TOPIC 4.4

What interactions cycle matter through Earth's spheres?

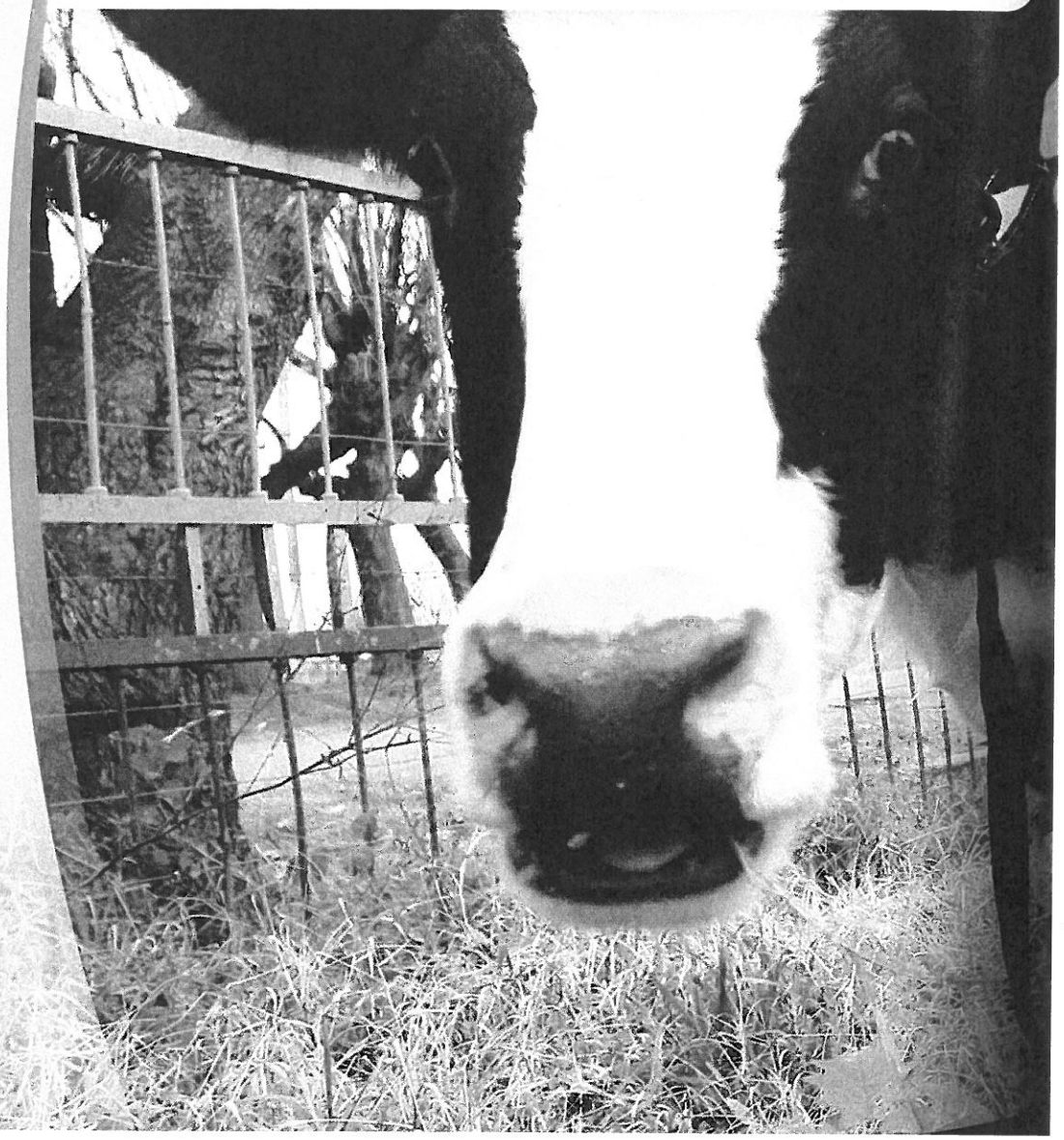
Methane (CH_4) is one of the more powerful greenhouse gases, and it comes from a perhaps unexpected source: cows. As you read in Topic 4.2, the true source of the methane in this case is the bacteria that live in the cows' guts. The cows release methane when they burp and "pass gas." Burping and windy cows might seem funny, but where the carbon cycle and climate change are concerned it's no laughing matter. Scientists in Argentina did an experiment in which they strapped plastic bags to the backs of cows (such as the one in the photo), ran tubes from the bags to the cows' stomachs, and collected the gases produced. The scientists discovered that one 550 kg cow produces 800 L to 1000 L of methane and other greenhouse gases per day. That's a lot when you consider that Canada has about 13 million cows!

