

8

Earth's climate system is influenced by human activity.



Skills You Will Use

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.

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



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 8.2 Recording a child's growth



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 8.3 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

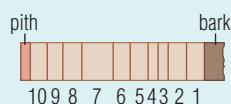


Figure 8.4

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?

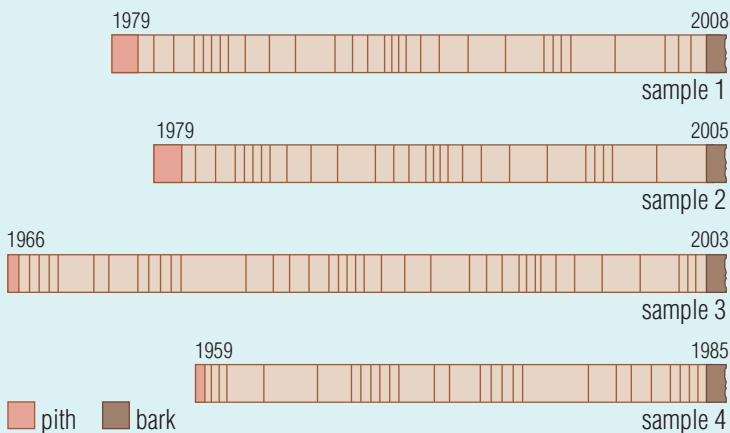


Figure 8.5

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 CO₂ 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, CO₂ concentrations remained stable around 280 ppm. Around 1750, about the same time the Industrial Revolution started, CO₂ 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.

Trends in Global Greenhouse Gas Concentrations in the Atmosphere (1750–2008)

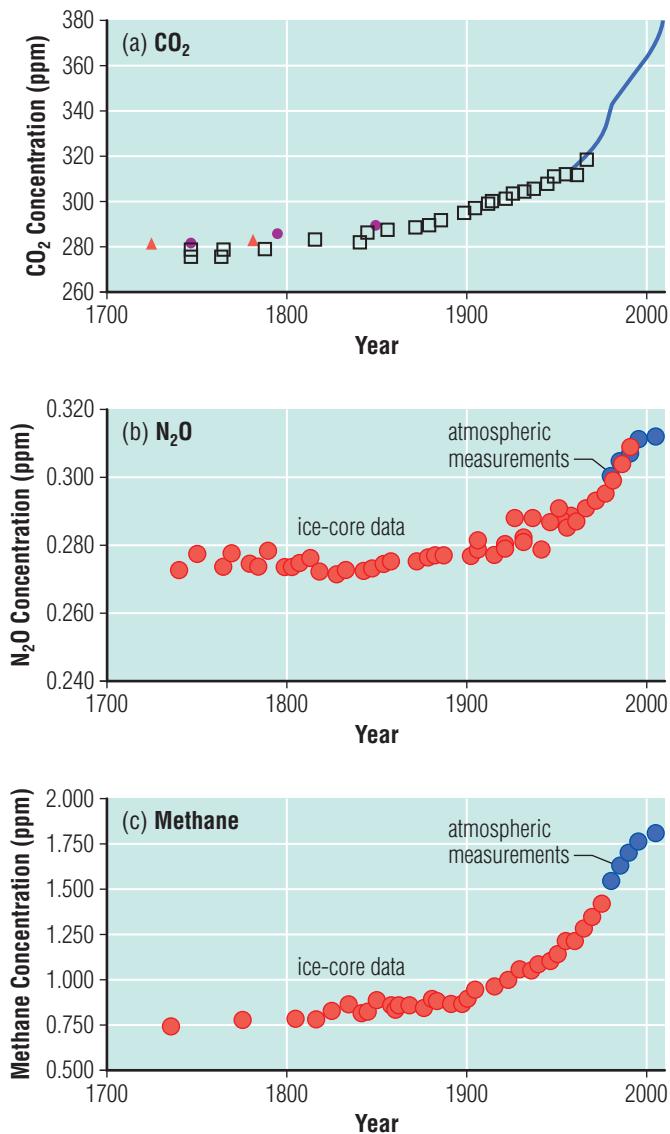


Figure 8.8 Global changes in (a) carbon dioxide, (b) nitrous oxide, and (c) methane concentrations since the mid-1700s. Carbon dioxide data were collected from three sets of ice core data (triangles, squares, and circles) and directly measured from the atmosphere (blue line).

