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

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

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.

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.

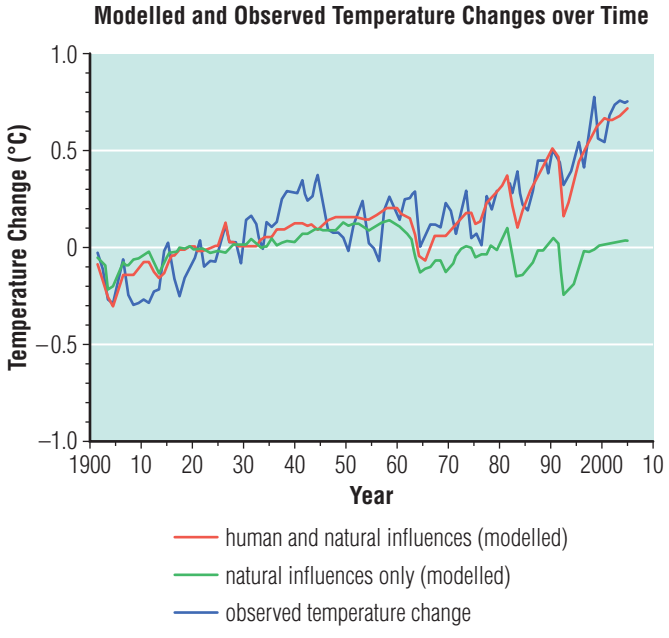
Computer Models

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).

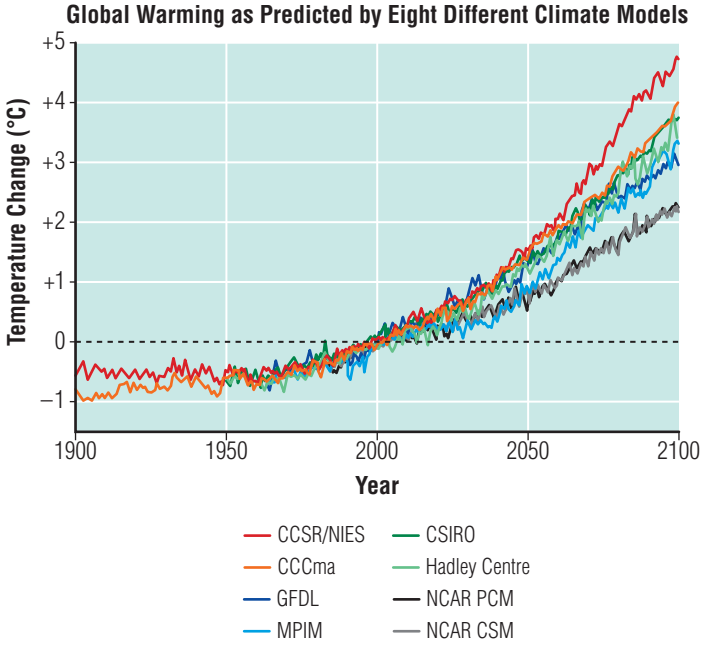
When a model is developed, it must be tested to make sure it will give believable predictions of future climates. Scientists run the model to see if it accurately reproduces past data. If it produces data that match what we already know from actual measurements of world climates, then it will likely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

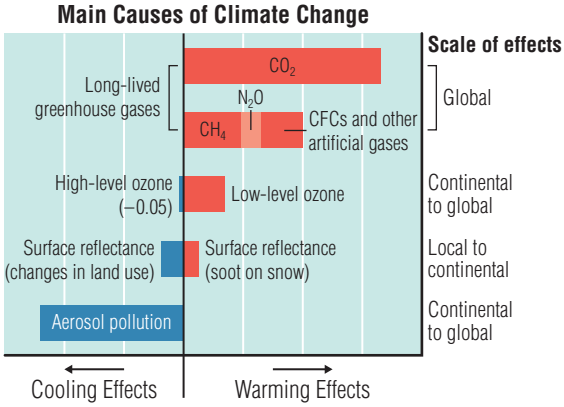
Figure 9.6 Though the models differ, the trend is the same for all of them.

