Section 8.3 Cycling of Matter and the Climate System

(Student textbook page 333 to 340)

In this section, students will learn about the natural cycles of carbon, nitrogen, and water. Students will explore the capacity of these cycles to store carbon and nitrogen. They will learn how human activity has released stored carbon and nitrogen.

Specific Expectations

- **D2.1** use appropriate terminology related to climate change, including, but not limited to: *albedo*, *anthropogenic*, *atmosphere*, *cycles*, *heat sinks*, and *hydrosphere*
- **D2.4** investigate a popular hypothesis on a cause-and-effect relationship having to do with climate change, using simulations and/or time-trend data that model climate profiles
- **D3.4** identify natural phenomena known to affect climate, and describe the role of both in Canada's contribution to climate change
- **D3.5** describe the principal sources and sinks, both natural and/or anthropogenic, of greenhouse gases
- **D3.7** describe, in general terms, the causes and effects of the anthropogenic greenhouse effect, the depletion of stratospheric and tropospheric ozone, and the formation of ground-level ozone and smog
- **D3.8** identify and describe indicators of global climate change

Common Misconceptions

- Students may believe that plants take in food from the outside environment (only true for carnivorous plants) and/or plants get their food entirely from the soil via roots. They may also have misconceptions about carbon dioxide, believing it is a source of energy. (It is used in photosynthesis. Plants respire for energy like all other organisms, breaking down oxygen into carbon dioxide).
- Students may not see plants as a source of carbon dioxide because plants are carbon sinks. Plants respire just as other organisms do.
- Students may believe that oxygen and carbon dioxide create a carbon dioxide cycle. This does not occur. Carbon dioxide is created and destroyed in other cycles (the carbon cycle).
- Students may believe it is undesirable to have bacteria in soil. In fact, bacteria present in soil make it possible for plants to use nitrogen, which they require.

Background Knowledge

Nutrients cycle through the ecosystem, in and out of terrestrial and aquatic stores, and in and out of organisms. All living things require carbon and nitrogen. These elements are incorporated into carbohydrates, fats, DNA, RNA, and proteins that make up cells in living things. Animals obtain their nutrients by eating plants or by eating animals that ate plants. Plants obtain nutrients in two ways. Carbon is obtained through plant leaves in the process of photosynthesis. Nitrogen is obtained through their roots with the help of bacteria in the soil. The elements are recycled through the ecosystem from living organisms to dead organisms to decomposers and then into the environment where the cycle repeats.

The carbon cycle is actually the interconnections between the four major reservoirs of carbon. In general, the reservoirs are plants, the terrestrial biosphere, oceans and rocks (or sediments). Forests are reservoirs containing 86 percent of Earth's above-ground carbon and 73 percent of the carbon in soils.

The global carbon budget balances the increases and decreases (the exchanges) of carbon between reservoirs. Carbon budgets can also be used on a regional scale, to measure the exchange of carbon and determine if the area is a carbon sink or a carbon source.

The supply of nitrogen is a critical factor that drives the types and diversity of plants, interactions of grazing animals and their predators, and the productivity of plants. By increasing the amount of nitrogen cycling, humans are indirectly affecting many natural systems. These effects include increasing the global concentrations of nitrous oxide in the atmosphere and increasing regional concentrations of other forms of nitrogen that form smog. As well, in some regions, soils and bodies of water are becoming acidified. Biodiversity that depends on low-nitrogen soil is being lost, in turn reducing populations of organisms that depend on this biodiversity.

Literacy Support

Using the Text

- The material in this section will be easier to understand and retain if it is supported by illustrations or even rough sketches. Ensure that students accompany their notes with some type of diagrammatic representation.

Before Reading

- Have students flip through the section to preview the text features and the headings. Have them look at the key terms and consider if they are already familiar with any of the words. This will help them identify the main ideas contained in the section.
- ELL Preview the Key Terms with English language learners before reading. Draw students' attention to words they already know that share prefixes with the Key Term *biogeochemical cycle*. Have students make connections to predict the meaning of each Key Term.

During Reading

- Have students make study notes as they progress through the section. They will need to identify the most important information and decide how to record in a way that is most meaningful to them.
- ELL Students can be encouraged to make study notes in their first language, and to create an English translation.

After Reading

- Ask each student to write a short two-sentence summary of the main points of the section. You can then have students work in groups to compare their summaries and agree on one. The summaries can be shared with the class and recorded so they can be used as a review.