WORDS MATTER

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

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.

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)	<ul style="list-style-type: none">burning coal, oil, gasoline, and natural gascement makingdeforestation
methane (CH_4)	<ul style="list-style-type: none">coal miningproduction of petroleum productsnatural gas leaksrice paddies, landfills, cattle
nitrous oxide (N_2O)	<ul style="list-style-type: none">burning coal, oil, gasoline, and natural gasfertilizer

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.

During Reading



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.

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.

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.

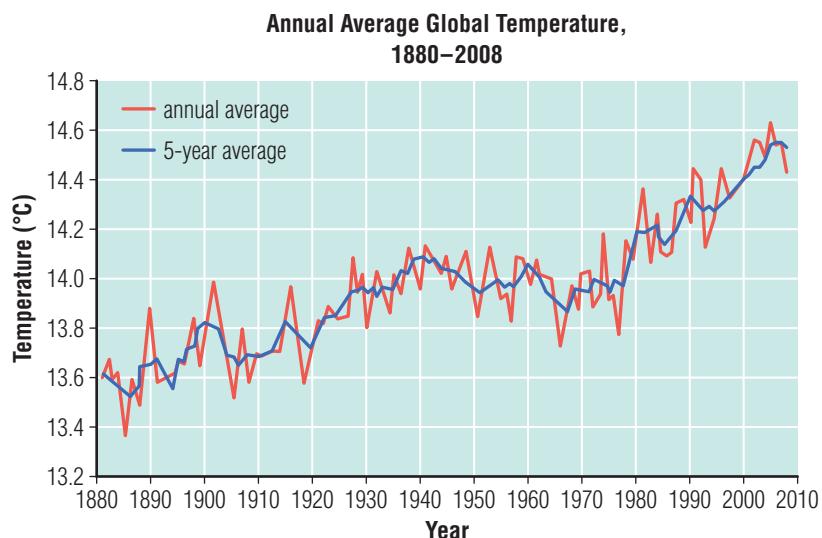


Figure 8.11 The average global temperature has increased substantially since 1980. The graph shows little sign of levelling off.



(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

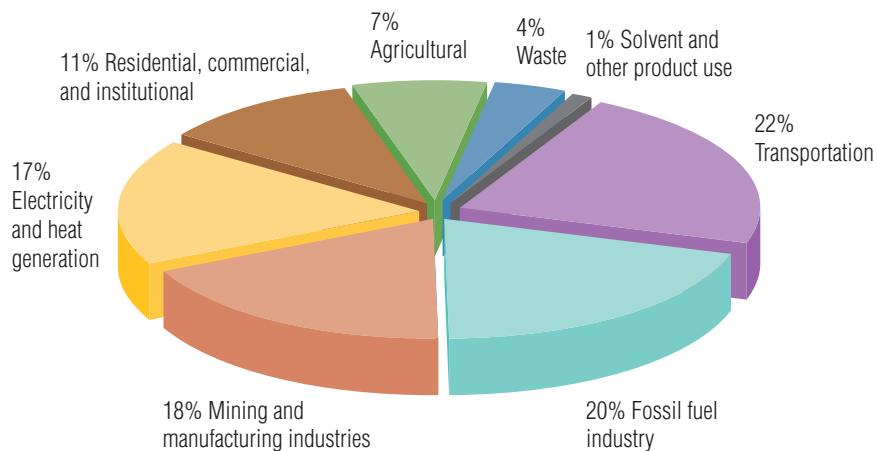


Figure 8.13 Human activities that produce greenhouse gas emissions

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](#).

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 | • aluminum foil |
| • water | • retort stand and clamp |
| • hot plate | • stopwatch or timer |
| • thermometer | • 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?