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."

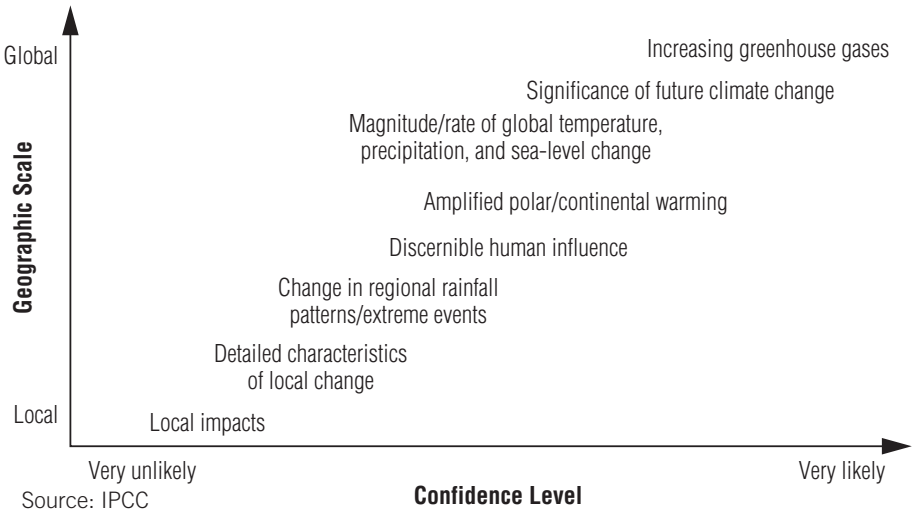


Figure 9.9 This graph shows events related to climate change, arranged according to IPCC levels of confidence (horizontal axis) and whether events are more local or more global in scale (vertical axis). Global events are those observed worldwide; local events are observed only in particular regions on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

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.

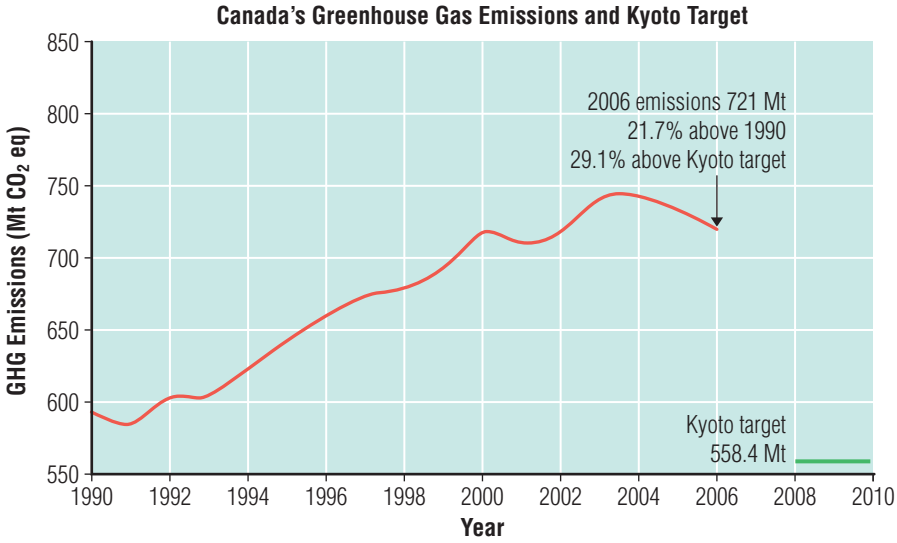
Kyoto Protocol on Climate Change

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?