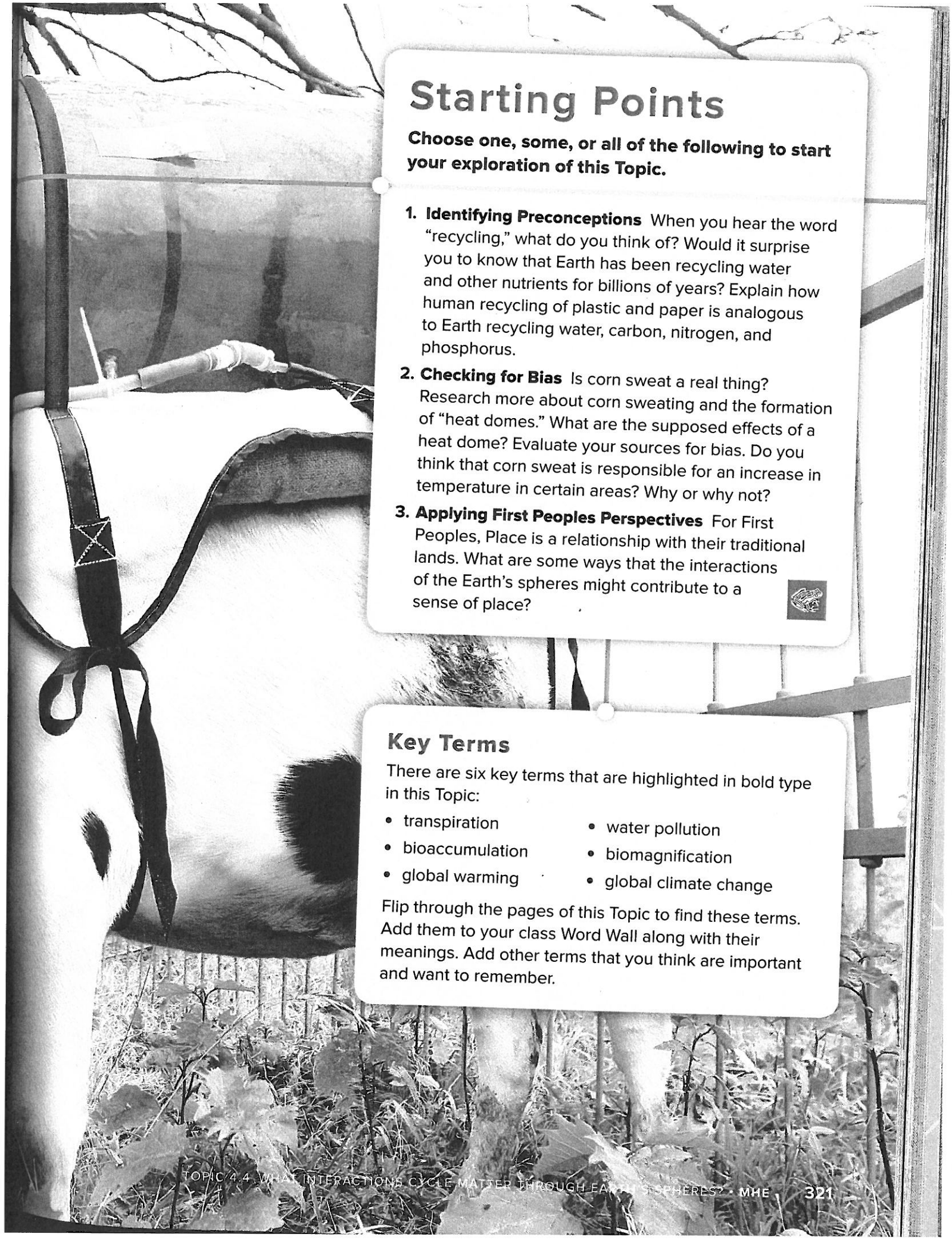
Key Concepts

- The water cycle is a continuous cycle driven by solar energy and gravity.
- Carbon is cycled through interactions between living and non-living things.
- Nitrogen is cycled through interactions between living and non-living things.
- Phosphorus is cycled through interactions between living and non-living things.

Curricular Competencies

- Formulate multiple hypotheses and predict multiple outcomes.
- Analyze cause-and-effect relationships
- Demonstrate an awareness of assumptions, question information given, and identify bias





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you hear the word "recycling," what do you think of? Would it surprise you to know that Earth has been recycling water and other nutrients for billions of years? Explain how human recycling of plastic and paper is analogous to Earth recycling water, carbon, nitrogen, and phosphorus.
2. **Checking for Bias** Is corn sweat a real thing? Research more about corn sweating and the formation of "heat domes." What are the supposed effects of a heat dome? Evaluate your sources for bias. Do you think that corn sweat is responsible for an increase in temperature in certain areas? Why or why not?
3. **Applying First Peoples Perspectives** For First Peoples, Place is a relationship with their traditional lands. What are some ways that the interactions of the Earth's spheres might contribute to a sense of place?

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- transpiration
- bioaccumulation
- global warming
- water pollution
- biomagnification
- global climate change

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

The water cycle is a continuous cycle driven by solar energy and gravity.

Activity

Amount of Water on Earth

On a map of Canada or British Columbia, locate Vancouver and the Tsay Keh Dene Nation at the north end of Williston Lake. The distance between these two locations is nearly 1400 km. Now picture a ball with a diameter of 1400 km. (In other words, the ball is 1400 km across.) All the water on Earth could fit into that ball. Do you think that is a lot or not? Explain.

When you study **Figure 4.16**, you can see that there is water on Earth's surface in the form of ponds, lakes, rivers, the ocean, snow, and ice. There is water under Earth's surface in the form of ground water. And there is water in the air in the form of water vapour. All this water continuously cycles through ecosystems by means of the interaction of three main processes: evaporation, condensation, and precipitation.