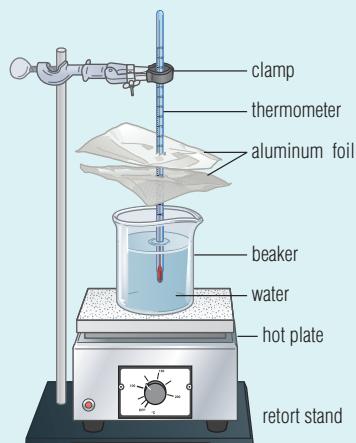


Figure 8.14 Step 3

8.1 CHECK and REFLECT

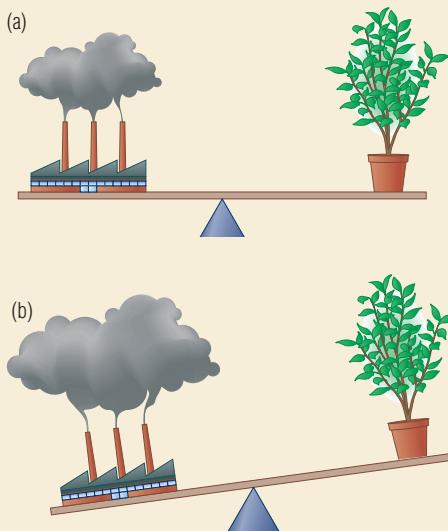
Key Concept Review

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

Connect Your Understanding

- Compare the type of data derived from tree growth rings to that derived from the Greenland Ice Core Project.
- 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?
- Describe the relationship between the anthropogenic greenhouse effect and climate change.
- Is it possible that climate change could occur in only one part of the world? Explain.
- 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**.

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.

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.



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

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.

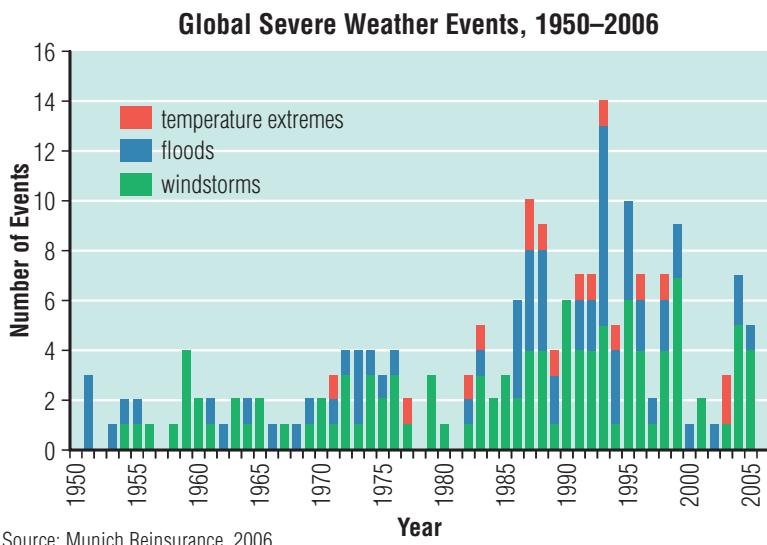
Wildfires

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 drier.

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).



Source: Munich Reinsurance, 2006



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



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

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.



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

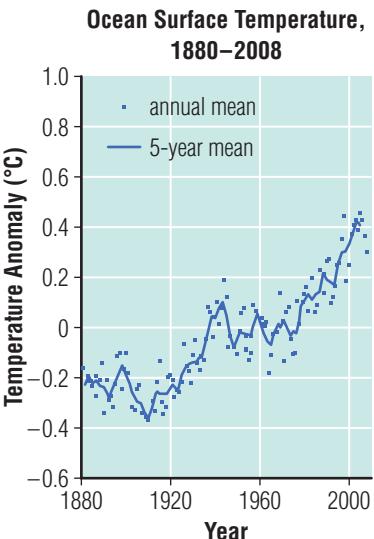
The most obvious effects of rising global temperatures have so far been on land. The impact of rising temperatures on oceans is less obvious because water warms up more slowly. Think about walking barefoot on a summer day: the sidewalk is much hotter than the damp grass. As well, convection currents 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.



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.



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.