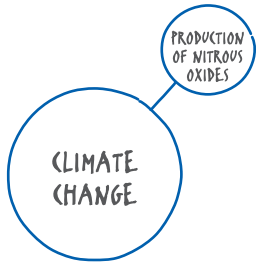
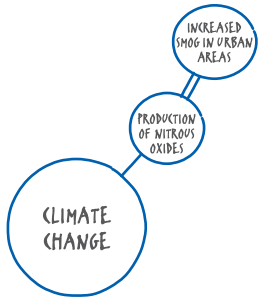
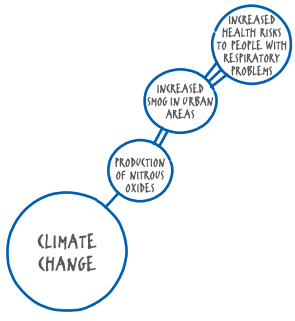
Directions	Example
An Impact Wheel starts with an issue at the centre of the wheel. The issue in this activity is climate change.	
Around the centre of the wheel, list the evidence for climate change. Circle each piece of evidence. Draw a line between each piece of evidence and the centre circle of the 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

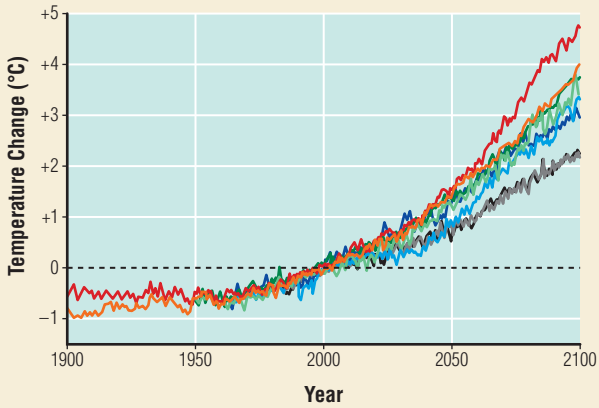
9.1 CHECK and REFLECT

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).

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

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.

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.

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

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.

Suggested Activity •

C23 Decision-Making Activity on page 358

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.

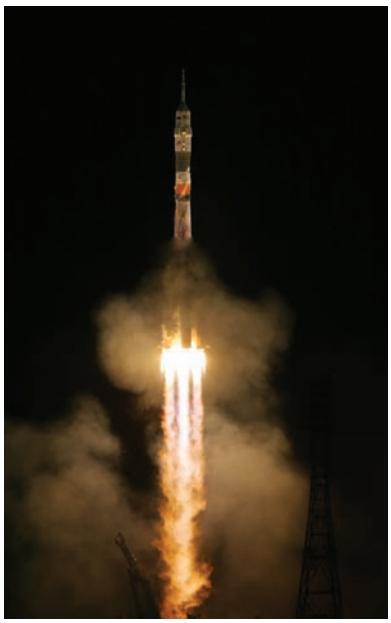


Figure 9.31 Rockets could be used to transport chemicals into the atmosphere.

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)

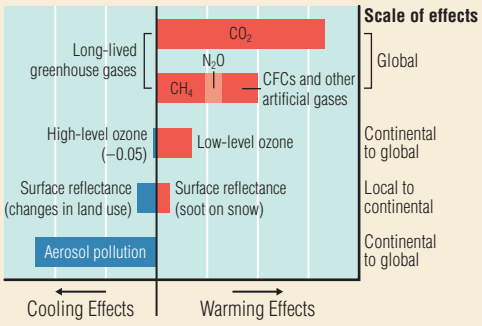
6. (a) Define sustainable development. (k)

(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)

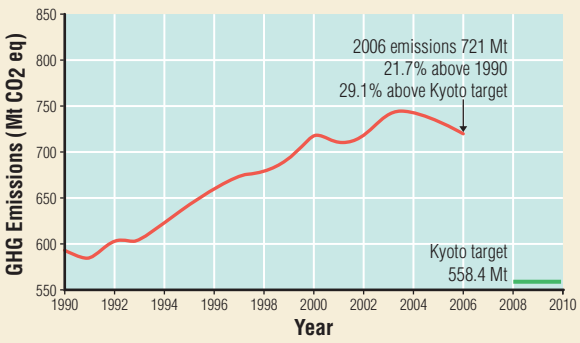
20. Why do you think governments are struggling with their Kyoto commitments? (t)

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?