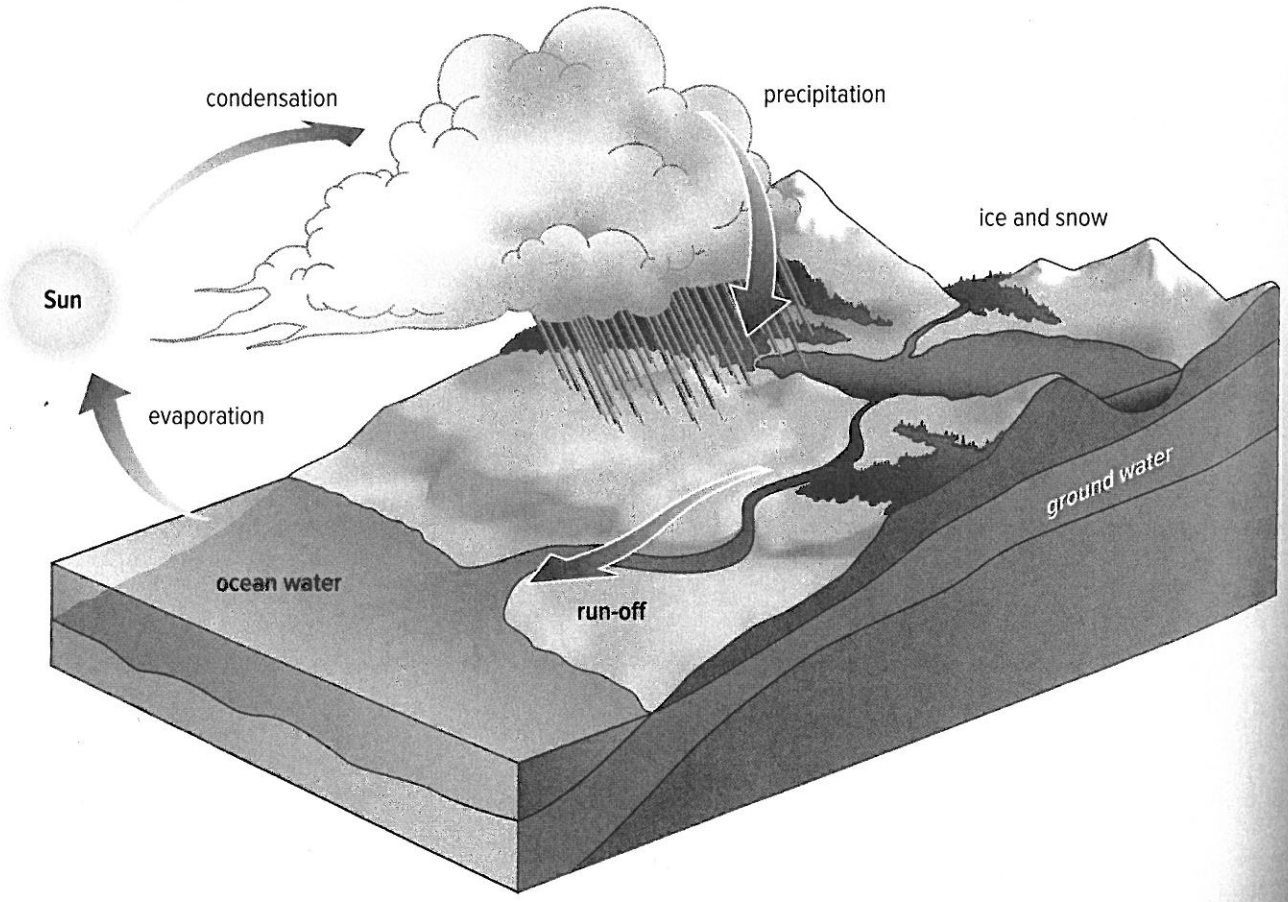


Figure 4.16 During the water cycle, water is exchanged among the hydrosphere, atmosphere, and geosphere.

The Water Cycle

Heat from the Sun causes water at Earth's surface to evaporate. As the warm air rises, it cools and condenses, forming clouds. Water falls back to Earth's surface when it rains, snows, sleets, or hails. Water that moves over Earth's surface is called run-off and moves downhill toward the lowest point due to gravity.

So far, you've seen that water moves through the hydrosphere, the atmosphere, and the geosphere. What about the biosphere? One process that involves water moving through the biosphere is transpiration. **Transpiration**, shown in **Figure 4.17**, is the process by which water is absorbed by the roots of plants, carried through the plant, and lost as water vapour through small pores in the leaves.

transpiration process by which water is absorbed by the roots of plants, carried through the plant, and lost as water vapour through small pores in the leaves