Using the Images

- Encourage visual learners to summarize the illustrations throughout the section as a preview to the material.
- As students read work through the text, have them summarize the captions of the diagrams in their own words. They can combine these into an organizer for the section.
- Before reading this section, have students look at the photographs and illustrations and relate them to their own experiences. They should be familiar with some aspects of the biogeochemical cycles shown in the section.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Activity 8-4 Modelling Carbon Stores, page 336	Students model carbon in various stores and correctly identify which store holds the most carbon based on data provided. They describe how different factors affect the amount of carbon stored and correctly identify any relationship between the amount of carbon stored and the length of time it remains in store.	Use Science Skills Toolkit 9 Using Models and Analogies in Science to support this activity. Alternatively, provide students with **BLM G-17 Using Models and Analogies in Science.**
Learning Check, page 337	Students explain the relationship between the terms biogeochemical cycle and store, and identify different carbon stores. They describe components of the carbon cycle and explain how a human activity can upset the global carbon budget. Answers to question 3 show the correct relative times that carbon spends in each of the carbon reservoirs. Answers to question 4 show an understanding of how carbon reservoirs and the carbon cycle are being affected by the large volume of carbon released by burning fossil fuels.	Allow students to answer the questions verbally. Alternatively, have students work in pairs or teams and present their findings to questions 3 and 4.
Section 8.3 Review questions, page 340	Students describe and illustrate the carbon and nitrogen cycles. They explain how humans affect the carbon and nitrogen cycles.	Provide students with **BLM 8-11 The Carbon Cycle**, **BLM 8-12 The Carbon Cycle Concept Map**, **BLM 8-13 Know Your Nitrogen,** and **BLM 8-14 Questions About the Nitrogen Cycle** for support. Encourage students to use alternative methods for communicating their answers (for example, students could use a skit or song to describe the carbon cycle). Provide students with **BLM G-43 Flowchart** to help them answer question 2.

Instructional Strategies

- DI This material is very well suited to spatial learners. It can be adapted for others as well, particularly logical-mathematical and bodily-kinesthetic learners, by changing the format of results.
- ELL Have students review the vocabulary, and add it to the word wall or to their first language translations.
- ELL Check often for comprehension, among all students, and especially English language learners. Students may need to demonstrate their understanding of the concepts in a variety of ways.
- Biogeochemical cycles are complicated and full of information. Have students work in teams to break down the carbon cycle and nitrogen cycle into its components (each team gets one "arrow" between elements in the cycle). They can then design and create a model with all of the pieces added together. Use **BLM A-6 Developing Models Checklist** for assessment.
- Before beginning, ask students to predict where nutrients are stored in the biosphere. This class discussion can form the basis for recording information as students progress through the section.
- Chunk the reading into smaller, manageable parts. Do each cycle individually and provide structured directions to proceed through each chunk.

Activity 8-4 Modelling Carbon Stores (Student textbook page 336)

Pedagogical Purpose

Students explore carbon sinks and determine which type of carbon store holds the most carbon in storage. The modelling shows students the relative sizes of the different carbon sinks.

Planning		
Materials	Per group: 10 yellow sticky notes 1 blue sticky note	1 pink sticky note 5 photographs of carbon reservoirs (rocks, ocean, oil, trees, sky)
Time	20–30 min	

Background

Carbon stays stored in rocks and sediment for millions or even billions of years and is stored in fossil fuels for hundreds of millions of years. Comparatively short-term reservoirs are oceans (500 to 1000 years), vegetation (5 years), soil (25 years) and the atmosphere (50 to 500 years).

Activity Notes and Troubleshooting

- Write the rules at the front of the class and make sure students are referring to them as they complete the activity.
- Have extra sticky notes of all colours on hand.
- Students may wish to find their own photographs and bring them in. If so, give them time in the library beforehand.

Additional Support

- This is an excellent activity for bodily-kinesthetic and spatial learners. Have students work in cooperative mixed-ability groups to answer the questions.
- Before the activity, have students discuss the carbon cycle and review notes they have made. They may want to read Table 8.6 for more detail on Earth's carbon stores.
- Before beginning the activity, check to make sure students understand what is being modelled. Continue to check during and after the activity.
- Provide students with **BLM G-17 Using Models and Analogies in Science.**
- Use **BLM A-33 Interpreting Data Rubric** for assessment.