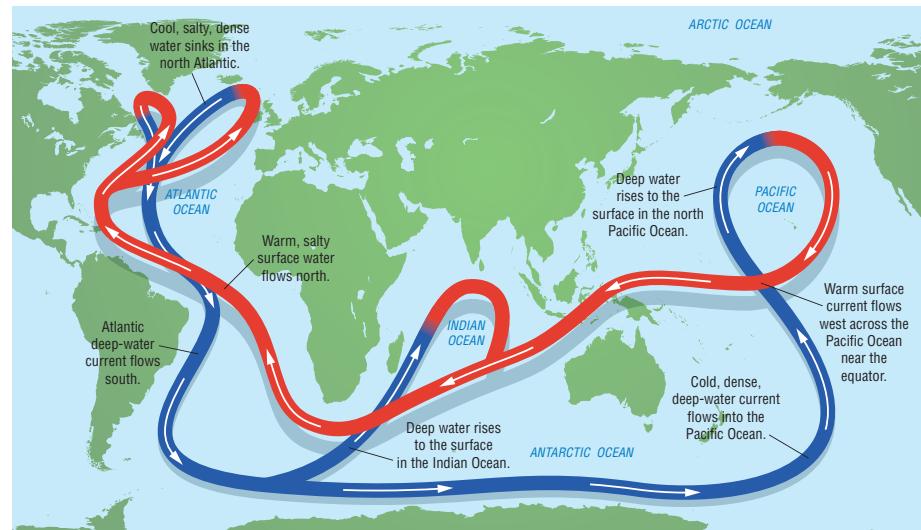
Figure 8.27 Drift Bottle Project leader Eddy Carmack throws another bottle into the ocean.

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.

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.

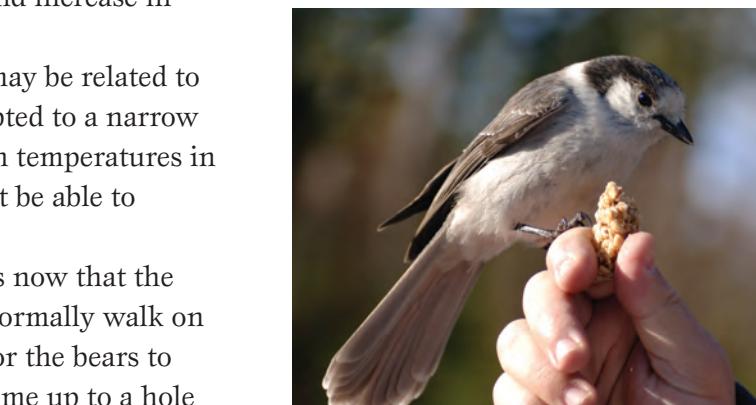
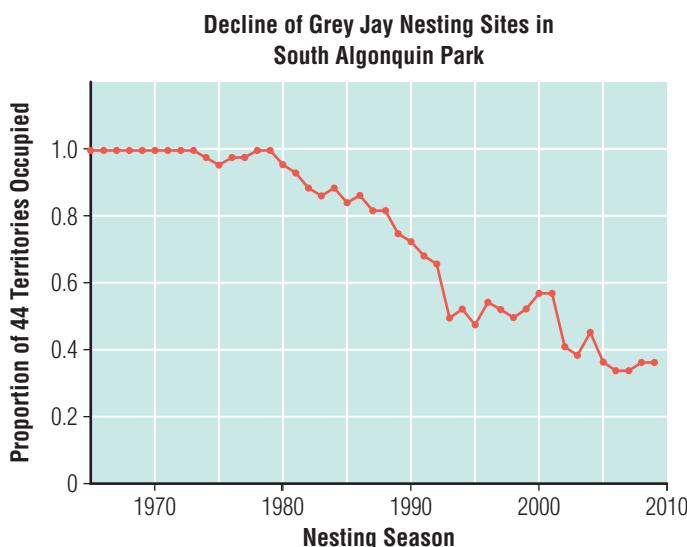


Figure 8.29 Grey jays are no longer nesting at what was the southern edge of their range 40 years ago.



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

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.

