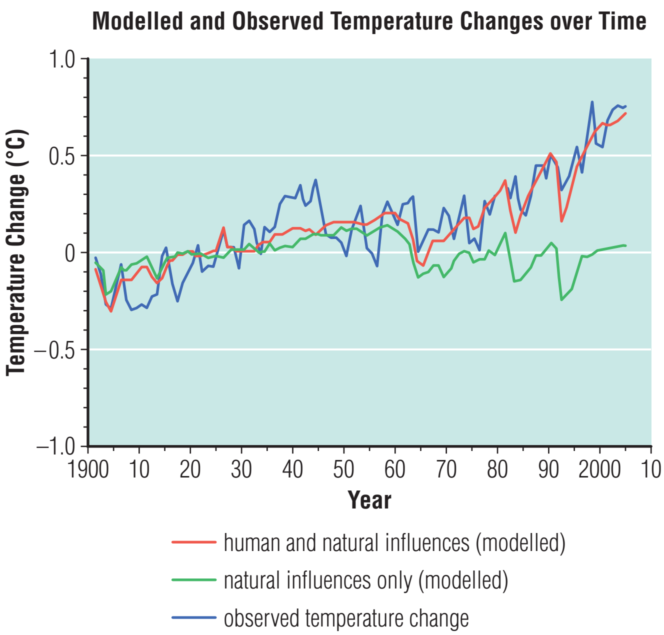
Computer Models

Figure 9.4 A lot of computer power is needed to run modelling programs.

The models involve mathematical equations that describe interactions in the physics, biology, and chemistry of Earth's climate system. These equations are so complicated that computers must be used to solve them and create descriptions of possible future climate patterns (Figure 9.4).

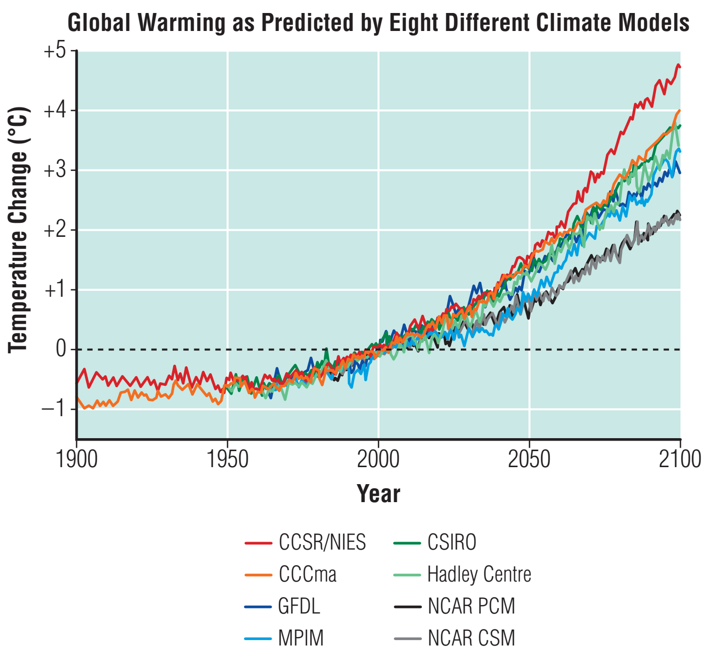
When a model is developed, it must be tested to make sure it will give believable predictions of future climates. Scientists run the model to see if it accurately reproduces past data. If it produces data that match what we already know from actual measurements of world climates, then it will likely give us good predictions of future climates.

After scientists confirm that a model is usable, they run it to make climate predictions. The computer models that scientists have been using indicate that the climate will continue to change. The amount of change will depend on what happens to emissions of greenhouse gases. The models are run for different emission scenarios. For example, in one scenario, emissions remain the same as they are today. In another one, the emissions increase by a certain percentage. Currently, even the most



Source: Dorling Kindersley

Figure 9.5 Modelled data show that the closest match to the observed global mean temperature is a combination of human and natural influences.



Source: Dorling Kindersley

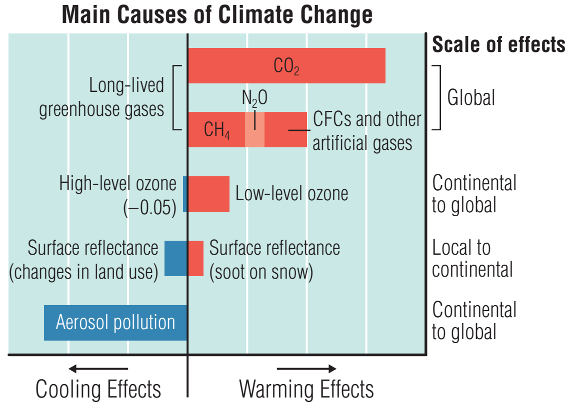
Figure 9.6 Though the models differ, the trend is the same for all of them.

conservative scenarios indicate that Earth's climate is changing (Figure 9.5 on the previous page).

The models are reliable but they may not account for all of the complexities of Earth's climate system. Climatologists themselves acknowledge that predicting the effect of cloud cover, for example, is difficult. Still, even those computer models that show conservative levels of climate change are predicting dramatic possible future changes (Figure 9.6 on the previous page).

Aerosol Pollution

Scientists believe that increases in aerosol pollution have masked the severity of the warming (Figure 9.7). This means that the extent of the problem may be worse than it seems from the computer models. Aerosol pollution is the presence in the atmosphere of tiny particles (aerosols) generated by natural (volcano eruptions, forest fires) and anthropogenic (burning of fossil fuels) sources (Figure 9.8). Since the explosion of the volcano Krakatoa in 1883 and the subsequent three-year drop in average global temperatures, scientists have known that aerosols in the atmosphere have a cooling effect. Scientists feel that Earth would be much hotter now if it were not for the effect of aerosols. It is difficult to predict the amount of global aerosol pollution because it depends partly on unpredictable events. Therefore, it is difficult to predict its effect on climate change.



Source: Dorling Kindersley

Figure 9.7 Main causes of climate change. Aerosol pollution has a net cooling effect, so it could be masking the severity of the warming.

Figure 9.8 Volcanic ash erupting from Mount St. Helens in Washington state

Canada's Future Climate Modelled

Computer climate models are predicting some initial positive effects for Canada. Since rising average temperatures extend growing seasons, these models predict that we may be able to raise crops such as wheat farther north if soils are suitable. The Intergovernmental Panel on Climate Change (IPCC) projected that the Great Lakes region may be able to grow more fruit. However, the computer models also predict that higher temperatures will be accompanied by more precipitation and more frequent and severe weather events, such as flash floods, harsh winters, and windstorms.

Confidence Ratings of Climate Change Models

Even the most conservative predictions of the potential effects of climate change are now pointing to a need for action. However, it is important to realize that some events are more significant than others. Therefore, scientists have found ways to estimate their confidence in

Table 9.1 IPCC Confidence Ratings for Predictions

Confidence Rating	Probability That Result Is True
Virtually certain	>99%
Very likely	90–99%
Likely	66–90%
Medium likelihood	33–66%
Unlikely	10–33%
Very unlikely	1–10%
Exceptionally unlikely	<1%

Source: IPCC

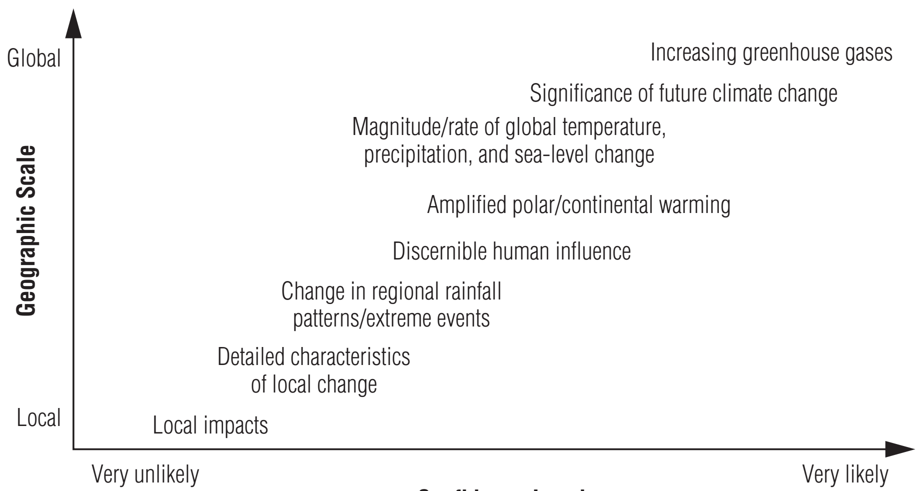
their computer models, evaluations, and predictions. Through statistical and other methods, each type of data analysis can be given a particular **confidence level**. The IPCC uses the rating scale shown in Table 9.1 to communicate its level of confidence in each event in their climate change models.

Some of those events are shown in the confidence level graph in Figure 9.9 on the next page. The IPCC scientists give higher confidence levels to their predictions and conclusions when they have:

- more data (such as long-term temperature data)
- more accurate measurements (such as measurements of atmospheric temperatures at different altitudes)
- a greater understanding of the factors involved in a particular climatic event (such as the effect of the time of year on insolation).

The IPCC has stated, "There is considerable confidence that climate models provide credible quantitative estimates of future climate change. Models have consistently provided a strong and unambiguous picture of significant climate warming in response to increasing greenhouse gases."

Figure 9.9 This graph shows events related to climate change, arranged according to IPCC levels of confidence (horizontal axis) and whether events are more local or more global in scale (vertical axis). Global events are those observed worldwide; local events are observed only in particular regions on Earth. In general, events on a global scale can be linked to climate change with more confidence than can local events.



Source: IPCC

Learning Checkpoint

1. Describe computer model predictions of the future climate.
2. What types of mathematical equations are involved in computer models?
3. Why do scientists check that new computer models can reproduce past data?
4. How do scientists think climate would be affected if aerosol pollution was eliminated?
5. What does the IPCC predict for the Great Lakes region?

Political Action on Climate Change

Climate research depends on international co-operation. To do the best possible job, scientists in different countries share climate data along with their tools for collecting and analyzing the data. As well, the IPCC publishes its findings in comprehensive reports that are available to governments, industry, citizens' groups, scientists, and the general public. These reports can help all these groups make more informed decisions on climate change.

However, although our understanding of global energy systems has improved greatly, the challenge now is to encourage government action and ensure international co-operation to reduce the anthropogenic greenhouse effect, the contribution of human activities to greenhouse gas emissions.