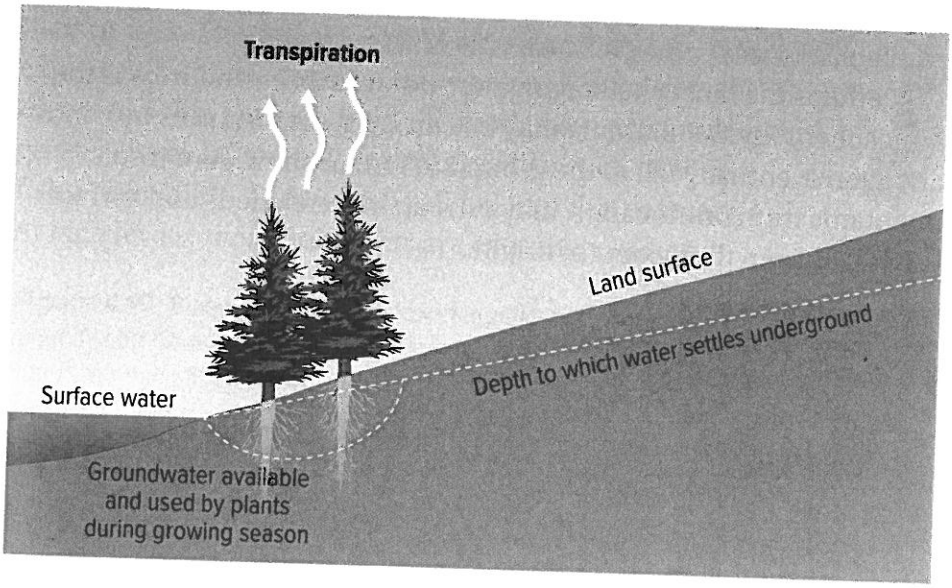


Figure 4.17 Studies show that about 10% of water vapour in the atmosphere is released by plants.

Activity

Model the Water Cycle

Use materials provided by your teacher to model the water cycle. Trace a single drop of water through your model.

Connect to Investigation 4-F on page 337

Extending the Connection

Water Conservation

The water cycle ensures that Earth will never run out of water. In fact, the total amount of water on Earth (the amount in that 1400-km-diameter ball) always stays the same. So why are we concerned about conserving water resources? (Hint: What is the difference between the total amount of water on Earth and the amount of water that is available in any one place at any one time?)

Human Impact on the Water Cycle

water pollution any physical, biological, or chemical change in water quality that has an adverse effect on organisms or that makes water unsuitable for desired uses

Water pollution is any physical, biological, or chemical change in water quality that has an adverse effect on organisms or that makes water unsuitable for desired uses. Water may be polluted by natural sources such as volcanoes and landslides. However, human activities can affect water quality as well.

Point sources of water pollution, such as the one shown in **Figure 4.18**, include factories, power plants, sewage treatment plants, and oil wells. These sources are fairly easy to monitor and regulate. Non-point sources of water pollution, also shown in **Figure 4.18**, include run-off from farm fields and feedlots, lawns, construction sites, logging areas, roads, and parking lots. Pollution from non-point sources tends to be periodic. As a result, it is more difficult to monitor, regulate, and treat non-point sources of water pollution.

Perhaps the most challenging non-point source to address is the atmosphere itself. Pollutants may be carried great distances by winds and then eventually fall to the ground in rain or snow. As a result, pollutants from one location may turn up in watersheds and surface waters far from their point of origin.

Figure 4.18 Industrial pipes that discharge waste are a point source of water pollution. Run-off from construction sites is a non-point source of water pollution.

Activity

Write Your Own Take a Stand Feature

Use the Internet and other resources to research water pollutants in your area. Choose one water pollutant that interests you. Find a specific instance where it has caused a problem in your area. Use the Take a Stand feature in this textbook as a model to write your own feature. At a minimum, your feature should include

- a description of the problem, including the pollutant involved, its source, and its effect on the environment and/or human health
- solutions as to how the problem can be dealt with

Organisms Magnify Water Pollutants

Some pollutants do not degrade easily so they stay in the environment for a long time. These include the pesticide DDT, heavy metals such as mercury, and PCBs. PCBs are chemicals that were used in hundreds of different products, from plastics to paints. Production of both DDT and PCBs is now banned in Canada. Why is this the case?

DDT and PCBs, along with heavy metals, enter waterways and are taken up by microscopic organisms such as phytoplankton and bacteria. The pollutants collect in the cells and tissues of these organisms. This process is called **bioaccumulation**. When predators, such as zooplankton and fish, eat these organisms, the pollutants build up further in the predators' fatty tissues. Because predators consume a lot of prey, the pollutants become concentrated in their tissues. This effect is called **biomagnification**. **Figure 4.19** explains how these two processes occur. Notice how the organisms that are highest in the food chain accumulate the greatest levels of the pollutant. Large fish such as sharks, fish-eating birds, and humans all fall into this category. At high levels, these pollutants are extremely harmful.

bioaccumulation the process by which pollutants collect in the cells and tissues of organisms

biomagnification the increase in concentration of pollutants in tissues of organisms that are at successively higher levels in a food chain or food web