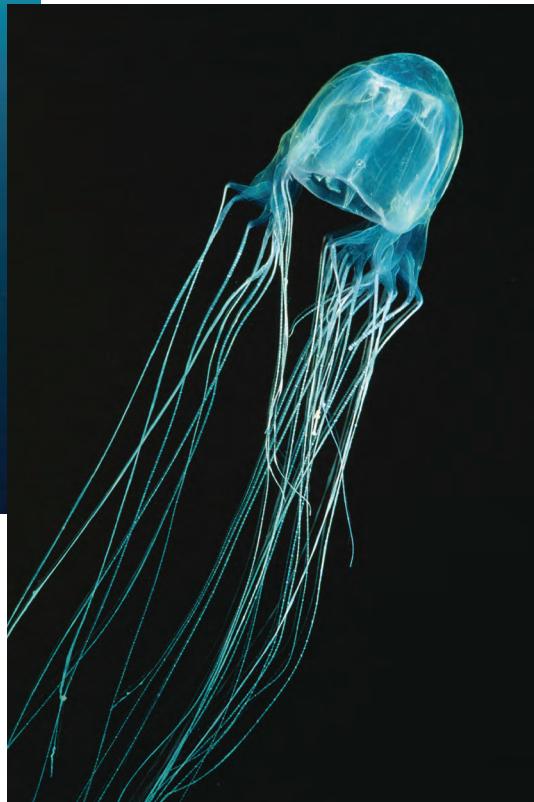


Figure 8.36 Box jellyfish are now found around the world. The “bell” is about 10–15 cm in diameter, and the tentacles up to 1.5 m long.

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. Rework 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 CO₂ 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.

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.



(a)



(b)



(c)



(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.

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.

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.

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.



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

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.

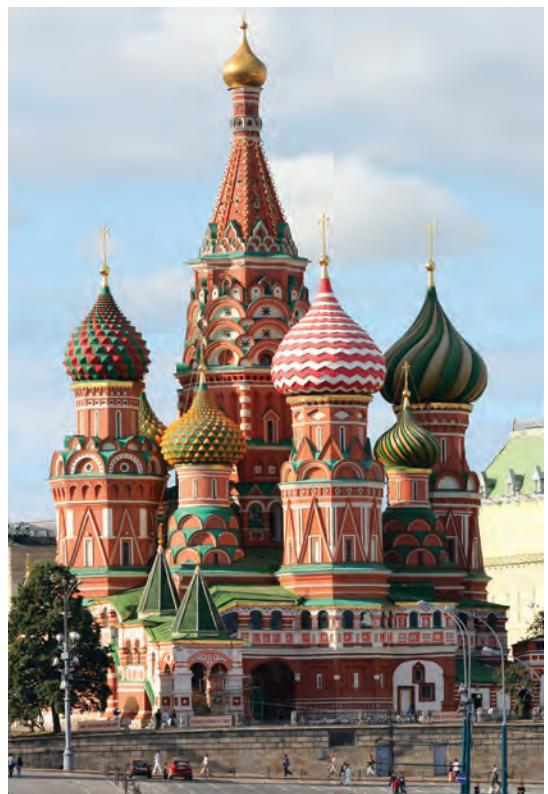


Figure 8.43 St. Basil's Church in Moscow's Red Square. Moscow is the capital of Russia, a G8 country.



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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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)	<ul style="list-style-type: none"> Severe weather events can damage the infrastructure for energy distribution, communication, and transportation.
Disease	<ul style="list-style-type: none"> Tropical diseases such as malaria could spread as climates become warmer.
Population displacement	<ul style="list-style-type: none"> 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.