Answers

1. Rocks and sediments store the most carbon. The carbon remains stored for millions or even billions of years.
2. Fossil fuels are the fossilized remains of plants and animals that were covered by sediments millions of years ago. The types and amount of plants and animals that were fossilized affects how much carbon is stored. The recent change in rate of release could be modelled by removing sticky notes from the fossil fuel photograph and placing them on the atmosphere photograph.
3. The thermohaline circulation pattern keeps the cold water deep under the ocean surface, trapping the carbon in the ocean.
4. Example: The largest amount of carbon is stored in sediments, and those stores hold carbon the longest. Fossil fuels hold carbon for hundreds of millions of years, but do not store as much as the oceans. Therefore, there is not real correlation.

Learning Check Answers (Student textbook page 337)

1. A biogeochemical cycle is a natural process that exchanges matter and energy between the abiotic environment to living things and back to the abiotic environment. A store is a part of a biogeochemical cycle in which matter or energy accumulates.
2. The carbon could be transformed into fossil fuels, dissolved in oceans and transferred to the deep ocean by currents, or settle to the deep sea as marine sediment or the shells of marine animals and be transformed into sedimentary rock.
3. Example: If one day was shown on the timeline as 1 mm, 1 million years would be 365 km long.
4. Example: Burning fossil fuels releases carbon from the rocks store into the atmosphere. The carbon would naturally have stayed in the rocks for many millions more years. By putting more carbon into the atmosphere, the carbon can move into the oceans or stay in the atmosphere instead of being trapped in the rocks.

Section 8.3 Review Answers (Student textbook page 340)

1. Ocean floor sediments, sedimentary rocks, and to some extent, fossil fuels and the calcium carbonate shells of some marine invertebrates are the sinks in the carbon cycle.
2. Students should create flowcharts that show carbon moving between the oceans, the atmosphere, rock (marine sediments and sedimentary rock) and living things on Earth (vegetation, soil, and organic matter).
3. In the short term, trees would remove carbon from the atmosphere. After they have reached their maximum size and begin to die, the trees will release their carbon into other reservoirs.
4. Humans are releasing carbon into the atmosphere. The carbon has been stored for hundreds of millions of years as fossil fuels. Releasing this carbon increases the amount of carbon dioxide found in the atmosphere and the ocean. At the same time, humans are using more than half of the planet's land area for human activity, replacing large amounts of natural terrain with concrete, brick and asphalt that are not involved in the carbon cycle. We have replaced swamps and forests that used to store and cycle carbon with cities and farms that do so far less efficiently.
5. Nitrogen can be converted by lightning or high temperature combustion into NO_x (usually NO_3 nitrates), by the action of certain nitrogen-fixing bacteria into NH_4, or by industrial processes into NH_2, NO_x, or NH_4 forms.
6. The total human-induced increase of global N fixation is about 150 Tg/y. The total amount of nitrogen fixation before 1850 was about 150 Tg/y; so 150 Tg/y divided by 150 Tg/y equals a 100 percent increase or a doubling of the amount of nitrogen fixation every year.
7. Many golf courses apply large amounts of fertilizer. This fertilizer commonly contains nitrates, which can run-off the golf course into ponds and can encourage algae growth.
8. Answers may vary. Diagrams should show that the carbon cycle and nitrogen cycle both flow into the atmosphere from living and nonliving sources. Without labels, these cycles look very similar. Living organisms both absorb carbon and nitrogen from their food and excrete carbon and nitrogen back into the cycle.

Real World Investigation 8-A Recognizing the Effects of El Niño and La Niña on Southern Canada

(Student textbook pages 341 and 342)

Pedagogical Purpose

Students explore how the temperature of the ocean's surface can affect climates that are thousands of kilometres away. By graphing and comparing sea surface temperatures of the equatorial Pacific Ocean with precipitation and temperature trends in Canada, students recognize that Canada's climate is affected by global events.

Planning		
Materials	Graph paper	Coloured pencils (red and blue)
Time	60 min	

Background

El Niño means "little girl." The name was first used by fishers to describe the warmer waters off the coast of South America. La Niña means "little boy." It is the opposite of El Niño and describes colder waters. El Niño is a disruption of the ocean-atmosphere system originating in the tropical Pacific and typically occurs every three to seven years. The winds reverse and flow eastward, increasing the sea surface temperature in the eastern equatorial Pacific Ocean, creating significant changes to weather patterns. It is not known what triggers the winds to reverse direction. The El Niños of 1982–83 and 1997–98 were the warmest in five decades.