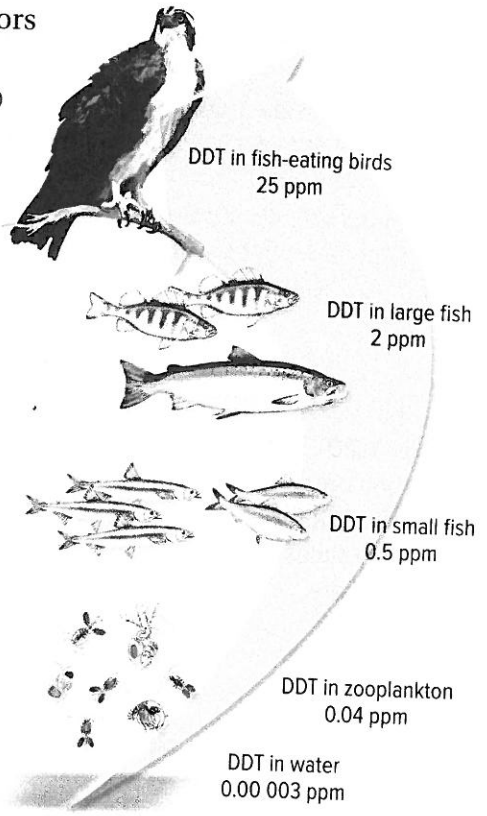


Figure 4.19 Bioaccumulation and biomagnification work together to magnify certain water pollutants in large predators. The unit ppm means "parts per million" of the pollutants. One part per million (1 ppm) is like one second in 11.5 days, or one minute in two years, or one car in bumper-to-bumper traffic from Vancouver, British Columbia, to Toronto, Ontario. **Would someone who eats small fish such as sardines consume as much DDT as someone who eats large fish such as tuna? Why or why not?**

Activity

Pass It On

Design an activity to explain bioaccumulation and biomagnification to a class of younger students. Create your activity, and then test it on a group of students. Improve the activity based on any feedback you receive.

Before you leave this page . . .

1. A cycle is a pattern of change that repeats itself forever. In what way does the water cycle demonstrate the features of a cycle?
2. Describe how transpiration ties the hydrosphere and the biosphere together.
3. Make a T-chart to list the differences between point source and non-point source water pollution.
4. Compare and contrast bioaccumulation biomagnificationt.

CONCEPT 2

Carbon is cycled through interactions between living and non-living things.

Activity

Sources and Sinks

In each of the nutrient cycles you will read about next, the carbon cycle, the nitrogen cycle, and the phosphorus cycle, there are sources of each nutrient and sinks for each nutrient. A source is any process that releases more of the nutrient than it absorbs. A sink is just the opposite, any process that absorbs and stores more of the nutrient than it releases. As you read about each nutrient cycle, identify the sources and sinks for the nutrient. Record the information in a table that you create.

Figure 4.20 shows how carbon moves through Earth's spheres. Carbon dioxide gas moves from the atmosphere into the biosphere and back again through the processes of photosynthesis and cellular respiration. Carbon dioxide also moves back to the atmosphere when organisms die and their bodies decompose. Carbon enters the geosphere when the remains of organisms are trapped under layers of sediment.

Not all the carbon involved in the carbon cycle is used immediately by living things. Some is stored in the woody tissues of long-living trees. Some is stored in the slowly decomposing remains of organisms, which become buried deeply in the ground. With the passage of time, some of this stored carbon will eventually be transformed into the carbon-rich fuels that we know as coal, oil, and natural gas. This is what happened about 300 million years ago to form the coal, oil, and natural gas that we use today as fuel.

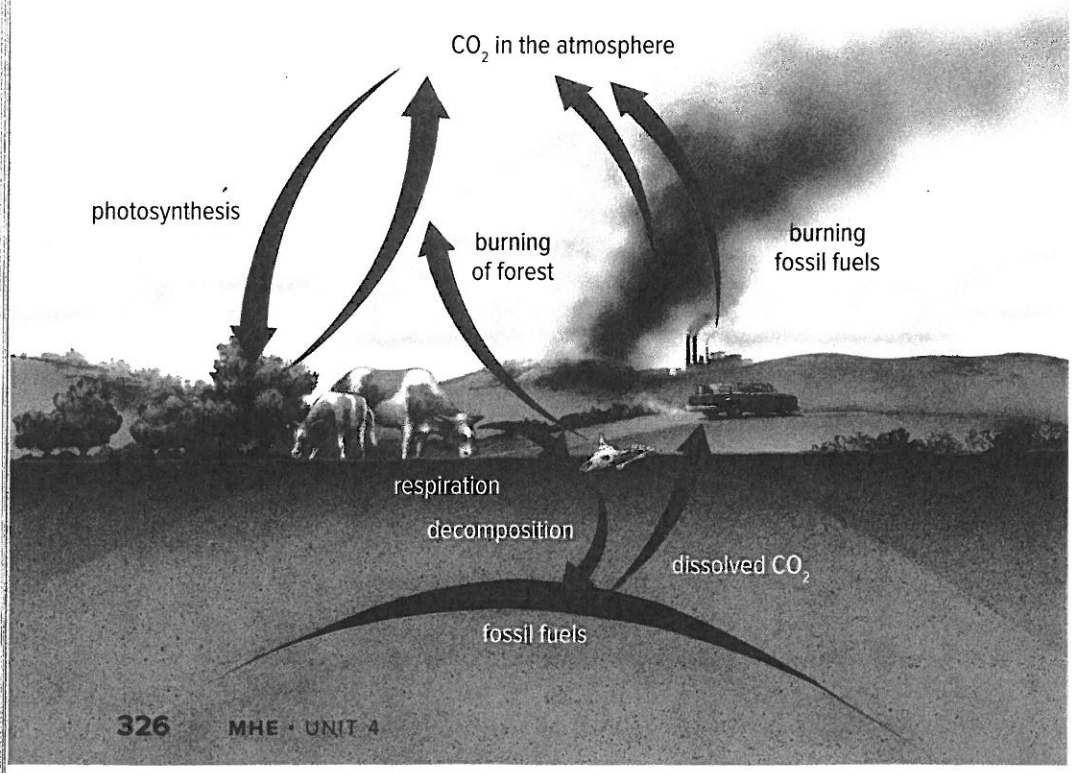


Figure 4.20 During the carbon cycle, carbon is exchanged among the biosphere, atmosphere, and geosphere.