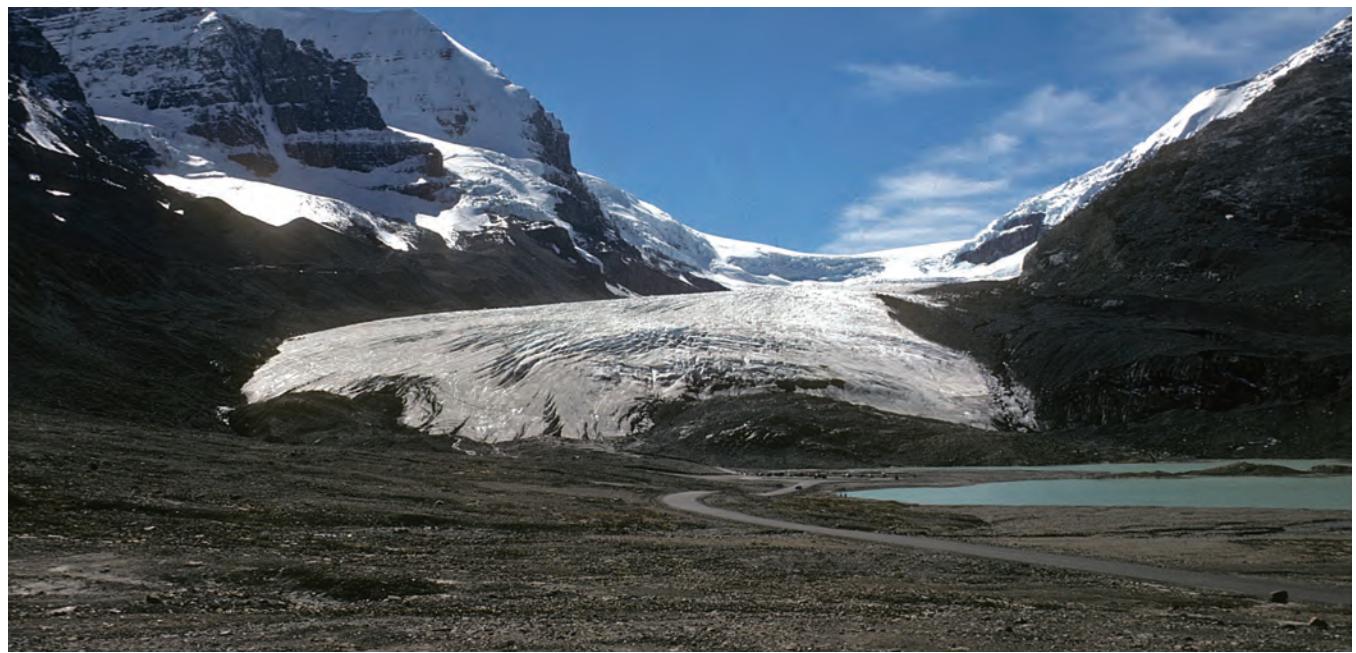
Source: IPCC



(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.

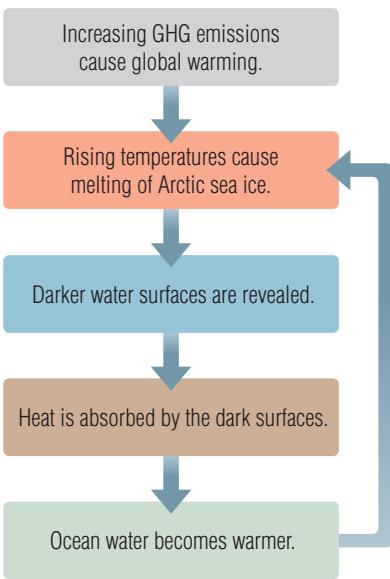


Figure 8.46 Positive feedback loop of melting ice. GHG stands for greenhouse gas.

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.

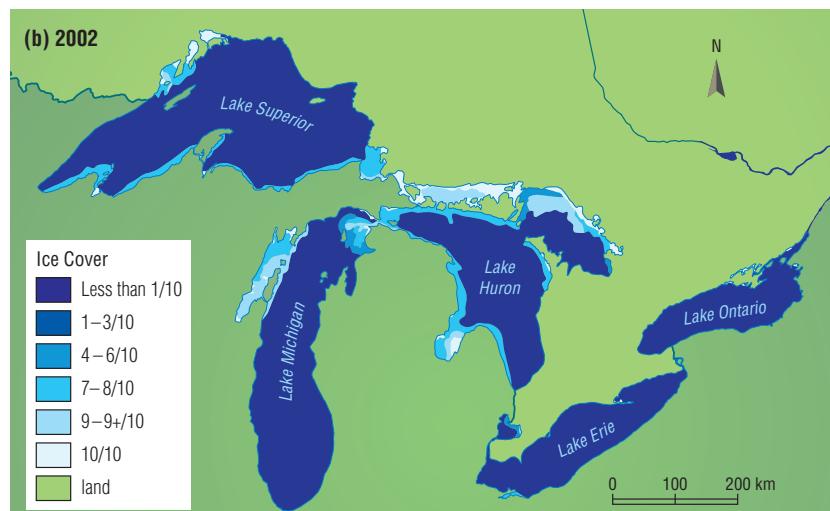
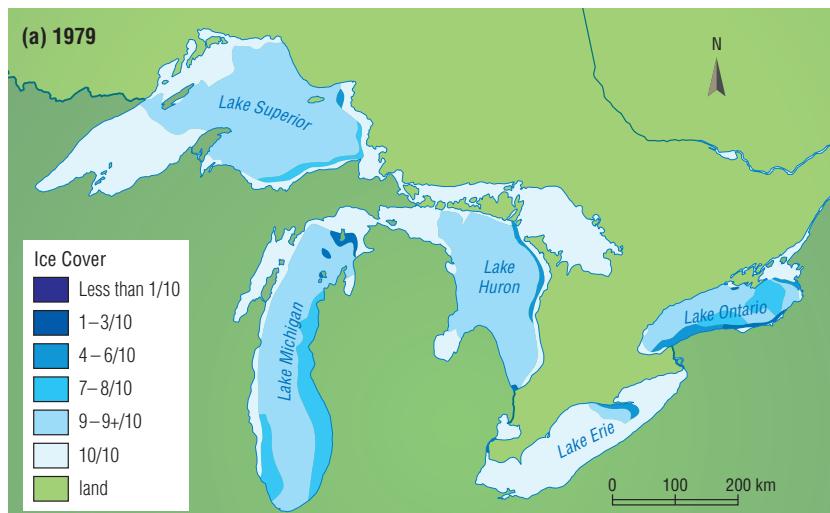