In normal conditions, when the trade winds are blowing west across the southern Pacific Ocean, the sea surface temperature is on average 8°C higher than it is in the west. Cooler water temperatures in the east, off the coast of South America, are caused by cold water upwelling from the deep ocean. This water is very rich in nutrients and supports a great deal of ocean biodiversity. More rainfall occurs over the warmer water in the western Pacific, while the eastern Pacific is relatively dry. When El Niño occurs and the winds reverse and flow eastward, the sea surface temperature in the eastern equatorial Pacific Ocean increases, creating significant changes to weather patterns. The western Pacific region may experience droughts, while extreme precipitation falls in the eastern Pacific Ocean. Fisheries are negatively affected off the coast of South America.

Activity Notes and Troubleshooting

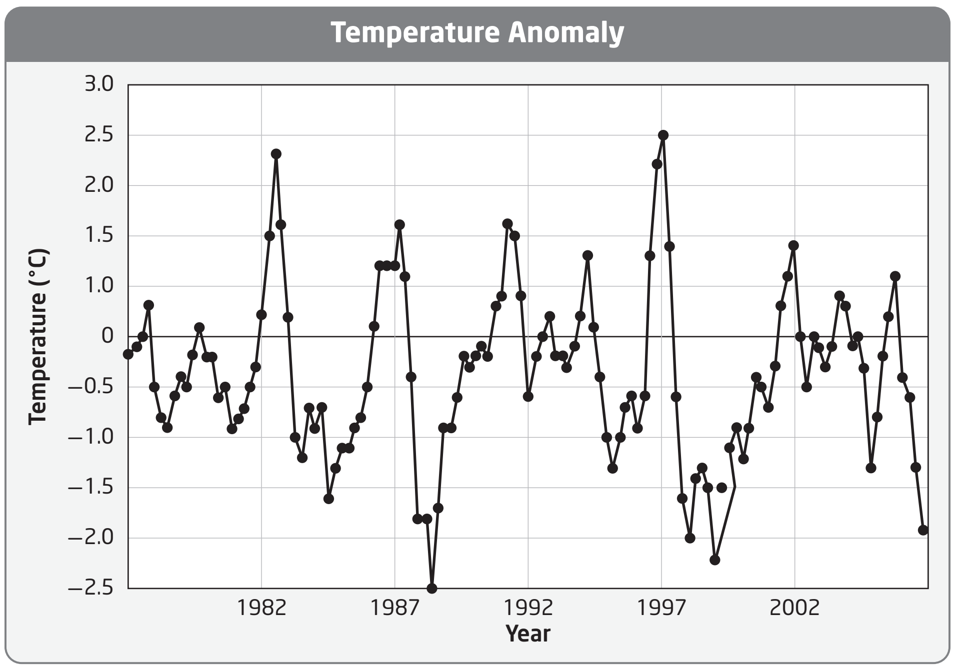
- Students may have difficulty plotting the data, particularly because there is so much of it. You may wish to have students input the data into a spreadsheet and generate a graph using a computer.
- El Niño and La Niña events may last several years. Clarify this with students so that they do not identify events as occurring in discrete years, but rather sometimes over a range of years.
- Some of the questions, such as question 6, require extra research on the part of students. Have resources on hand to help students and save time.
- El Niño and La Niña events, though cyclical, have varying effects on Canada. Remind students of this when they are answering question 8.
- Have students review **BLM 8-15 The Ocean's Currents**, which covers El Niño and La Niña.

Additional Support

- DI Spatial and logical-mathematical learners may enjoy this investigation. Ensure that at least one of these learners is in each group, if possible.
- ELL Use a variety of concrete and visual aids to help with this material.
- Models and manipulatives will be helpful to all students as they consider the effects of El Niño and La Niña.
- Check often for comprehension, among all students, and especially English language learners. Students may need to demonstrate their understanding of the concepts in a variety of ways.
- If interest centres have already been established on this topic during earlier sections, encourage students to review the material at the centres. If not, create an interest centre on this topic and have students add to it as they complete the investigation.
- Use **BLM A-19 Graph from Data Checklist** and **BLM A-33 Interpreting Data Rubric**.

Answers

1. and **2.**



1. 1977, 1979, 1982, 1986 to 1987, 1991 to 1994, 1997 to 1998, 2002 to 2006

2. 1983 to 1985, 1988 to 1989, 1995 to 1996, 1998 to 2000, 2005, 2007

3. 1978, 1980, 1981, 1990

4. The graphs show temperature and precipitation in Canada.

5. During the winter of an El Niño event, the air temperature tends to be warm over most of Canada, with the greatest warming centred around Manitoba and western Ontario, where a temperature deviation of up to +3°C (averaged over the last nine El Niño events) can be found. Southern Canada also tends to be drier during an El Niño winter. Southern British Columbia tends to receive less snow.