Upsetting the Balance

The amount of carbon dioxide that is used by photosynthesis and given off by cellular respiration is nearly the same. In this way, the amount of carbon dioxide is balanced. However, when we burn trees, coal, oil, and natural gas for fuel, the carbon stored long ago is released into the air in the form of carbon dioxide. This upsets that balance. As well, human activities have removed huge numbers of trees to make space for homes, buildings, and farmland, and to make products such as furniture and paper. So, there are fewer trees available to use the extra carbon dioxide in the atmosphere. As a result, the extra carbon dioxide builds up in the air and helps to trap heat in the atmosphere. This is one of the sources of the extra carbon dioxide that adds to the processes known as **global warming** and **global climate change**.

Climate change can be caused by either natural factors or human activity. Earth has experienced many periods of climate change due to natural processes such as natural variations in greenhouse gases, changes in ocean and atmospheric circulation, and changes in Earth's orbit. For example, during the Cretaceous period, around 90 million years ago, high levels of volcanic activity released large amounts of carbon dioxide into the atmosphere, quadrupling the concentration of carbon dioxide in the atmosphere compared to today's values. Carbon dioxide is a significant greenhouse gas. As a result, global temperatures rose well above average. The graph in **Figure 4.21** shows that scientists estimate that the temperature of water at the bottom of the ocean during that time was about 19°C. Today water near the bottom of the ocean is around 3°C.

global warming an increase in the average temperature of Earth's surface

global climate change a long-term change in Earth's climate

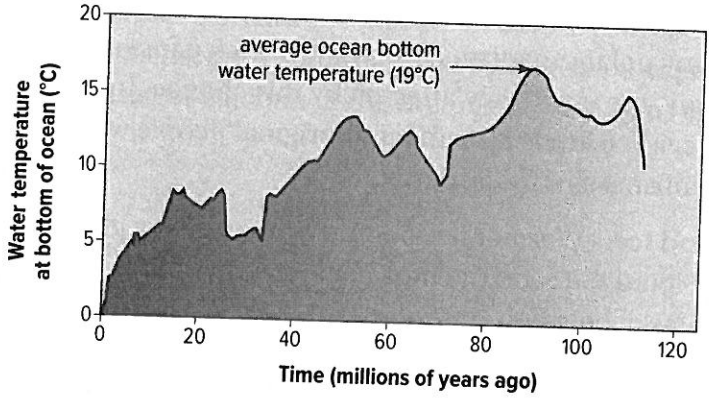


Figure 4.21 High levels of volcanic activity released greenhouse gases that warmed global temperature significantly during the late Cretaceous period. As a result, scientists estimate that the temperature of water at the bottom of the ocean was near 19°C.

Unlike events in the past, current climate change is the result of human actions. There is a solid relationship between the recent increase in greenhouse gases (at least 70% in the last 40 years) and rapidly increasing global temperatures. This increase in greenhouse gases is mainly due to human activities that burn fossil fuels. These activities release carbon dioxide and other greenhouse gases, such as methane, chlorofluorocarbons, and nitrous oxide.

The Effects of Excess Carbon in the Carbon Cycle

Earth's surface temperature has increased by between 0.56°C and 0.92°C in the past 100 years. This small change may not seem like a big deal. However, it is important to keep in mind that Earth's climate is a system. This means that a change in one aspect of climate, such as temperature, can result in changes to other aspects, such as precipitation levels, wind patterns, and storm severity. Climate change is expected to affect conditions in all of Earth's spheres. Some of these changes are already evident, as you will read below. The flowchart in **Figure 4.22** explores some relationships between warming global temperatures and their effects around the world.

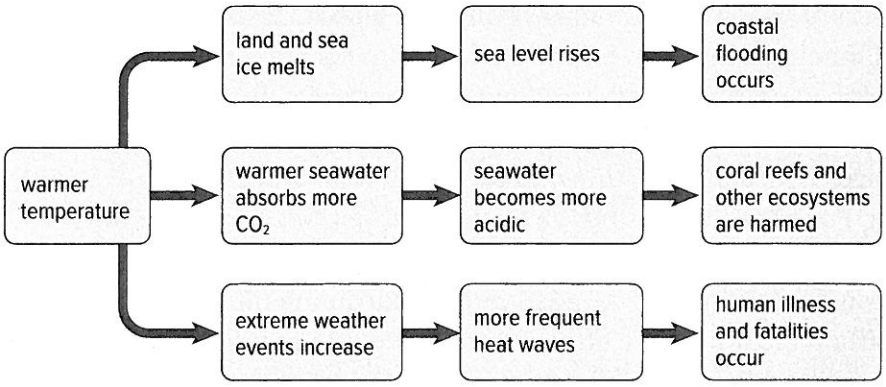


Figure 4.22 Warmer global temperatures are linked to changes in Earth's environment.