United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) is an agreement by 192 of the world's nations to act to stabilize greenhouse gas emissions caused by human activity (Figure 9.10). The founding of the UNFCCC marked the first time that the world community acknowledged that human activities could cause climate change. The objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

In operation since 1992, the UNFCCC enables the process for making international agreements on future actions related to climate change. It organizes meetings to discuss scientific and political action on climate change (Figure 9.11).

Figure 9.10 The United Nations building in New York City

Figure 9.11 A UNFCCC meeting in Poznań, Poland, in December 2008

Figure 9.12 Some young people have summer jobs planting trees in areas where the trees were cut for wood products.

The nations that signed the UNFCCC also agreed that any actions taken to stabilize greenhouse gas emissions must not threaten global food production or the economic interests of any nation and must support sustainable development. **Sustainable development** is the use of the world's resources in ways that maintain these resources for future generations with minimal environmental impact.

For example, to meet the standards of the UNFCCC, the forestry industry in Canada must manage our forests in a manner that ensures that the total amount of forest cover does not decrease. To do this, forestry workers plant tree seedlings on about half the area they harvest, and the industry is working to increase that area (Figure 9.12). Photosynthesis, a carbon sink, removes large quantities of carbon dioxide from the atmosphere. Thus, forests play an important role in stabilizing greenhouse gases. Forests also provide habitat for many wildlife species, offer recreational opportunities for humans, and contribute to the hydrologic cycle. These roles, along with the economic importance of forestry, must all be considered whenever Canada proposes any change to its forestry practices.

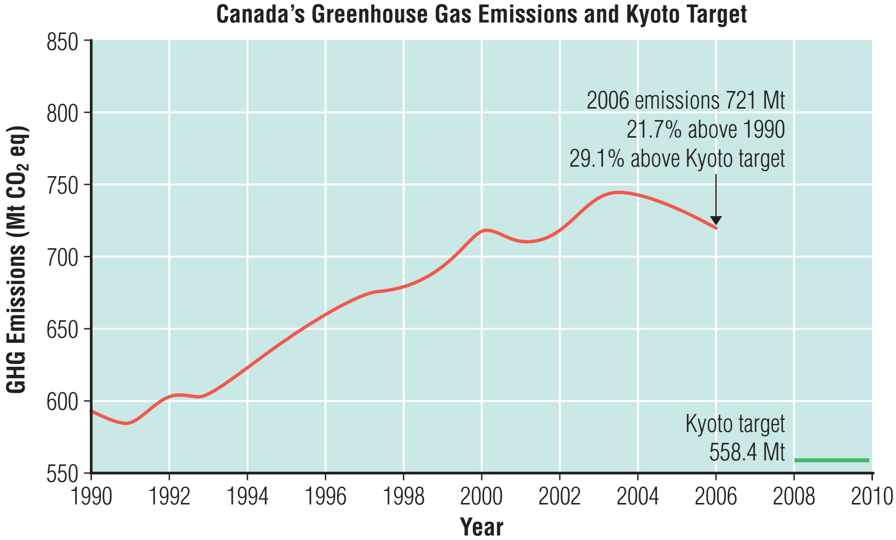
Kyoto Protocol on Climate Change

In Kyoto, Japan, in 1997, Canada and 160 other countries agreed in principle to set a goal of an average of 5 percent reduction in global greenhouse gas emissions by 2012. This UNFCCC agreement is called the **Kyoto Protocol**. The agreement went into effect in February 2005. As of 2008, 183 countries had ratified the protocol.

The Kyoto Protocol is generally seen as an important first step toward a truly global emission reduction regime that will stabilize greenhouse gas emissions. As well, it provides the framework for any future international agreement on climate change. Each country was assigned a target, with developed countries agreeing to higher targets than developing countries. According to the Kyoto Protocol, Canada must reduce its emissions of greenhouse gases to 6 percent below 1990 levels. However, between 1990 and 2006, Canada's emissions increased by about 22 percent. In 2006, Canadians reduced our contribution of greenhouse gases to the atmosphere by 1.9 percent from 2005 and 2.8 percent from 2003 (Figure 9.13).

Emission-Reduction Credits

A key feature of the Kyoto Protocol is a concept called emission-reduction credits, which are credits given to a country for actions that contribute to the global reduction of greenhouse gas emissions. Emission-reduction credits do not mean that there has been a reduction in the emissions of that country. Instead, these credits are awarded for the following actions:



Source: Environment Canada

Figure 9.13 Canadian contributions of greenhouse gases to the atmosphere. Greenhouse gases, which include carbon dioxide, nitrous oxide, and methane, are measured together in megatonnes (Mt) of "CO_2 equivalents." The Kyoto Protocol target is shown at the bottom right.

- A developed country helps a developing country reduce its emissions.
- A developed country helps another developed country to reduce its emissions when it has a temporary economic problem; for example, the country being helped is recovering from a major war or natural disaster.
- A country engages in practices that help to remove carbon dioxide from the atmosphere, such as planting trees to reforest a logged area.

The emission-reduction credit system offers some flexibility in how nations meet their goals, which allows them to make sustainable changes more easily. This system is similar to the purchasing of carbon offsets (also called carbon credits) by individuals. However, some people see the emission-reduction credits as a way for richer nations to avoid having to reduce the amount of greenhouse gases they emit.

Suggested Activity •
C20 Decision-Making Activity on page 346

Economics and the Kyoto Protocol

The Kyoto Protocol involved the signing of the treaty, followed by ratification or acceptance by the government of each country. Many developed regions, such as Canada, the United States, and the European Union, signed the treaty and agreed to the principles of the protocol. However, as of the summer of 2008, the United States had neither ratified nor withdrawn from the protocol. Canada ratified the Kyoto Protocol in 2002. China and India also both ratified the protocol in 2002, but because they are categorized as developing countries, they are initially not committed to reduction targets.

Many critics of the Kyoto Protocol argue that since the United States, one of the largest emitters of greenhouse gases, has not ratified the agreement, the protocol is weakened. However, in July 2008, the leaders of the G8 countries announced that they had agreed to halve greenhouse gas emissions by 2050. This announcement was criticized as ambiguous because the goal was extremely long term and did not set out the steps to be taken in the immediate and short term to reach this goal.

National and Provincial Actions

Although Canada has agreed to the principles of the Kyoto Protocol, many people argue that the plans to meet our targets are insufficient, and we will not be able to meet our Kyoto commitments. One reason for this could be the Alberta oil sands development, where oil is extracted at a high cost in greenhouse gas emissions (Figure 9.14). Figure 9.15 shows a coal-fired electricity generating plant in Ontario, which also emits large amounts of greenhouse gases but is slated to close within the next decade or so. Table 9.2 shows the targets legislated by each province and territory.

Go Green is Ontario's Action Plan on Climate Change. This five-point plan aims to:

- reduce Ontario's greenhouse gas emissions
- improve public transit in the Greater Toronto Area and Hamilton
- encourage the development of jobs related to green technologies
- decrease the use of coal-fired power plants and increase the amount of electricity generated from renewable sources such as wind, sunlight, and falling water
- protect green spaces and agricultural land

Figure 9.15 Nanticoke Generating Station in southwestern Ontario. This generating station burns coal but has installed scrubbers to reduce its emissions of greenhouse gases.

Figure 9.14 The Alberta oil sands development

Table 9.2 Greenhouse Gas Emission Targets by Jurisdiction

Jurisdiction	Target	Announced
Federal	Reduce greenhouse gas emissions to 20%, below to 2006 level by 2020.	2007
Alberta	Reduce emissions by 50% relative to business-as-usual by 2050 or 14% relative to 2005.	2008
British Columbia	Reduce greenhouse gas emissions to 33% below 2007 levels by 2020 and 80% reductions by 2050.	2007
Manitoba	Reduce greenhouse gas emissions to 6% below 1990 levels by 2012; first step is to reduce greenhouse gas emissions to below 2000 levels by 2010 (resulting in more than 3 Mt reduction).	2008
New Brunswick	Reduce greenhouse gas emissions to 10% below 1990 levels by 2020.	2007
Newfoundland and Labrador	Reduce greenhouse gas emissions to 10% below 1990 levels by 2020.	2007
Northwest Territories	Reduce greenhouse gas emissions to 10% below 2001 levels by 2011.	2007
Nova Scotia	Reduce greenhouse gas emissions to 10% below 1990 levels by 2020.	2007
Nunavut	No explicit targets	
Ontario	Reduce greenhouse gas emissions to 15% below 1990 levels by 2020.	2007
Prince Edward Island	Reduce greenhouse gas emissions to 75–85% below 2001 levels by 2050.	2008
Quebec	Reduce greenhouse gas emissions to 6% below 1990 levels by 2012.	2006
Saskatchewan	Reduce greenhouse gas emissions to 32% below 2004 levels by 2020.	2007
Yukon	Reduce greenhouse gas emissions to 25% below 1990 levels by 2010.	2008

Source: Environment Canada, *Turning the Corner: Detailed Emissions and Economic Modelling,* 2008

The goals on the previous page are the plan's general goals. Go Green also includes more specific goals to be met along the way. Many departments in the government work together to try to meet these goals. Ontario also has a Climate Change Secretariat that reports directly to the premier. In 2009, the Ontario Ministry of Education unveiled its "Acting Today, Shaping Tomorrow" policy, which will include environmental education in every grade for students in the province.

During Writing

Thinking Literacy

Analyzing and Evaluating Information

Once you have gathered facts, figures, and details necessary to help you make a judgement or express an opinion, analyze their importance, depth, and relevance to your topic. Organize the information from most significant and relevant to least, then figure out how everything fits together to help you evaluate or judge the impact of a situation.

Take It Further

Climate models are complex and require a lot of computer power to run. Even using supercomputers, each climate model can take many months to run. In 2003, UK climate analyst Myles Allen came up with the idea of enlisting the aid of private citizens and their computers. Find out more about this initiative, and decide if you or your school could help. Begin your research at ***ScienceSource***.

DI Key Activity

C20 *Decision-Making Analysis* Skills Reference 4

SKILLS YOU WILL USE
- Thinking critically and logically
- Using appropriate formats to communicate results

Evaluating the Future Effects of Climate Change

Issue

As our understanding of climate change increases, we must consider the effects of climate change on our future lives. What are the potential effects of climate change on the environment, economy, and society of Ontario?

Background Information

Canada is a member of the G8 group, which means that our country offers a high standard of living to its citizens. Climate change may seem welcome if it means more moderate winters.