6. In the case of the cold La Niña event—the opposite of the warm El Niño event—the coastal waters off British Columbia tend to be cool. In a La Niña winter, the Canadian air temperature (especially west of Quebec) tends to be below normal. The precipitation in southern Canada tends to be above normal. Southern British Columbia tends to receive more snow.
7. The next El Niño event should occur in 2009 or 2010.
8. Changes to surface temperature in the oceans are caused by changes to the normal patterns of trade winds. If these trade winds reverse, warm waters in the Western Pacific move eastwards, warming the water off the coast of South America and causing heat and moisture to rise from the ocean off of Ecuador and Peru. The changes in atmospheric circulation affect the jet stream that normally flows over Canada, changing patterns of precipitation and temperature.
9. Students answers' will vary depending on their research results. Many atypical precipitation and temperature events, including the ice storm, coincide with El Niño events.
10. Students' answers will vary; however, they should mention that El Niño has effects on precipitation and temperature and how being aware of these effects can help people predict and adapt to changes in weather.
11. Students' answers will vary. Southern Oscillation (SO) reflects air pressure differences in the South Pacific Ocean. Using this term with the El Niño term identifies the cause of the phenomenon as changes in air pressure that affect trade winds.
12. Depending on where students get their data, they may or may not find correlations with northern sea ice anomalies and the El Niño and La Niña events. Have students properly identify their sources of information. They can compare results with other students who are also extending their skills on this question.

Plan Your Own Investigation 8-B Comparing Heat Absorption of Water and Soil (Student textbook page 343)

Pedagogical Purpose

The characteristics of water and soil are significant factors in the weather and climate of a region. Students design their own investigation to explore their hypothesis about the ability of soil and water to absorb and release heat. Students then extend their thinking to infer how the temperatures of soil and water affect local conditions.

Planning		
Materials	Retort stand 2 clear plastic containers 2 thermometers Water Masking tape	Ruler Overhead light with clamp Watch or clock Dark, dry soil
Time	45 min	
Safety	• Ensure students wear thermal gloves when touching the lamp. • Remind students to be careful to make sure the lamp and cord do not make contact with the water. • Check lamp cords for fraying. • Test light bulbs before the lab. Replace any broken bulbs.	

Background

The key to this investigation is to recognize that water has a much greater specific heat capacity than dry soil.

Because water has a high specific heat capacity, its temperature will not increase as much as the temperature of nearby land. It warms the air to a lesser degree than land during the day. However, at night, the situation is reversed because the land will have cooled and cools the air above it. The water, taking longer to cool, will continue to warm the air above it.

Activity Notes and Troubleshooting

- Students' plans should involve exposing the soil and water to the same amount of radiant energy and measuring the temperatures over a period of timed intervals. To facilitate the placement of the thermometers, have students place the thermometers in the water first (because they will be able to see where the bulbs are) and then match the height of thermometers in the soil. Both thermometers must be equal to control the experiment.
- If students are having trouble coming up with a plan, have an experimental setup at the front of the class and have a discussion on what could be measured and compared using the setup.

Additional Support

- Have students recall Activity 8-2 What Heats the Atmosphere? The results of that activity may help students visualize what needs to be done in this investigation.
- As a class, review specific heat capacity. Have students research the specific heat capacity of different materials. Their findings can be posted at the front of the class.
- Have students work in mixed-ability groups, making sure that everyone has a defined role to play.

- Break the investigation into chunks, beginning with developing the hypothesis. Once students have come up with an approved hypothesis, have them move onto planning. You may wish to have students complete each chunk on a different day, so students can consider their hypothesis and ideas for a day before completing the rest of the investigation.
- Provide students with **BLM G-30 Developing a Hypothesis** and **BLM G-33 Experimental Design Worksheet** for support.
- Use **BLM A-3 Designing an Experiment Checklist**, **BLM A-27 Hypothesizing Rubric** and **BLM A-31 Designing Experiments Rubric** for assessment.
- For additional challenge, encourage students to answer Inquiry question 4 and extend their investigation to different materials.