Melting Sea Ice—Warmer temperatures are causing sea ice to melt in the Arctic and Antarctic. Between 2005 and 2007, sea-ice levels in the Arctic Ocean decreased by 20%. This is the largest change in sea-ice levels recorded since scientists began taking these measurements in 1978. Many polar organisms that rely on sea ice for survival, such as polar bears, are negatively affected by this change. In the Arctic, decreasing sea-ice levels also affect Aboriginal people who hunt marine organisms as a food source.

Melting Land Ice—Warmer temperatures are melting glaciers around the world. **Figure 4.23**, on the next page, shows changes in the Bear Glacier in Alaska between 2002 and 2007. Glacial melting changes the volume and flow of rivers. These changes affect local flooding, sea level, and water available for human use, such as irrigation. As temperatures continue to warm, permafrost (permanently frozen ground) in the higher latitudes is also at risk of melting. Permafrost covers one quarter of the northern hemisphere to a depth of 700 m. When it melts, it is expected to release large amounts of methane gas that will accelerate climate change.

Rising Sea Level—Sea level is rising at a rate of about 2 mm to 3 mm per year. Already, two uninhabited islands in the Pacific Ocean have slipped beneath the waves. Salt water is also intruding into underground supplies of drinking water. In addition to coastal flooding, sea-level rise destroys wetlands, mangroves, and salt marshes. These are important habitats for aquatic organisms and birds. Melting land ice is linked to this rise in sea level, and its effects will increase as the planet warms. For instance, the Antarctic Ice Sheet contains 90% of Earth's ice. Scientists predict that complete melting of the ice sheet will raise sea level by 50 m.

Changing Ocean Chemistry—Sea surface temperature has increased over the last 100 years and is continuing to rise. As oceans warm, seawater absorbs more carbon dioxide from the air. When this gas dissolves in ocean water, the water becomes more acidic. This has a harmful effect on ocean ecosystems, as explained below.

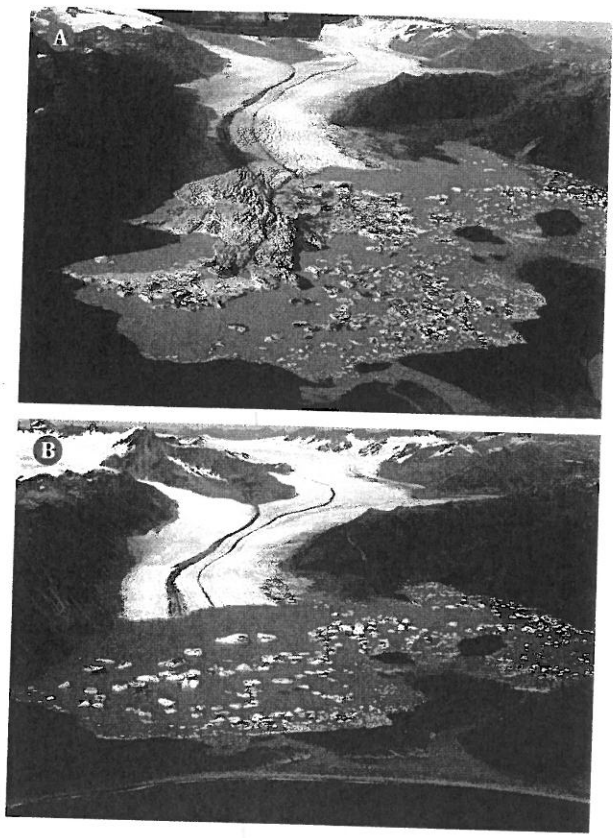


Figure 4.23 Bear Glacier can be viewed from northern British Columbia. Photo A of the glacier was taken in 2002. Photo B shows the glacier in 2007. Between 2002 and 2007, the glacier retreated by several kilometres and decreased significantly in height.

Changing Ecosystems—Changes in temperature, ocean chemistry, and sea level are altering global ecosystems. When possible, organisms are relocating their habitats and moving out of these danger zones. Plant growth patterns have shifted north over the last 30 years due to warmer temperatures. When a move is not possible species may not be able to survive. Corals that form reefs are one example of temperature-sensitive organisms that are unable to move. Corals, as well as shelled organisms, are also threatened by increased ocean acidity. This acidity dissolves calcium in the organisms' skeletons and shells.

Extending the Connection

Climate Change and Human Illness

Conduct research to find out more about how excess carbon in the carbon cycle leads to human illness and fatalities. Create an infographic to display the results of your research. Be sure to include any relevant facts or statistics in your product.

Before you leave this page . . .

1. How does burning fossil fuels upset the balance of the carbon cycle?
2. Make a table to describe the effects of excess carbon in the carbon cycle on each of Earth's spheres.

CONCEPT 3

Nitrogen is cycled through interactions between living and non-living things.

Activity

Fertilizer Ingredients

Read the ingredients on the bag of fertilizer provided by your teacher. Do you think fertilizer is a source or a sink for nitrogen in the nitrogen cycle? How do you think applying fertilizer to agricultural crops and gardens could affect the nitrogen cycle? How might it affect the hydrosphere and the biosphere?

Nitrogen is another nutrient that cycles in ecosystems. It is a major part of all cells and a key building block for proteins, which all cells need. Nitrogen makes up 78% of air, but most living things cannot use nitrogen from the air. Instead, they depend on certain kinds of bacteria, called nitrogen-fixing bacteria, in the soil and water to change the nitrogen into forms that plants can use. These forms include ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). **Figure 4.24** shows how nitrogen moves through Earth's spheres.