However, because climate change is having global physical, environmental, and social effects, it could affect life in Ontario in ways that we do not yet know. A danger is that in times of economic uncertainty, climate-change factors could be ignored. Job losses and other economic difficulties could turn people's attention to what concerns them individually.

A graphic organizer called an Impact Wheel can help you analyze the future impact of climate change. You can create an Impact Wheel on a piece of chart paper, in your notebook, or on the board in your classroom. Follow the directions in the chart in Figure 9.16.

Analyze and Evaluate

1. Review your Impact Wheel. Describe any patterns you observe.
2. State the impact of climate change in Ontario that was the most surprising to you.

Skill Practice

3. Try to be open to many different possibilities when recording your impacts on the climate wheel. What was more difficult for you: organizing the evidence, thinking of the possible effects, or thinking of the impacts?

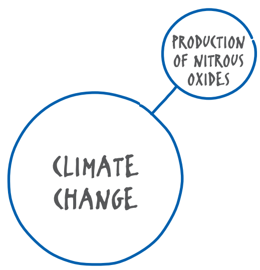
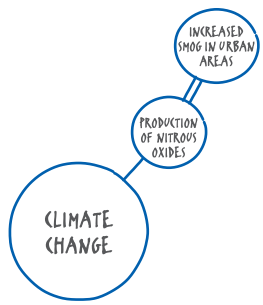
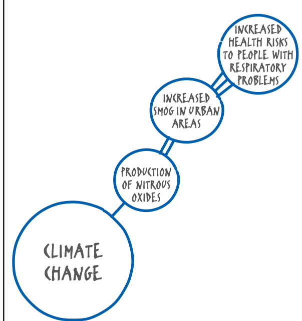
Directions	Example
An Impact Wheel starts with an issue at the centre of the wheel. The issue in this activity is climate change.	
Around the centre of the wheel, list the evidence for climate change. Circle each piece of evidence. Draw a line between each piece of evidence and the centre circle of the wheel, so that each piece of evidence is a spoke on the wheel.	
For each piece of evidence on your chart, list one or more possible effects of that change. Join the possible effect(s) to the piece of evidence with a double line.	
Finally, list the possible impacts on your community or province. Join each of these points with a triple line.	

Figure 9.16 Creating an Impact Wheel

9.1 CHECK and REFLECT

Key Concept Review

1. Explain why research on climate change requires international collaboration.

2. Explain the function of the United Nations Framework Convention on Climate Change. Why was its founding an important step in international action on climate change?

3. Describe the Kyoto Protocol.

4. Explain what emission-reduction credits are, and give an example of how they might be used by Canada.

5. Look at Table 9.1 on page 340 about confidence ratings.
   (a) The highest rating is "virtually certain," > 99 percent true. What types of events in your life would you confidently classify as virtually certain?
   (b) What types of events in your life would you classify as "exceptionally unlikely"?
   (c) Do the same for each of the categories in between.

Connect Your Understanding

6. How do the confidence ratings given to various analyses of data contribute to the discussion about climate change?

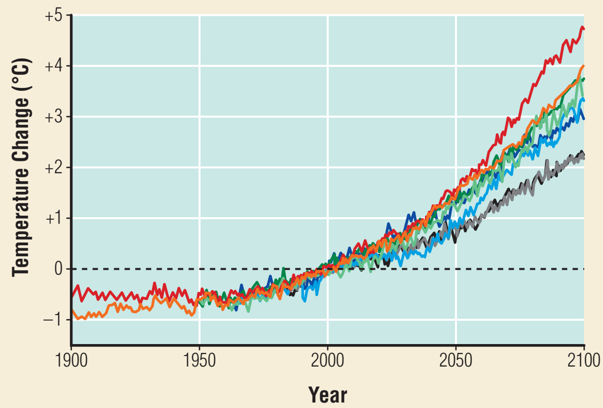
7. Describe the IPCC and its role in climate change research.

8. Explain why there is a general consensus that governments and people need to act with respect to climate change.

9. Study Table 9.2 on page 345, and comment on the reasons you think the different jurisdictions have different targets.

10. Why is it important to consider the role aerosols play in masking the greenhouse effect?

11. This graph shows the predictions of climate models from eight different labs.
    (a) Write a title for this graph.
    (b) Why is it important to consider all the climate models as a group?
    (c) What are the advantages and disadvantages of using computer models to predict the future?



Question 11

12. Why do you think Canada is having difficulty meeting its Kyoto Protocol targets?

13. Do you think the fact that the United States has not ratified the Kyoto Protocol affects the usefulness of the protocol? Explain.

14. What is Ontario's Climate Change Action Plan as outlined in this textbook? Do you think it will be effective? Explain your reasoning.

Reflection

15. What is one thing you learned about political action on climate change that you would like to learn more about?

For more questions, go to ***ScienceSource***.

9.2 Action on Climate Change: Mitigation and Adaptation

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

- We can mitigate climate change by reducing greenhouse gas emissions and sequestering carbon.
- We can adapt to climate change by learning what can happen and planning for those events.
- Each citizen has control over his or her own decisions and has influence over society's actions.

Figure 9.17 Sewage treatment plants remove contaminants from sewage and waste water.

Figure 9.18 Society must reduce the gases that are causing climate change.

Understanding Waste

The burning of fossil fuels can be compared to eating food. When you burn fossil fuels, you produce waste in the form of carbon dioxide emissions. When you eat food, your body produces waste. About 150 years ago, society did not understand that this waste could cause serious health problems. As our understanding increased, we built sewers and sewage treatment plants — a huge amount of infrastructure — to deal with human waste (Figure 9.17).

Now we must deal with another of the wastes from our society — excess greenhouse gas emissions (Figure 9.18). We now know that these emissions cause climate change. We also know that climate change can cause serious human health problems, rising sea levels, food production problems, disrupted wildlife, political and economic turmoil, and severe weather events. As our understanding of climate change increases, we have to learn how to deal with it.

Society will deal with climate change at many levels. International agreements will compel countries to reduce their greenhouse gas emissions. Countries will develop technologies for carbon storage and make plans to build infrastructures to prevent possible damage. Communities will improve their waste handling and encourage citizens to "go green." And individuals can turn off their lights, plant trees, use public transportation (where available), and recycle.

To deal with human waste, society had to learn about personal hygiene and build the infrastructure to deal with it on a large scale. At this time in history, society must learn to deal with greenhouse gas emissions in the same way.

C21 *Quick Lab*

Ounce of Prevention, Pound of Cure

There is an old saying that "An ounce of prevention is worth a pound of cure." An ounce is less than 30 g, while a pound is over 450 g. This saying illustrates that doing little things is often a good strategy. Otherwise, you may end up with a big problem!

For example, if you attended class each day, did your homework regularly, and studied for your tests, you would likely pass your grade 10 science course. If you did not do these things and failed to earn your credit, you would have to repeat the course. In this example, the "ounce of prevention" is what you did to ensure your success. The "pound of cure" is having to repeat the course because you did not earn the credit.

Materials & Equipment

- pencil and paper

Purpose

To relate the saying "An ounce of prevention is worth a pound of cure" to climate change

Procedure

1. Think about the old saying and the example used to illustrate it. Write whether or not you think this old saying is still useful today.
2. Think of another time when you could apply "An ounce of prevention is worth a pound of cure" in life. Write it in a style similar to the example.
3. Think about all the things you have read about climate change — the causes, the impacts, the effects, the efforts to reduce the effects — and write whether or not you think this saying is applicable. Explain.
4. (a) Pair up with a classmate, and take turns listening to each other's answer to step 2.
   (b) How were your examples similar and/or different? Discuss your ideas.
   (c) Repeat for your responses to step 3.

Questions

5. Look at Figures 9.19 and 9.20, and explain how one could be considered an "ounce of prevention" and the other a "pound of cure."
6. Think of at least one other saying you think is applicable to climate change, and explain.

Figure 9.19 Replacing a light bulb

Figure 9.20 The aftermath of a storm

What Can We Do about Climate Change?

Climate change is a huge scientific, economic, societal, and political issue in our world today. We cannot turn back the clock and remove the excess greenhouse gases already in the atmosphere. But we can prevent more greenhouse gases from getting there by reducing or eliminating further greenhouse gas emissions. This will mitigate, or reduce the intensity of the effects of, climate change. **Mitigation** is making something milder or less severe.

Since the vast majority of scientists agree that climate change is, at this point, inevitable, we must also learn how to adapt to its effects, as discussed in Chapter 8. Adaptation in this case means developing procedures and technologies to counteract some of the effects of climate change and to help us live with the effects we cannot control by technology.

In 2007, the IPCC *Synthesis Report: Summary for Policymakers* stated with high confidence that "neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change." The IPCC urged policy-makers around the world to continue all efforts to mitigate the risks of climate change, because these efforts were the best way to minimize the impacts the world is facing now. These recommendations were based on the best computer modelling information possible. Some scientists and environmentalists have even said that the IPCC estimates are conservative.

WORDS MATTER

To sequester something means to put it into seclusion, away from everything else. "Sequester" is derived from the Latin *sequestare*, which means to commit to safekeeping. In chemistry, a sequestered chemical has been bound to another chemical so that it is no longer active.

Mitigation of Greenhouse Gas Emissions

There are two main ways to reduce greenhouse gas emissions to the atmosphere.

- Society must reduce its overall energy use and find new ways to produce and store energy that do not involve fossil fuels.
- Greenhouse gases generated by industries must be removed from waste products and converted chemically to a non-gaseous product, or **sequestered**, which means stored permanently.

Both methods will reduce the **carbon footprint**, which is the total amount of greenhouse gas emissions caused directly and indirectly by an individual, community, industry, or country. Many current initiatives are based on this idea. ENERGY STAR is an international symbol that shows consumers that a product, such as a clothes washer or a window, has met certain standards for energy efficiency. Ontario's Drive Clean program requires drivers to take their automobiles for regular emissions testing. If the minimum requirements are not met, the owner of the car must have the car repaired until it meets the standards.

Since the early grades, you have probably learned in science classes to reduce your energy use — turn off lights and other electrical equipment when you are not using them, use rechargeable batteries, and recycle glass, paper, and metals (Figure 9.21). There are many reasons to do this, but the main one is to reduce the greenhouse gas emissions that are produced when energy is generated. People need to reduce their use of the two main sources of greenhouse gas emissions: electricity use and burning fossil fuels.