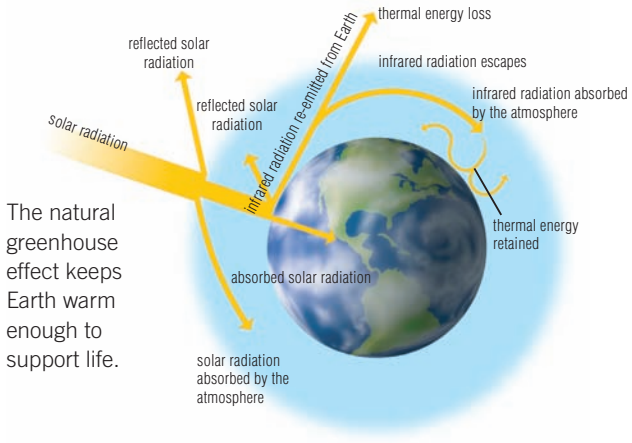
UNIT C Summary

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)

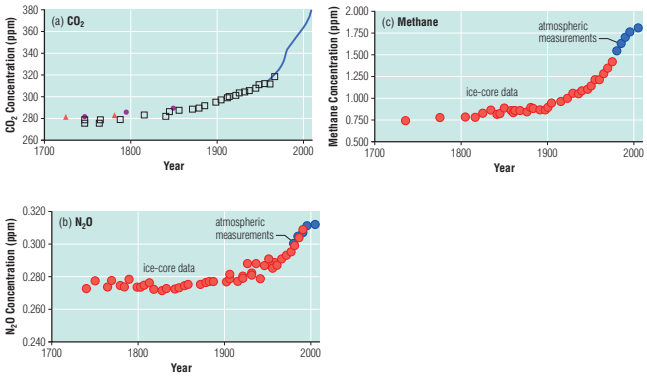
KEY VISUALS



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

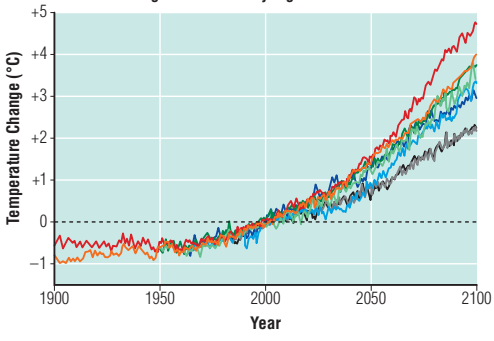
- anthropogenic greenhouse effect (p. 300)
- carbon sink (p. 302)
- carbon source (p. 301)
- climate change (p. 303)
- economic system (p. 322)
- fossil fuels (p. 301)
- global warming (p. 303)
- global warming potential (p. 298)
- persistence (p. 298)
- positive feedback loop (p. 326)
- runaway positive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

Trends in Global Greenhouse Gas Concentrations in the Atmosphere



- 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)

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)

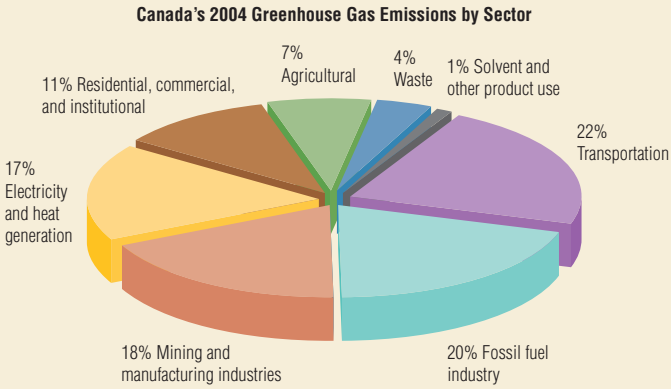
Physical Effects of Climate Change

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

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? t

44. For each sector below, list an adaptation strategy and describe a possible government policy and some implementation considerations. t