Answers

1. The soil will absorb the most energy because it has a lower specific heat capacity and therefore warms up faster.
2. Students' answers will vary depending on their hypotheses and their results. Assuming they were able to rationalize their hypothesis, students should have results that support it.
3. A large body of water will require more time to heat up and cool down than the surrounding land. The climate of the surrounding region will be moderated by the water, because the water will always change more slowly. For example, when the Sun goes down, the air will cool, but the water will stay warmer. This will influence and warm the air more than if the large body of water was not present. Also, the water will heat the air above it (when the air cools at night), increasing the air pressure and causing breezes and wind to form.
4. Have students logically justify their hypothesis. Remind them of the albedo effect and to include their knowledge of albedo in their thinking. Students should be able to infer that glaciers and icecaps will cool the surrounding regions because they reflect more heat (thus absorb less). This is the opposite of what would happen with large bodies of water.

Problem-Solving Investigation 8-C Modelling the Greenhouse Effect (Student textbook page 344)

Pedagogical Purpose

Students explore the greenhouse effect and the influence it has on the environment. Students build models to compare the temperature with and without the greenhouse effect. This knowledge can then be extended to further their understanding of the anthropogenic greenhouse effect.

Planning		
Materials	For each group: 2 glass jars or transparent pop bottles (same size and shape) Light bulb Socket with clamp Watch, stopwatch, or clock Elastic band 2 small pieces of cardboard	Ring stand with clamp 2 thermometers or temperature probes Clear plastic wrap Graph paper Masking tape
Time	40–45 min	
Safety	Ensure students use caution when handling the lamp. The light bulb will become very hot. Check lamp cords for fraying. Test light bulbs before the lab and replace broken bulbs.	

Background

The greenhouse effect is caused by gases absorbing and emitting infrared radiation from Earth's surface that would otherwise have been lost into space. It is called the greenhouse effect because the water and carbon dioxide gas act in a similar way to the glass in a greenhouse, which allows shorter-wavelength radiations to be transmitted, but absorbs or reflects longer wavelength infrared radiation back into the greenhouse. On a hot, sunny day, unless the glass is covered, the plants in a greenhouse can be killed by this effect. Students are likely familiar with the fact that pets should not be left in cars on hot days.

Activity Notes and Troubleshooting

- Most students will put the cardboard and a thermometer in both beakers and plastic wrap over one beaker. The second beaker would act as a control. The plastic-wrapped test beaker should be much warmer than the control.
- Strictly speaking, the experiment is not only testing the ability of the plastic wrap to stop radiation from leaving the test beaker. The plastic is also stopping warmed air from leaving by convection.
- Remind students about the function of a control in experimental design. They may need reminding that the test and the control should both receive the same amount of radiation from the lamp.
- Ask students to keep movement to a minimum to avoid creating cooling breezes over the beakers.

Additional Support

- **ELL** Have students describe their proposed experimental setup to their partners or to you. Have students sketch and label the experiment setup.
- **DI** This is a good activity for spatial and logical-mathematical learners.
- Students can complete this investigation in mixed-ability groups.

- Enrichment—Have students design an experiment that actually uses carbon dioxide to test and measure its greenhouse effect. If time and resources permit, carry out the experiment.
- Provide students with **BLM G-17 Using Models and Analogies in Science**.
- Use **BLM A-6 Developing Models Checklist** for assessment.

Answers

1. The plastic-wrapped test beaker should have warmed more than the uncovered control.
2. The model was accurate in letting radiation penetrate a transparent medium, which then blocked infrared radiation from leaving again. The model was inaccurate because thermal energy could leave the control beaker by convection, thus resulting in a cooler temperature. Also, the plastic wrap allows most infrared radiation to be passed into the beaker. In a greenhouse or in the atmosphere, most infrared radiation is blocked. The heating effect is a result of short wave radiation absorbed at the surface being emitted as infrared radiation and then blocked.
3. Design ideas and refinements will vary. Example: Put actual carbon dioxide in the test beaker and place a transparent barrier over both. Use larger containers. Remove the infrared radiation from the lamp with thick glass or water in a glass tray. Put dark soil at the base of the beakers. Put soil and plants in both containers.
4. Students should extend their understanding of what the model represents to connect with the idea that more greenhouse gases (equivalent to more of a barrier) are being released due to human activity.
5. Student answers will vary. Design modifications could include the following: put actual carbon dioxide in the test beaker and place a transparent barrier over both; seal both beakers after putting a few drops of water in the test beaker; continue to add water (to increase water vapour and therefore greenhouse gases).