Figure 9.21 A CBC promotion encouraged many people to save energy and report their saving to a website.

Reducing Greenhouse Gas Emissions by Reducing Electricity Use

Most of us are unaware of how much we rely on electricity. It lights our homes, runs transit systems such as subways and elevators, and cooks our food. Our computers even help us think. To meet our current energy needs, some of our electricity is generated by burning coal. If industries and individuals demanded less electricity, less coal would need to be burned, and less carbon dioxide would escape into the air.

Engineers and inventors are busy designing many different "energy efficient" items — appliances, water heaters, light bulbs, air conditioners — that use less electricity. The residents of a city in Texas bought so many energy efficient appliances that they substantially reduced their overall demand for electricity. As a result, the local electricity company did not need to build another generating station, and thus less greenhouse gas was emitted. If each Ontarian reduced his or her electricity needs, a greater proportion of the electricity generated could come from sources that do not emit greenhouse gases, such as those illustrated in "Science Everywhere" on page 331.

Many of our day-to-day activities do not require electricity; they could be accomplished without electricity if done differently. Fifty years ago, few toys had batteries, but children enjoyed playing with them just as much as today. People hung their laundry outside to dry, using free solar and wind energy instead of electricity (Figure 9.22).

Figure 9.22 Clothes dry quickly in the wind and sunshine, and people say they smell better!

Also, many of the ways we now heat and cool our homes use more energy than in the past. In summers past, instead of buying an air conditioner, people used fans and opened their windows. Now, people insulate older buildings to keep them cooler in the summer, and save money on their electricity bill. Government campaigns suggest that businesses and apartment owners use less air conditioning, allowing the buildings to stay a little warmer. In some workplaces, the air conditioning has been set so low that some employees bring sweaters to wear at work in the summertime! A simple change in lifestyle — setting the air conditioner even two degrees higher in the summer — means that less electricity needs to be generated. And the sooner we all use less electricity, the sooner the coal-fired generating stations can be closed.

Figure 9.23 Some home owners install a small solar panel of solar cells such as this one to generate enough electricity for their own home.

Renewable Electricity Generation

Renewable electrical energy is generated in several different ways, using wind, sunlight, falling water, and ocean tides (Figure 9.23). None of these emits greenhouse gases while generating electricity. In 2009, Ontario proposed to build several wind farms offshore on the Great Lakes. The wind farm near Shelburne, Ontario, has 45 turbines, each of which produces 1.5 MW (megawatts), enough energy to power 400 homes. Compared with generating electricity from fossil fuels, one turbine alone prevents the release of 4000 tonnes of greenhouse gas into the atmosphere, equivalent to the emissions from 850 cars. However, like most climate change mitigation efforts, wind farms have their critics: some people find them noisy and unsightly.

Scientists and technologists are also working on ways to store energy in efficient and cheap batteries. For example, electricity is generated 24 hours a day, but is used mainly between 6:00 a.m. and midnight. Since the demand is not as high overnight, the excess could be stored in efficient batteries to supplement the supply during the day. Another example is batteries for electric cars. Batteries today do not hold enough power for a long journey in an electric car.

Figure 9.24 Traffic jams produce a lot of greenhouse gas emissions because the car engines still run even though the cars are stopped. Stopping an electric car stops the engine running and therefore saves energy and reduces emissions.

Reducing Greenhouse Gas Emissions by Reducing Fossil Fuel Consumption

We use fossil fuels mainly to heat our homes and for transportation (Figure 9.24). Taking public transportation (where available), car pooling, and purchasing locally made and grown items (that require less tranportation) reduce the amount of fossil fuels used per person. Walking and bicycling use no fossil fuels at all! Each time you choose to walk or bicycle, you are reducing your carbon footprint.

Car companies are producing more fuel-efficient vehicles, as well as "hybrid" vehicles that run on both gas and electricity. Electrically powered cars will soon be available, mainly for city use. These cars produce no emissions, but they do use electricity when they are being charged. Inventors are also designing hydrogen- and solar-powered cars.

To reduce the amount of fossil fuels needed to heat buildings, the buildings themselves need to be energy efficient — built in a way to ensure minimum energy loss. If you kept all your windows open during the winter months, the heated air would escape. Heating your home would require more fossil fuel use and produce more greenhouse gas emissions. Some older homes have leaky windows and little or no insulation in the walls or ceiling, which is just like leaving windows open. The Ontario government is encouraging homeowners to make their homes more energy efficient by offering home energy audits and home retrofit rebates. Each improvement results in less wasted energy.

Sequestering Carbon Dioxide

Nature removes carbon dioxide from the atmosphere and stores it in plants, soil, and the oceans, both in algae and dissolved in the water itself. These natural methods of carbon sequestration are being used to their limit due to the effects of climate change and the ever-increasing levels of greenhouse gas emissions. Humans are now looking at alternative methods of sequestering carbon dioxide.

Some scientists are studying the carbon-sequestering potential of natural systems in order to understand it better. The information could help them invent new technologies or processes to increase the efficiency of these systems.

Other scientists are researching ways to capture the carbon dioxide released by large sources, such as power generating stations and oil refineries. The idea is to store carbon dioxide in geologic formations deep underground, possibly in oil and gas reservoirs that have been used up. But capturing and storing carbon dioxide would take a lot of energy, and the long-term effects are unknown. There is also a risk of leakage.

During Writing

Thinking Literacy

Expressing an Informed Opinion

When you have researched and then carefully chosen your information for writing, you will be ready to express an informed opinion. Think about the topic and the direction that your research has indicated. Form a thesis statement by combining the topic with your informed point of view. Organize your researched evidence to support your thesis statement.

Carbon Offsets, Emissions Trading, and Carbon Taxes

Several non-technological solutions are also being implemented to reduce greenhouse gas emissions. Individuals can purchase **carbon offsets** to reduce their personal carbon footprints. Carbon offsets allow people to compensate for their greenhouse gas emissions by contributing money to improve a carbon sink (Figure 9.25). For example, the National Hockey League teams purchase carbon offsets each time they travel by air. The money is used for a variety of activities, such as developing renewable energy sources and replanting forests.

Suggested Activity
C23 Decision-Making Activity on page 358

Governments are legislating the reduction of greenhouse gas emissions. For example, a government may decide on the maximum amount of carbon dioxide that each company can emit. If a company reduces its emissions by more than the government limit, it can trade this “extra” amount to other companies that have exceeded their maximums. This idea is known as “cap and trade” or **emissions trading**.

A **carbon tax** is a charge to an individual or company for creating greenhouse gas emissions. It is considered a tax on pollution. The government collects the taxes and may use the proceeds to reduce other taxes or to help mitigate pollution or climate change. However, some governments believe that paying higher prices for goods or services that cause greenhouse gas emissions would harm the economy. In 2008, the British Columbia government instituted a carbon tax on gasoline, propane, coal, and home heating oil. At the same time, the

Figure 9.25 The funds raised from carbon offsets can be used to maintain carbon sinks such as this forest.

government reduced other taxes so the carbon tax is revenue neutral. This means that the government will not earn any additional money from this new tax because of the reductions in the other taxes. Carbon taxes are not usually popular among the general public. However, many experts believe that serious reductions in greenhouse gas emissions will not happen unless people have to pay a significant carbon tax.

Adapting to the Effects of Climate Change

People have to manage the impacts of weather- and climate-related events, such as bad storms and drought. Municipalities that experience frequent hurricanes have stronger building codes, to make buildings able to withstand a moderate hurricane. People have developed irrigation systems for occasional droughts and moved away from areas that receive frequent droughts (Figure 9.26). These actions are adaptations to often-experienced events. To reduce the impacts of climate change, however, we need to develop more adaptation methods and technologies.

Learning Checkpoint

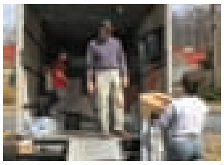
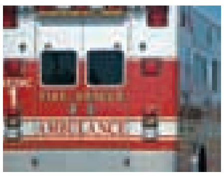
1. Why must society reduce its overall energy use?
2. What happens when a lot of people buy energy-efficient appliances?
3. Could drying your clothes without using electricity affect climate change? Explain.
4. Why is energy demand lower at night?
5. Where are scientists considering sequestering carbon dioxide?

Figure 9.26 Irrigation sprinkler systems have been used on farms for many years. Before sprinklers were invented, farmers dug trenches between the rows and ran water down the trenches.

Adaptive Capacity

While our provincial and federal governments, along with other governments around the world, struggle with how to meet Kyoto Protocol targets, the IPCC issued its most recent report, entitled *Climate Change 2007*. In its *Synthesis Report: Summary for Policymakers*, the panel summarized the projected impacts for policymakers and stressed the need for adaptation to climate change. The report outlines adaptation strategies, which involve all aspects of society working together (Table 9.3). However, the panel acknowleges, "Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies." In other words, many of the developing countries cannot afford some of the adaptation strategies on their own. They will need assistance from other countries.

Table 9.3 IPCC Strategies for Adaptation to Climate Change Impacts

Sector of Society	Adaptation Options or Strategies	Government Policies	Possible Difficulties and Opportunities in Implementation
Water 	• harvesting rainwater • water storage • water re-use • efficient water use and irrigation	• water resources management • water-related hazards management	Difficulties: • expense • human resources • physical barriers
Agriculture 	• adjust planting dates • adjust crop variety • erosion control • soil protection through tree planting	• training • crop insurance • financial incentives (e.g., subsidies and tax credits)	Difficulties: • access to new varieties and markets Opportunities: • longer growing season in higher latitudes • revenues from "new" products
Communities in coastal zones 	• relocating people • seawalls and storm surge barriers • creation of marshlands/ wetlands as a buffer against sea-level rise and flooding	• land-use policies • building codes • insurance	Difficulties: • financial barriers • technological development time • availability of relocation space
Human health 	• action plans for health during heat waves • emergency medical services • improved climate-sensitive disease control • maintenance of safe drinking water	• public health policies that recognize climate risk • strengthened health services • regional and international co-operation	Difficulties: • vulnerable populations • financial capacity Opportunities: • upgraded health services • improved quality of life
Tourism 	• diversification of tourism attractions and revenues • shifting ski slopes to higher altitudes • artificial snow-making	• integrated planning with other sectors • financial incentives (e.g., subsidies and tax credits)	Difficulties: • financial challenges • potential adverse impacts (e.g., artificial snow-making may increase energy use) Opportunities: • revenues from new attractions
Transport 	• design standards and planning for roads, rail, and other infrastructure to cope with warming and drainage problems • encouraging people to use public transport and to buy locally	• integrating climate change considerations into national transport policy • investment in research and development for special situations (e.g., permafrost areas)	Difficulties: • financial and technological barriers • availability of less vulnerable routes Opportunities: • improved technologies and integration with key sectors (e.g., energy)
Electrical energy 	• use of renewable sources • strengthen transmission and distribution infrastructure • energy efficiency • reduced dependence on single sources of energy	• national energy policies and financial incentives to encourage use of alternative sources • incorporating climate change in design standards	Difficulties: • access to viable alternatives • financial barriers • acceptance of new technologies Opportunities: • stimulation of new technologies • use of local resources

Source: International Panel on Climate Change

The IPCC clearly points out that it is imperative to act now in order to deal with not only the potential future impacts of climate change but also the impacts that are already inevitable. The technologies to mitigate or adapt to these impacts either already exist or are being developed. Right now, renewable energy sources, for example, contribute only a small proportion of the world's energy needs. The world as a whole and every individual must reduce overall energy use and rebalance the use of resources worldwide.