(a) water

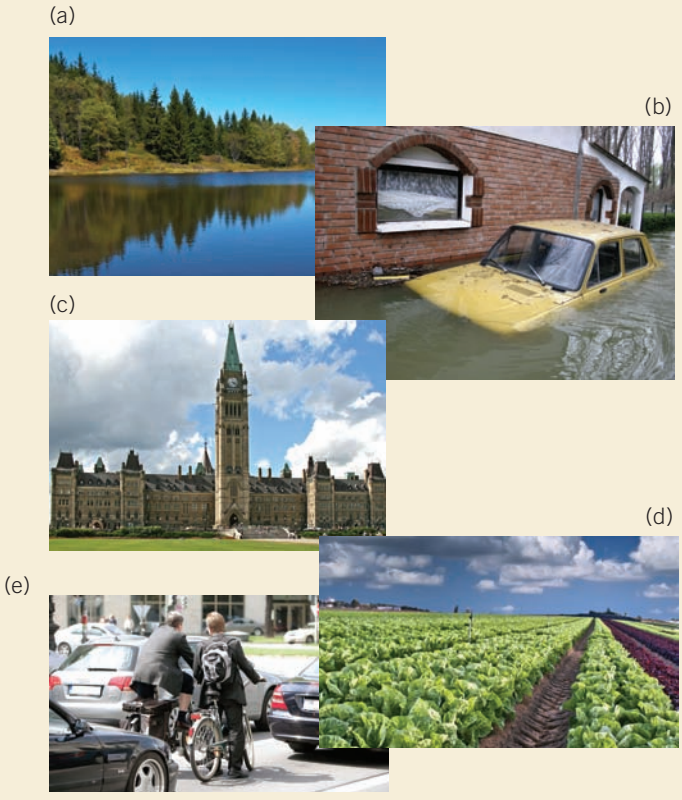
(b) agriculture

(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. t

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. t



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. a

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

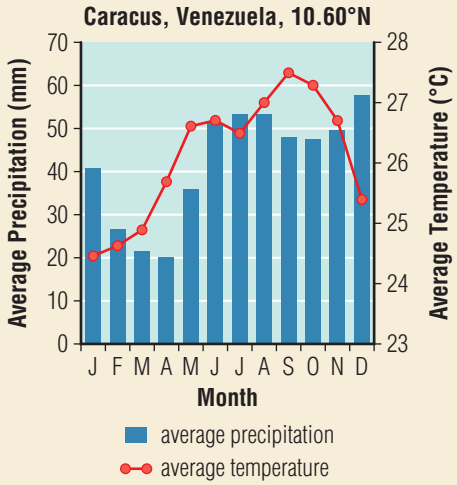
Month	Average Temperature (°C)	Average Precipitation (mm)
Jan	–20.7	33.9
Feb	–18.4	22.7
Mar	–11.7	31.7
Apr	–2.4	39.0
May	6.2	53.7
June	11.9	71.1
July	15.4	101.3
Aug	14.4	75.8
Sept	9.4	90.0
Oct	3.4	73.3
Nov	–4.7	54.3
Dec	–16.3	34.7

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

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

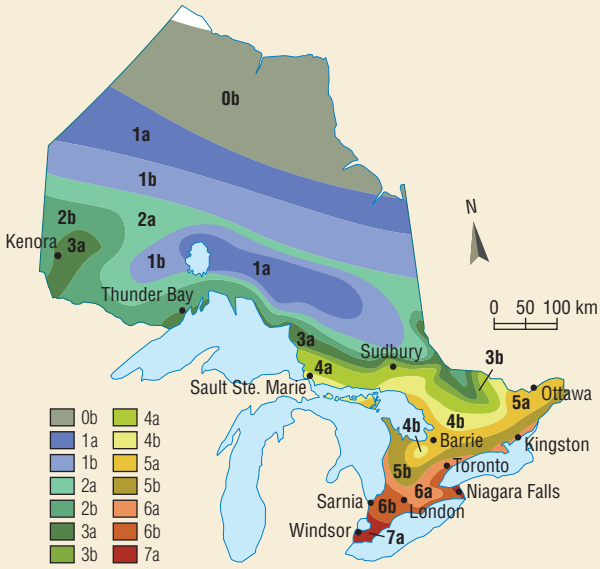
51. Below is a horticulture map for Ontario, which shows the plant hardiness zones. t

(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)