Figure 8.47 The ice cover has diminished dramatically on the Great Lakes in winter: (a) 1979, (b) 2002. Since less solar radiation is now being reflected by Great Lakes ice, Ontario's winters have become warmer but snowier.

Source: Canadian Ice Service

- 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.

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

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

Skill Practice

- Earth's climate system is influenced by human activity. **329**

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

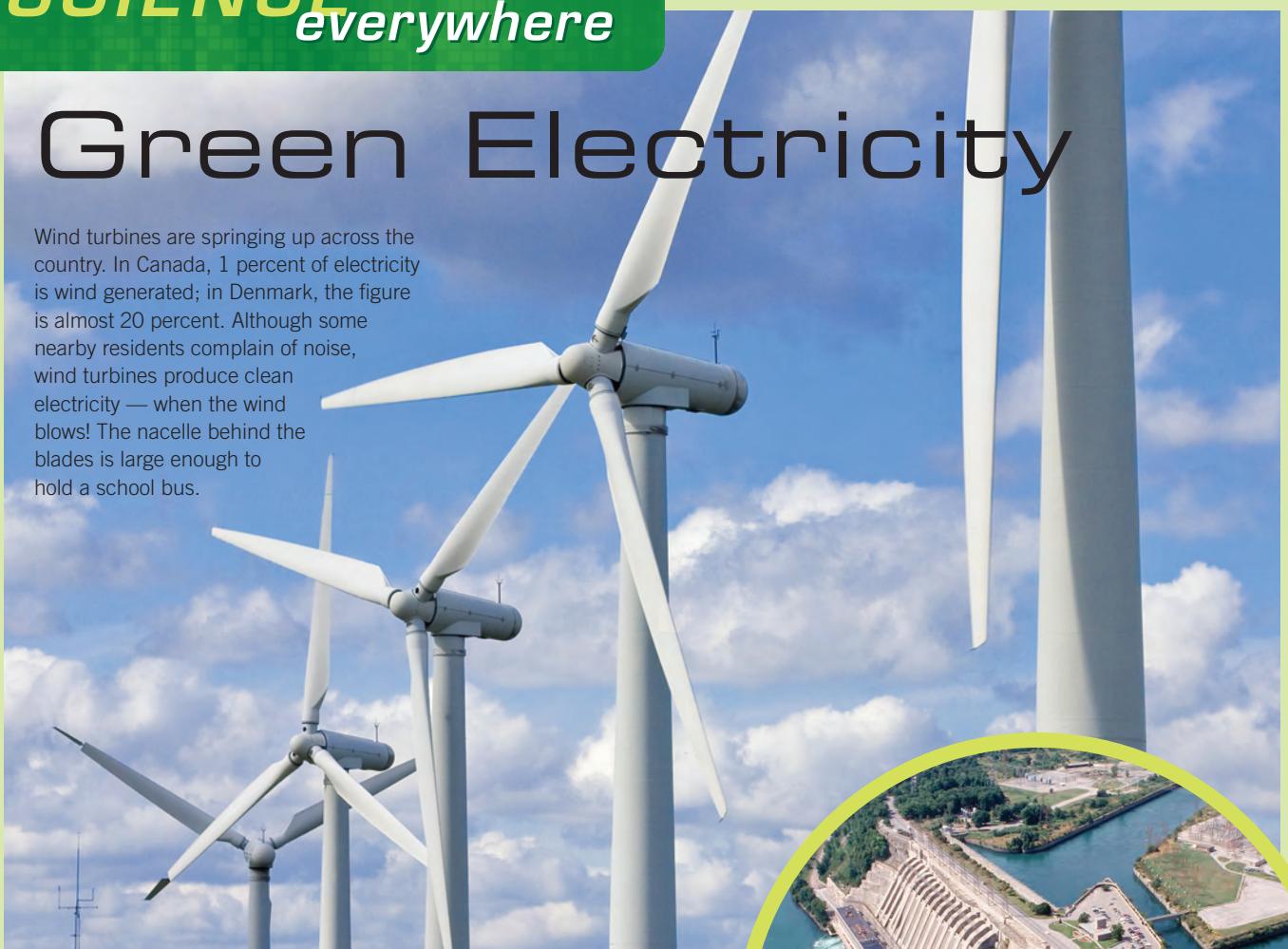
Reflection

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**.

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.

ACHIEVEMENT CHART CATEGORIES

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

Key Concept Review

- Describe how greenhouse gases can affect Earth's net radiation budget. **k**
- Why did the level of greenhouse gas emissions begin to increase during the Industrial Revolution? **k**
- Explain the steam engine's role in the Industrial Revolution.
- Describe some severe weather events that have affected (a) Ontario and (b) the rest of Canada. **k**
- Describe how greenhouse gas emissions are being affected in each photograph below. **k**



(a)



(b)



(c)



(d)

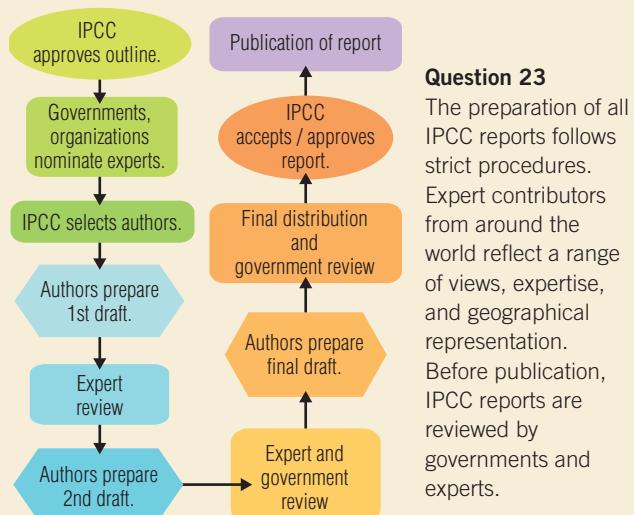
Question 5

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

- Describe one similarity and one difference between the natural greenhouse effect and the anthropogenic greenhouse effect. **k**
- (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**
- Mockingbirds are becoming more common in southwestern Ontario than a decade ago. Explain why this is happening. **k**
- Explain why the use of fossil fuels has increased over the past century. **k**
- Describe one method that scientists use to measure changes in the concentration of greenhouse gases over time. **k**
- List the sources of human-generated nitrous oxide emissions. **k**