According to Natural Resources Canada, "Adaptive capacity refers to the capabilities of a region, community, or group to implement effective adaptation actions. In Canada this capacity is generally high, owing to high levels of education, access to technology, and strong and effective institutions. As a result, Canada is well positioned to take action on adapting to climate change. However, there are significant differences in the ability to adapt among different sub-regions and population groups, resulting in different vulnerabilities to climate change." Even though Canada has a high adaptive capacity, we will still be affected by climate change.

Imbalance of Resource Use among Countries

It is crucial for governments to address climate change, but they are also struggling to balance economic, social, and other environmental goals. While the developed countries are responsible for the greatest amounts of greenhouse gas emissions, there is a concern that China and India — two developing countries with very large populations — are in a period of economic and social growth that the developed countries have already experienced (Figure 9.27). Economic growth is linked to increased production of greenhouse gases.

Figure 9.27 With its large population and strong economic growth, India may experience a rapid increase in greenhouse gas emissions.

Table 9.4 illustrates this concern. Oil is consumed to power cars, electricity-generating stations, and industry and is converted into plastics. Table 9.4 shows the amount of oil used per capita (per person) in several countries. Imagine the impact if the per-capita consumption statistics of China and India even started to approach that of Mexico.

Table 9.4 Per Capita Oil Consumption Per Year in Selected Countries

Country	Population (millions)	Per Capita Oil Use Per Year (Barrels)
United States	305.9	25
Canada	33.6	25
Mexico	106.7	7
China	1336.0	2
India	1144.8	1

Developed countries cannot continue to use so much more of the world's resources than developing countries. The developed countries have a social responsibility to reduce their own impact on Earth while helping developing countries raise their standards of living. There are a number of things we must do, all at the same time. These include learning more about the science of climate change and developing the technology that will help us mitigate it and adapt to it. We must also address the social and economic inequalities that exist both locally and globally. In this way, we can work together to protect Earth, our biosphere.

Personal Responsibility

In this unit, we have considered the science of climate change, the impacts of climate change on society and the environment, ways to mitigate climate change, and ways to adapt to climate change. Now we turn to the issue of personal responsibility.

The large issues societies face always come down to the choices that individuals make in their daily lives. Each decision we make can place an environmental burden on Earth or help lift that burden. Some of these decisions are obvious, such as driving fuel-efficient vehicles, but others are more subtle, such as which fruit to eat in February — fresh strawberries flown in from Peru or an Ontario apple picked in September and stored. When we leave most of the major decisions to governments and industries, we must remember that these large organizations are made up of people. In Canada, we, the consumers and voters, can make a difference.

Take It Further

While the decisions each person makes in his or her daily life are incredibly important in addressing climate change, many individuals go beyond their own lives to educate and persuade others. These individuals span all walks of life, ages, and nationalities. Their efforts may be local, national, or international. Research prominent individuals in the climate change field, and prepare a summary of the achievements of the one you find most inspiring. Begin your research at ***ScienceSource***.

Suggested STSE Activity
C24 Decision-Making Analysis Case Study on page 359

C22 STSE *Science, Technology, Society, and the Environment*

Fast Fashion: A Growing Concern

In Canada's early years, many couples celebrated their weddings in the best clothes they owned. If they did buy new outfits, they wore them again for other special occasions. It wasn't unusual for a person's entire wardrobe to fit into one small suitcase.

Currently, the trend is "fast fashion": clothes that are made to be fashionable but not to last. Perhaps sparkly purple shirts are the rage this season. No problem — a large manufacturer produces them very cheaply so everyone can get one, wear it for the season, and then discard it, because next year, fluorescent orange shirts will be fashionable.

This trend has very high environmental costs: greenhouse gas emissions to manufacture and transport the clothes, as well as the landfill space when you discard them.

1. If you had to pack your entire wardrobe (for a whole year) into one small suitcase, what would you include?
2. After you have made your choices, think about why you didn't include the rest of your wardrobe. Reflect upon how this exercise might affect any of your future buying decisions.

DI Key Activity

C23 Decision-Making Analysis

Skills Reference 4

SKILLS YOU WILL USE
- Thinking critically and logically
- Using appropriate formats to communicate results

Purchasing Carbon Offsets

Issue

Many everyday activities cause greenhouse gas emissions. However, many people find that while they can cut down on certain activities such as air travel, car travel, and home heating, they cannot completely eliminate these activities from their lives (Figure 9.28). Many have adopted the idea that since they are contributing to carbon sources, they should also contribute to carbon sinks in order to compensate for their greenhouse gas emissions.

Background Information

Websites have been set up where people can calculate the carbon emissions caused by everyday activities. They can then purchase carbon offsets to make up for them. The carbon offsets are usually donations to tree planting and renewable energy projects. Some people, such as the noted environmentalist David Suzuki, strongly advocate these programs. Others criticize these programs as a way for wealthier individuals to continue indulgent lifestyles without feeling guilty.

Analyze and Evaluate

1. Go to ***ScienceSource***, and research the system of purchasing carbon offsets.

2. Create a T-chart summarizing the pros and cons you discover in your research.

3. Write down what you think about the idea of purchasing carbon offsets as a way to combat climate change or to compensate for your carbon emissions. Back up your opinion with supporting evidence from your research.

4. Discuss your opinion and supporting evidence with a classmate.

5. Revisit your opinion. Make note of any changes in your opinion that were influenced by your discussion.

6. **Web 2.0** Develop your message as a Wiki, a presentation, a video, or a podcast. For support, go to ***ScienceSource***.

Skill Practice

7. Imagine that you are asked to write a small piece on this topic for your school newspaper. What would you write?

Figure 9.28 Many people travel by airplane for pleasure or for work.

CASE STUDY

C24 STSE **Decision-Making Analysis** Skills Reference 4

SKILLS YOU WILL USE

- Identifying issues to explore
- Justifying conclusions

Transportation Decisions

Issue

Transportation is an important issue in today's society. People travel from one place to another to go to school or work, to run errands, and for leisure. North Americans rely on private automobiles much more than people in European countries do. As a result, large urban centres experience traffic congestion, poor air quality, and increased greenhouse gas emissions.

There are many options for transportation. Some people walk, ride a bicycle or a motorcycle, take a taxi, or carpool to get to their destinations. These decisions depend on where you live, where you are travelling to, how quickly you need to get there, and how many people need to go.

If you decide you need a private car, you still have more choices to make; for example, the size and type of car and whether it is new or used.

Background Information

You have many choices, and each has advantages and disadvantages. Conventional cars burn fossil fuels; larger cars tend to be less fuel efficient. Smaller cars are more fuel efficent but tend to hold fewer occupants — some hold only two with no back seat (Figure 9.29). This may be a problem if you are transporting more than two people.

Hybrid vehicles possess a conventional fossil-fuel-burning engine along with a rechargeable energy storage system to improve fuel economy. Hybrid vehicles tend to be more costly than equivalent conventional cars but can save money during operation. A biofuel vehicle uses fuel produced from recently grown plant material such as sugar cane. The car still releases carbon dioxide, but growing another crop of biofuel plants results in a smaller increase of carbon in the atmosphere. This fuel is not a "fossil" fuel. However, biofuels are not widely distributed, and using land to grow fuel instead of food is very controversial.

Analyze and Evaluate

1. To make an informed decision, research each type of vehicle and come up with three to five positive and negative points for each one.
2. Make a chart like the one in Table 9.5 to summarize the positive and negative aspects of each type of vehicle.
3. Estimate a negative and a positive score out of 10 for each car.
4. According to your research, which type of car has the most negative points? Which type of car has the most positive points?
5. **Web 2.0** Develop your decision as a Wiki, a presentation, a video, or a podcast. For support, go to ***ScienceSource***.

Skill Practice

6. After exploring this issue, identify another issue you would like to explore that is related to transportation and its impact on the environment.

Figure 9.29 This car is fuel-efficient but carries only two people.

Table 9.5 Positive and Negative Aspects of Vehicles

Type of Vehicle	Positive Points	Positive Score /10	Negative Points	Negative Score /10
Conventional large				
Conventional small				
Hybrid				
Biofuel				

9.2 CHECK and REFLECT

Key Concept Review

1. Identify at least three human activities that add greenhouse gases to the environment.
2. Define the terms "mitigation" and "adaptation" as used by the IPCC.
3. What are two ways to reduce greenhouse gas emissions to the atmosphere?
4. List three different ways to generate renewable energy. Why is it called "renewable"?

Connect Your Understanding

5. Describe two choices you could make to reduce your contribution to greenhouse gas emissions.
6. Refer to the story on page 348. How can greenhouse gas emissions be compared to sewage? Explain how this is an effective comparison and in what way it is not effective.
7. (a) How does reducing electricity use decrease greenhouse gas emissions?
   (b) How does reducing fossil fuel use decrease greenhouse gas emissions?
   (c) How are reducing electricity use and reducing fossil fuel use related?
8. Describe some possible benefits and some possible risks associated with sequestering carbon dioxide.
9. How have humans adapted to hurricanes? droughts?
10. Describe each of the following terms, and give one example of each. Then, choose one of the terms and write a persuasive paragraph explaining why it is important.
    (a) carbon offsets
    (b) emissions trading
    (c) carbon tax
11. How will climate change test the human ability to adapt?
12. Use Table 9.3 (page 355) to answer the following.
    (a) What adaptations can be made to deal with water?
    (b) What government policies will help with agricultural issues?
    (c) Pick one of the other sectors, and write a paragraph about the planned adaptation for that sector.
13. Look at the information in Table 9.4 (page 356).
    (a) Reproduce the chart in your notebook, and add a fourth column called "Total Oil Use (Barrels)."
    (b) Fill in the fourth column by multiplying the per capita oil use by the population.
    (c) Study column 4 and make a statement about the data.
    (d) Which is more useful for a reader, oil use per capita or total oil use?
14. Climate change has been described as an international problem that requires an international solution. Think about this statement and the photograph below, and record your thoughts in a persuasive paragraph.

Question 14

Reflection

15. What are your own responsibilities to help the world adapt to climate change?
16. For what activities in your life would you consider buying carbon offsets?

For more questions, go to ***ScienceSource***.

Jay Ingram is an experienced science journalist, author of *The Daily Planet Book of Cool Ideas*, and host of *Daily Planet* on Discovery Channel Canada.

Human Volcano

The solution to global warming should be simple: just reduce the amount of carbon dioxide we release into the atmosphere. But so far, we've been unable to do that, and there are worrying signs that we are getting close to some sort of climatic disaster. So what can we do?

Many climatologists think this desperate situation calls for desperate measures. They argue that we might need to deploy technological fixes — on a global scale — to prevent irreparable damage. But those fixes would come with significant risks.

One example is the "human volcano." "Volcano" because natural erupting volcanos spew huge amounts of sulphates high into the atmosphere (Figure 9.30). These intercept sunlight and help cool Earth for as much as a year before they gradually fall to Earth. "Human" because we could do the same thing ourselves.

If we could transport huge amounts of sulphates into the atmosphere, and keep doing it, we could prevent global temperatures from rising. It's not yet clear exactly how we'd do that — by helium balloons with fire hoses attached, or aircraft, or rockets (Figure 9.31). It's a significant engineering challenge, but some think that challenge can be solved.

Figure 9.30 Real volcanoes spew sulphates into the atmosphere, but humans cannot control the amount or the timing.

Figure 9.31 Rockets could be used to transport chemicals into the atmosphere.

But huge amounts of sulphates in the atmosphere would create other issues. For instance, if we start putting sulphates up there while carbon dioxide continues to rise, we cannot afford to stop, otherwise global temperatures will shoot up. For that reason, most scientists only want to set the human volcano in motion if we are already reducing greenhouse gas emissions and keep doing so.

There's another good reason for doing both: if people thought the problem had been "fixed," they might lose their incentive to do anything about carbon dioxide emissions. And there are other questions. What unpredicted effects might this plan cause? And while it might hold temperatures steady, the oceans will continue to become more acidic, which can harm ocean life. But as chancy as the human volcano sounds, it's now one of our options.

Question

1. What other ideas like the human volcano have you heard about in the media? Outline the risks associated with using one of these ideas.

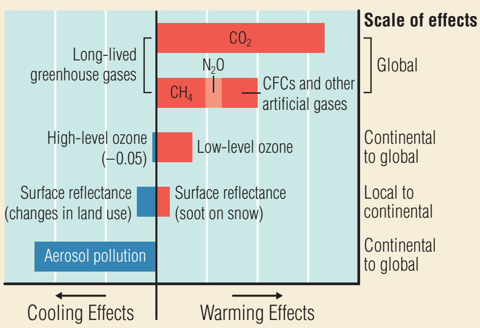
9 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

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

Key Concept Review

1. (a) What is a computer model? k
   (b) What are some advantages and disadvantages of computer models? k
2. How do computers help scientists understand Earth's climate system? k
3. What is the value of confidence ratings with respect to climate change events? k
4. (a) Describe the United Nations Framework Convention on Climate Change (UNFCCC).
   (b) What is the Kyoto Protocol, and how is it related to the UNFCCC? k
   (c) Describe the emission-reduction credit system. k
   (d) Has Canada ratified the Kyoto Protocol and is it living up to its Kyoto targets? k
5. Why is government action necessary to combat climate change? k
6. (a) Define sustainable development. k
   (b) Why is it important that nations practice sustainable development? k
7. Write a title for the graph below, and state which causes of climate change have: k
   (a) a net warming effect
   (b) a net cooling effect



Question 7

8. How has computer modelling influenced political action on climate change? a
9. (a) Define the terms adaptation and mitigation, as related to climate change. k
   (b) Give two examples of mitigation methods. k
10. Use Table 9.3 on page 355 to answer the following. k
    (a) List four adaptation strategies in the water sector.
    (b) What types of government policies could be implemented in coastal communities?
    (c) What opportunities or difficulties might the tourism sector face when implementing adaptations?
11. Use the information in this chapter to create a timeline of the international efforts Canada has been involved in with respect to climate change. k

Connect Your Understanding

12. Why is it significant that even conservative estimates indicate that Earth's climate is changing? a
13. Why did the United States not ratify the Kyoto Protocol? t
14. Explain why developed and developing countries are treated differently in the Kyoto Protocol. t
15. List the five points in Ontario's Action Plan on Climate Change, and comment on the one you think is most important. t
16. Distinguish between the use of carbon offsets and carbon taxes. t
17. How can emissions trading help some countries meet their Kyoto targets? t

18. Describe the research into carbon sequestering methods. t

19. Compare the ways large industries contribute to emissions with the ways individual choices contribute to emissions. a

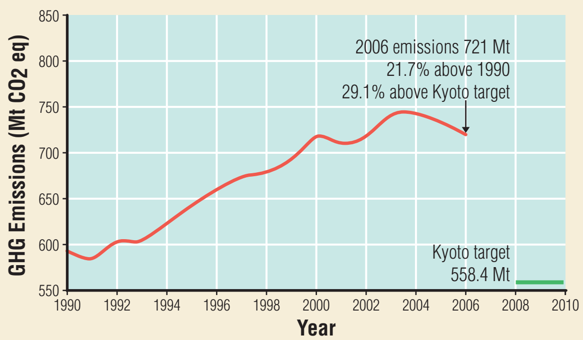
20. Why do you think governments are struggling with their Kyoto commitments? t

21. While it is vitally important to reduce greenhouse gas emissions, it is also important to adapt to the climate change that has already occurred and will occur because of emissions already released. Describe some adaptations you have read about, and imagine others you think still need to be developed. a

22. Explain why there is a general consensus that governments and people need to act now with respect to climate change. a

23. Why is it important to consider climate change when discussing issues of lifestyle? a

24. Create a title for the graph below. Then, write a statement comparing the pattern of Canada's greenhouse gas emissions with its Kyoto target. Based on this, do you think it likely that Canada will meet its Kyoto target? t



Question 24

25. A large amount of evidence supports the idea that human activity is causing climate change. However, action on reducing greenhouse gas emissions has been slow to come. Why do you think this is? a

26. Summarize Canada's national response to climate change to date, and comment on whether you think this is sufficient. t

27. Summarize Ontario's response to climate change to date, and comment on whether you think this is sufficient. t

Reflection

28. Canada signed the Kyoto Protocol, but we appear to have run into difficulty meeting our Kyoto targets. Write a letter to your local MPP and/or MP outlining why you think this is and what should be done about it. How did you decide whether to write to your federal or provincial member of parliament? c

After Writing

Thinking Literacy

Reflect and Evaluate

Review the "Before" and "During" writing strategies in this chapter. Create a flowchart to summarize the steps in the writing process indicated in those strategies. Put a check mark beside the steps that helped you with your case study about transportation decisions. Compare your results with a partner.

Unit Task Link

As you research for your unit task, consider government policy that has been enacted in the last 12 to 18 months. Have federal and provincial governments responded to the evidence presented by scientists? Have they enacted laws to reduce greenhouse gas emissions? What programs are being developed to adapt to climate change?

Home Quit

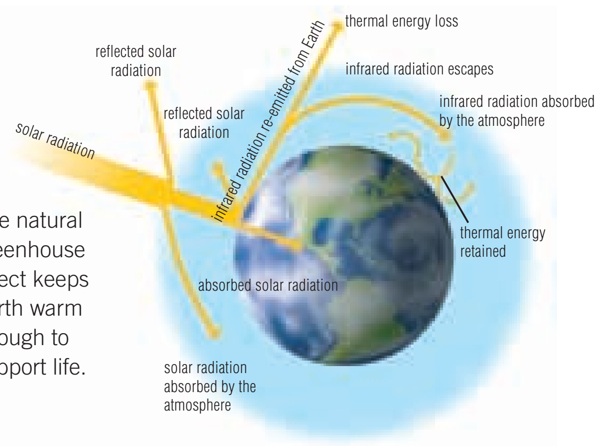
UNIT C Summary

KEY CONCEPTS	CHAPTER SUMMARY
7 Earth's climate system is a result of interactions among its components.	
• Climate • The natural greenhouse effect • Heat transfer	• Climate is weather averaged over many years. (7.1) • Climate affects the life of all organisms. (7.1) • The Sun is the source of all energy on Earth. (7.1) • Earth's biosphere is composed of different layers. (7.1) • Earth's natural greenhouse has kept Earth at a habitable temperature for millions of years. (7.2) • Thermal energy transfer can occur by conduction, convection, and radiation. (7.3)
8 Earth's climate system is influenced by human activity.	
• Anthropogenic greenhouse effect • Effects of climate change • Evidence of climate change	• Greenhouse gas concentrations in the atmosphere are increasing. (8.1) • Human activity is adding anthropogenic greenhouse gases to the atmosphere. (8.1) • Changes in greenhouse gas levels are changing Earth's climate. (8.1) • Physical effects of climate change include melting Arctic and Antarctic ice, more severe weather events, increasing global average temperatures, and changing ranges for organisms. (8.2) • Some climate change effects can trigger feedback loops that produce worse conditions. (8.3)
9 Local, national, and international governments are taking action on climate change.	
• IPCC and international legislation • Mitigation • Adaptation	• Future climate change is being predicted by computer climate models. (9.1) • International organizations are working to control climate change. (9.1) • Climate change effects may be mitigated by reducing greenhouse gas emissions. This can be done by reducing energy use, finding new ways to produce and store energy, and sequestering excess carbon. (9.2) • All levels of society, from individual to international, must learn to adapt to climate change effects. (9.2)

VOCABULARY

- albedo (p. 278)
- atmosphere (p. 265)
- biome (p. 268)
- biosphere (p. 264)
- climate (p. 262)
- conduction (p. 279)
- convection (p. 280)
- Coriolis effect (p. 281)
- greenhouse gases (p. 276)
- hydrosphere (p. 267)
- insolation (p. 276)
- lithosphere (p. 266)
- natural greenhouse effect (p. 276)
- net radiation budget (p. 277)
- radiation (p. 279)
- solar radiation (p. 264)
- thermal energy (p. 264)
- weather (p. 262)
- wind (p. 281)

KEY VISUALS



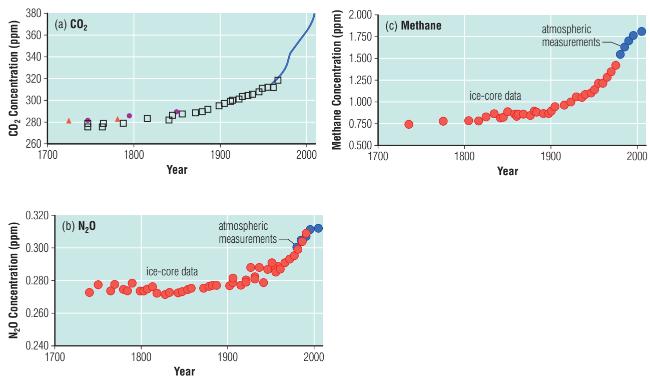
The natural greenhouse effect keeps Earth warm enough to support life.