- Describe the IPCC and its role in assessing climate change. **k**
- Describe two ways in which climate change may affect biomes. **k**
- Create a Venn diagram to show the similarities and differences between the natural greenhouse effect and the anthropogenic greenhouse effect. **t**
- How is albedo related to climate change? **a**
- 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? **a**
19. What does the burning of fossil fuels have in common with the process of respiration? **t**
20. List three different ways scientists have gathered evidence related to climate change, and describe the evidence you find the most persuasive. **t**
21. Why is it important to have an organization such as the IPCC when attempting to understand climate change issues? **t**
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? **t**
23. Study the following figure, and comment on how confident you are about IPCC reports. **t**



24. Think of your typical day, and list three ways you participate in Canada's economy. **a**
25. Choose one effect of climate change, and depict it visually. Use arrows, key words, and colour to make your points clearer. **c**
26. What do you think are the obligations of people who live in G8 countries to those who live in the developing world? **t**

27. How could a shift in consumer demand affect the production and distribution of goods? **t**
28. Many celebrities have embraced the climate change issue. What are the pros and cons of this phenomenon? Explain. **c**
29. Why is it important for you and every citizen to understand the science of climate change? **t**

Reflection

30. What is the most concerning thing you have learned about climate change in this chapter? Explain. **c**
31. How has the information you have learned about climate change affected your thinking? your actions? **a**
32. What is the most surprising thing you have learned about climate change in this chapter? **c**

Thinking Literacy

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.