VOCABULARY

- anthropogenic greenhouse effect (p. 300)
- carbon sink (p. 302)
- carbon source (p. 301)
- climate change (p. 303)
- economic system (p. 322)
- fossil fuels (p. 301)
- global warming (p. 303)
- global warming potential (p. 298)
- persistence (p. 298)
- positive feedback loop (p. 326)
- runaway positive feedback loop (p. 327)
- salinity (p. 314)

KEY VISUALS

Trends in Global Greenhouse Gas Concentrations in the Atmosphere

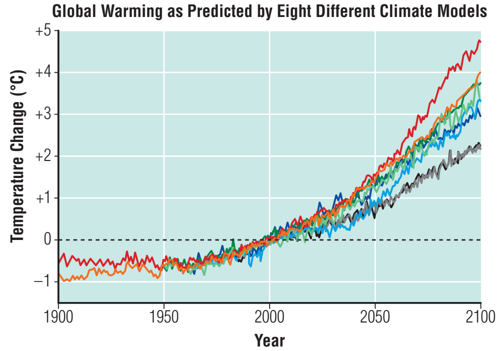


VOCABULARY

- carbon footprint (p. 350)
- carbon offsets (p. 353)
- carbon tax (p. 354)
- confidence level (p. 340)
- emissions trading (p. 354)
- Kyoto Protocol (p. 342)
- mitigation (p. 350)
- sequestered (p. 350)
- sustainable development (p. 342)

KEY VISUALS

Global Warming as Predicted by Eight Different Climate Models



All the computer models show that the climate is warming.

UNIT C Task

Getting Started

One of the exciting things about the science of climate change is that it is a dynamic and evolving field of study. It is also of interest and concern to every person on Earth. However, because a textbook cannot be changed after a certain point in the publishing process, many developments in the field of climate change have probably occurred since this book was published.

A supplement, sometimes called an appendix or addendum, is added to a published book, often because some of the information has changed or new discoveries have been made since the book was written.

Throughout this unit, you are using the textbook as a base for your study of climate change, but you may also be reading recent articles in newspapers and on the Internet. You may see magazines reporting on new discoveries or watch TV programs that give up-to-the-minute information or show recent events related to climate change. These reports, articles, and TV programs can be good material for a supplement that will be useful to next year's grade 10 class.

The Thames Barrier was built in 1982 to stop storm surges from coming up the Thames River and flooding parts of London, England. The flood gates remain open to allow ships to pass. When a storm surge is predicted, the gates are closed to block the water. If sea levels rise because of climate change, these barriers may not be high enough to prevent flooding in the future.

Your Goal

Review the developments and discoveries in climate change, and any events related to climate change, that have occurred in the last 12 to 18 months, and discuss them with your classmates. You can centre your discussion on why you think certain developments deserve to be added to the supplement that you will prepare. These developments could include the state of the climate when you write the supplement, new research and discoveries, significant events, and efforts and inventions to mitigate or adapt to the effects of climate change.

Criteria for Success

Your supplement is:

- informative, building on the material in the textbook and on supplements written by previous classes
- well illustrated with appropriate and engaging graphs and photographs
- interesting to read
- useful and will help next year's grade 10 class

What You Need to Know

As you review the news stories you have collected, you will realize that, although related, the stories probably fall into several general categories. By grouping the stories into these categories, themes may start to emerge that will help you find a topic for your supplement. Discussing your ideas with your classmates will help you develop your ideas.

Procedure

1. As you work through the unit, collect a portfolio of articles, Web pages, and journals related to climate change. Watch related television programs, and take notes. Tell friends and family you are doing this and that they may help by giving you items they come across.

2. Participate in a class discussion about the developments in climate change over the past 12 to 18 months. Decide on the topics and issues involved in climate change, such as scientific evidence, IPCC activities, government legislation, etc.
3. Group your articles according to topics and issues. Can you see similarities and differences in the ways others have grouped theirs?
4. Form groups of three or four students who are interested in writing a supplement about a similar topic/issue to the one you chose.
5. Discuss the topic/issue in your group. Why do you feel this topic/issue is worthy of a supplement? Make point-form notes during the discussion to help start your writing process. Perhaps others found articles from different sources that can help you with your supplement.
6. As a group, write a supplement on your topic. Write it in the style you think would be most effective to get your points across. You may choose a style consistent with the unit in this book or make up your own. Be sure to illustrate your supplement with appropriate graphs, diagrams, and photographs.

About 30 years ago, opossums were rare in Ontario. Now, they are found throughout southern Ontario.

How Did It Go?

7. By yourself, read a supplement written by another group in your class. Write a short list of strengths and another short list of possible improvements. Give these notes to the group that wrote the supplement.
8. In your group, use the comments from your classmates to make changes to your supplement.
9. Decide how to summarize your supplement. Organize a one-minute, oral, group presentation about your topic/issue and present it to the class.

Assessing Your Work

10. After listening to all the group presentations, write a persuasive paragraph about what you think is the most significant climate change topic or issue to emerge in the past 12 to 18 months.

Have there been any wildfires, droughts, heat waves, or ice storms over the past year?

UNIT C Review

ACHIEVEMENT CHART CATEGORIES

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

Key Terms Review

1. Create a concept map, with the term "climate change" at the centre, that links all the terms in the list below. Use additional words to clarify your understanding. c

albedo
anthropogenic greenhouse effect
atmosphere
biomes
biosphere
carbon footprint
carbon offsets
carbon sink
carbon source
carbon tax
climate
conduction
confidence level
convection
Coriolis effect
economic system
emissions trading
fossil fuels
global warming
greenhouse gases
hydrosphere
insolation
Kyoto Protocol
lithosphere
mitigation
natural greenhouse effect
net radiation budget
persistence
positive feedback loop
potential
radiation
runaway positive feedback loop
salinity
sequestered
solar radiation
sustainable development
thermal energy
weather
wind

Key Concept Review

7 Earth's climate system is a result of interactions among its components.

2. Explain the difference between weather and climate. k

3. Give an example of climate and an example of weather that illustrate the difference between these concepts. k

4. Create a diagram to illustrate how convection transfers heat. c

5. List the layers of Earth's atmosphere, and note one fact about each. k

6. Explain how temperature varies with altitude in Earth's atmosphere. k

7. Describe two examples of the effect of climate on your daily life. k

8. In a sentence, identify the main source of Earth's energy. k

9. Define "thermal energy." k

10. Describe Earth's biosphere. k

11. Describe the interactions of components in Earth's biosphere. k

12. Draw the table below in your notebook. Add a title, and fill in the table. k

Biome	Climate	Wildlife
Tundra		
Boreal forest		
Temperate deciduous forest		
Temperate grassland		
Temperate coniferous forest		
Mountains		

13. Explain why Earth's net radiation budget needs to be in balance. k

14. Draw a diagram showing how thermal energy is transferred in the atmosphere. k

15. Draw a diagram showing how thermal energy is transferred in the hydrosphere. k

16. Make a list of the effects of thermal energy transfer on Earth. k

8 Earth's climate system is influenced by human activity.

17. In a sentence for each, explain how climate change might affect the following: k
    (a) coral reefs
    (b) Pacific salmon
    (c) frogs and toads
    (d) Naumra's jellyfish
    (e) clams and snails

18. Describe how people in Canada and Afganistan affect greenhouse gas emissions. How will the two societies be able to deal with the effects of climate change? k

19. Distinguish between the terms natural greenhouse effect, anthropogenic greenhouse effect, and global warming. k

20. State the name of the international organization that assesses scientific information on climate change. k

21. Give an example of and describe a physical effect of climate change that would affect you in Ontario. k

22. Describe two pieces of evidence that point to the fact that climate change is occurring now. k

23. Draw a table like the one below, and name and describe the physical effects of climate change on Earth. k

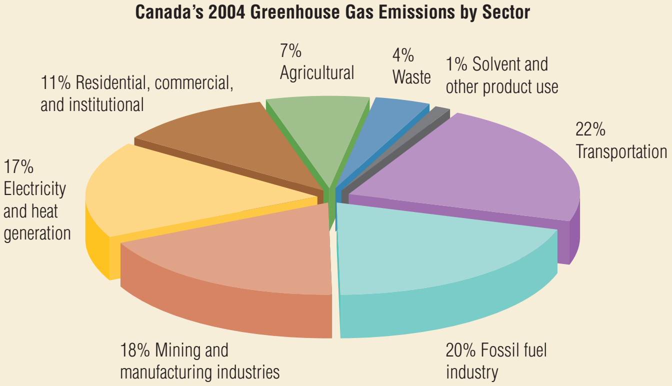
Physical Effects of Climate Change

Physical effect	Description

24. Describe the physical effect of climate change captured in the photograph below. k

Question 24

25. Different economic sectors contribute different amounts to Canada's greenhouse gas emissions. Capture the information in this graph in two to three sentences. a



Question 25

UNIT C Review (continued)

26. Dealing with climate change issues will require changes in thinking as well as changes in behaviour. How do you think these issues affect the amount of evidence individuals need in order to act? *a*

27. Describe the following initiatives: *k*

(a) ENERGY STAR

(b) Ontario's Drive Clean program

28. How does a simple act such as hanging laundry out to dry address climate change? Think of another similar idea you would be willing to try. *k*

29. Explain why developed and developing countries are treated differently in the Kyoto Protocol. *k*

9 Local, national, and international governments are taking action on climate change.

30. Why are the citizens of G8 countries responsible for a disproportionate amount of greenhouse gas emissions? *a*

31. Humans will be affected greatly by the effects of climate change, but so will other organisms. Why are people concerned that some organisms would be negatively affected while others may be positively affected? *a*

32. Why do you think it is important to learn about physical effects of climate change that may not have a direct or severe impact on your own region? *a*

33. How does the idea in the photograph below reflect the climate change issue? *a*

Question 33

34. Why do developing and developed countries differ in their contributions to climate change? *k*

Connect Your Understanding

35. Explain why gases such as carbon dioxide, methane, and nitrous oxide have a greater impact in causing changes to Earth's climate than does water vapour. *t*

36. What is the position of the IPCC on the relationship between the average global temperature increase and greenhouse gas emissions? *t*

37. Thinking in terms of "systems" means that many issues must be considered at the same time in order for true solutions to arise. How does this apply to tackling climate change issues? *t*

38. How has computer modelling influenced public opinion on climate change? *t*

39. A developed country such as Canada has resources to deal with some of the physical effects of climate change. However, other countries have less adaptive capacity to deal with these physical effects. What do you feel are the obligations of developed countries to developing countries in providing technology, assistance, and financial aid to deal with climate-change issues? Think about your response, then share your ideas with a classmate. *c*

40. The physical effects of climate change will affect different parts of Earth in different ways. Pick one of the physical effects, and show how it might affect Canada, then state how it might affect a different part of the world in a different way. *t*

41. Write a persuasive paragraph or create a mind map to explain how the science of climate change is related to both the physical and social impacts of climate change. *c*

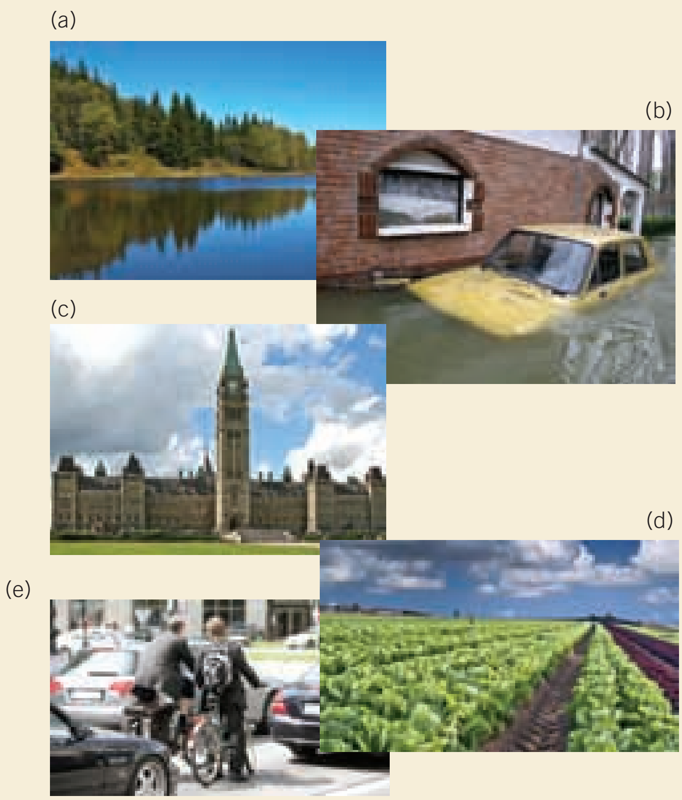
42. How might science and technology play a role in minimizing the societal effects of climate change? *a*

43. Aerosol pollution has a net cooling effect on climate. What are the implications for climate change data as aerosol pollution decreases? ⓣ

44. For each sector below, list an adaptation strategy and describe a possible government policy and some implementation considerations. ⓣ
    (a) water
    (b) agriculture
    (c) human health
    (d) electrical energy

45. Explain why it is important to understand principles of the natural greenhouse effect before studying the anthropogenic greenhouse effect. ⓣ

46. For each photograph below, write a caption that links it to climate, climate change, and/or a regional or global consequence of climate change. ⓣ



Question 46

Skills Practice

47. The towns of Moosonee, Ontario, and Farnborough, England, are located at similar latitudes. Construct a climatograph for both towns, using the data in the tables below. Write a paragraph describing the climates of both towns, and propose reasons for any differences. ⓐ

Average Climate Conditions 1971–2000, of Moosonee, Ontario, Canada, 51°16'N

Month	Average Temperature (°C)	Average Precipitation (mm)
Jan	–20.7	33.9
Feb	–18.4	22.7
Mar	–11.7	31.7
Apr	–2.4	39.0
May	6.2	53.7
June	11.9	71.1
July	15.4	101.3
Aug	14.4	75.8
Sept	9.4	90.0
Oct	3.4	73.3
Nov	–4.7	54.3
Dec	–16.3	34.7

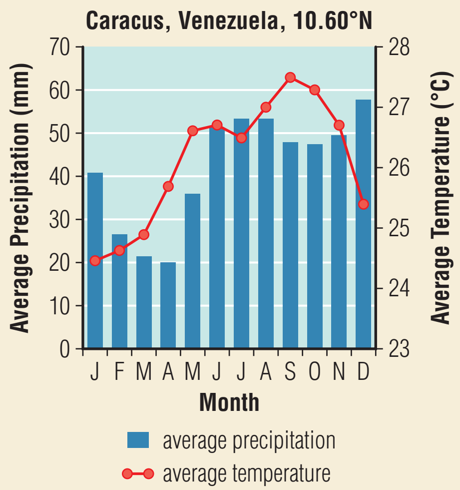
Average Climate Conditions, 1971–2000, of Farnborough, England, 51°29'N

Month	Average Temperature (°C)	Average Precipitation (mm)
Jan	4.7	62.5
Feb	4.8	40.6
Mar	6.9	47.7
Apr	8.7	47.6
May	12.0	51.1
June	14.8	51.6
July	17.3	39.6
Aug	17.0	49.4
Sept	14.3	61.2
Oct	10.9	71.2
Nov	7.2	60.3
Dec	5.6	64.5

UNIT C Review (continued)

48. Imagine that farmers in an area near your community are reporting that the growing season is longer than in the past. Write a hypothesis to explain this observation. Describe how you might use weather records to test your hypothesis. *t*

49. From the data presented in the climatograph below, write a travel brochure for visitors to Caracas. Include information such as the best time of year to visit, the type of clothing they should bring, and what kind of accommodation would be appropriate for a comfortable stay in this climate. *a*



Source: World Climate

Question 49

50. If you had the opportunity to visit any city in the world, what would it be?

(a) Look up the local weather in that city, and explain what you would pack for the trip if you were going today. *a*

(b) Classify the biome that the city is located in, and write a paragraph describing its characteristics. *t*

(c) Prepare a climatograph for this city or a major city nearby based on available information. *c*

(d) Using your climatograph, pick the month you would plan for your trip. *t*

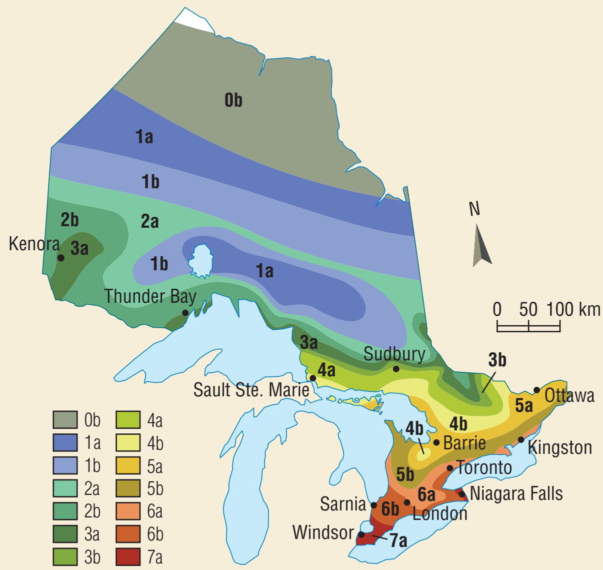
51. Below is a horticulture map for Ontario, which shows the plant hardiness zones. *t*

(a) What biome does zone 1b belong in?

(b) What is the biome of zone 7a?

(c) Why would gardeners find this map useful?

(d) Is this map similar to the biome map in Figure 7.13 (page 272)? Explain why or why not.



Question 51

Revisit the Big Ideas and Fundamental Concepts

52. Earth's climate system is dynamic and a result of interaction among its many components. Write a paragraph or draw a picture to illustrate this idea. *c*

53. The global climate is changing, mainly because of human activities. Write a persuasive paragraph explaining the significance of these human activities. *c*

54. Lifestyles change in many ways over generations. The photograph below shows teenagers doing the jive, a popular dance in the 1950s. How is your life today different from the life of the teenagers in the photograph? Have those lifestyle differences had a positive or negative impact on greenhouse gas emissions? Explain. *a*

Question 54

55. Changes in Earth's climate will have global and regional consequences, and people have a responsibility to assess their impact on climate change and identify effective courses of action to reduce this impact. Make a list of five ways you can reduce your personal impact on climate change and three ways you can influence corporate and/or governmental action on climate change. Rank these ways in order of easiest to hardest to implement. *a*

STSE Science, Technology, Society, and the Environment

56. One way municipal governments try to encourage people to reduce their effects on Earth is through programs such as green bin composting. This program diverts waste from landfills by turning organic material into compost for use in parks and gardens. Think about what you have learned in this unit and how your family makes use of these programs. Perhaps you already use the green bin regularly, or perhaps green bin composting is not available in your area. How could you turn what you have learned and your personal situation into a plan for action? *a*

57. Oceans cover about 70 percent of Earth's surface. Ocean currents affect heat transfer and precipitation patterns around the globe. As oceans become warmer, and less saline, their currents may change. This may, in turn, affect the climate. *t*

(a) How will oceans become warmer and less saline?

(b) How could ocean warming and reduced salinity affect the mechanisms that drive the ocean currents?

(c) Will modified ocean currents affect people and/or the environment in the future?

58. Consider the statement "Climate change will have profound effects on life as we know it unless action is taken immediately." What evidence would you consider before responding? *a*

Reflection

59. State your opinion of the current climate change situation in any format you choose. *c*