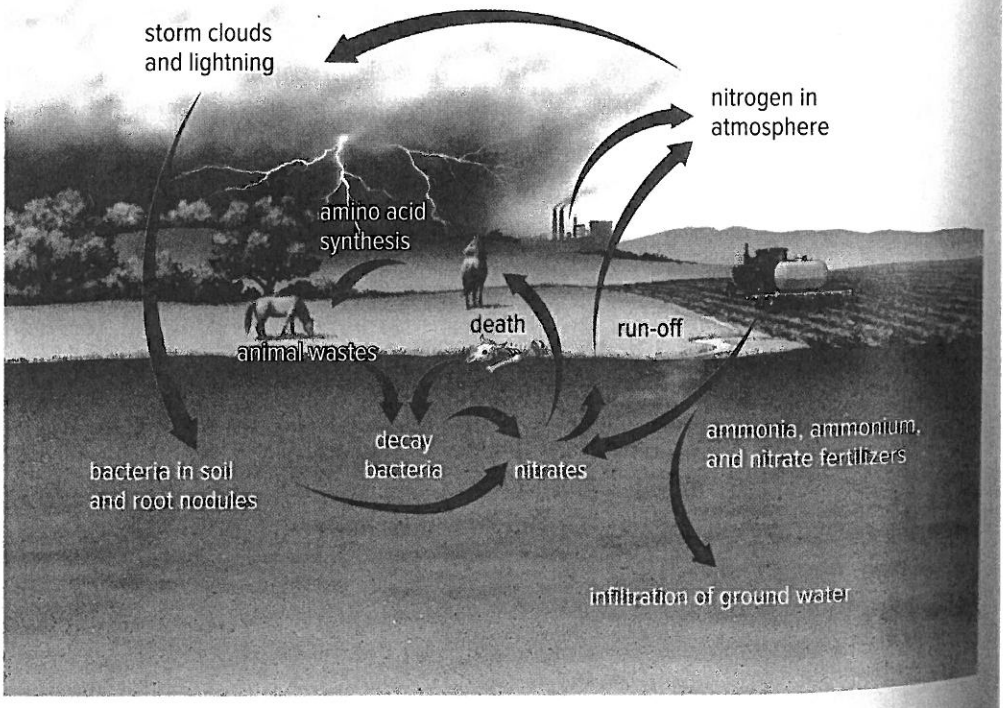
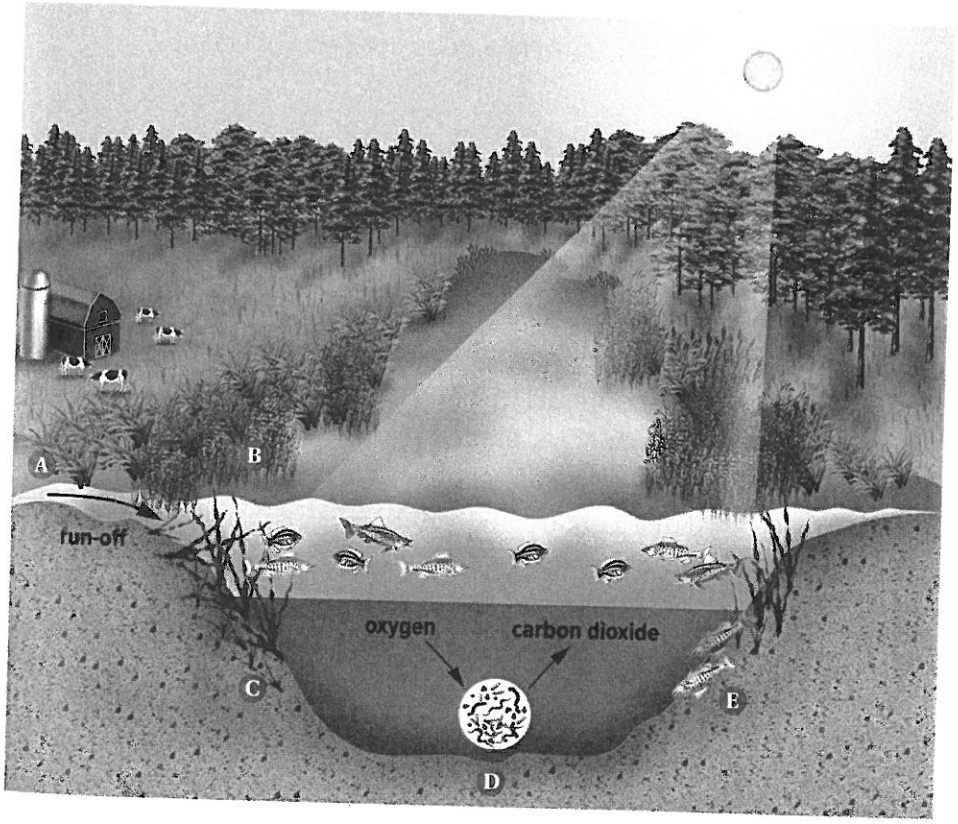


Figure 4.24 During the nitrogen cycle, nitrogen is exchanged among the atmosphere, biosphere, and geosphere.

Excess Nitrogen

Human activities dramatically increase the concentration of nitrogen in the atmosphere and the biosphere through the use of fertilizers (which contain nitrates), combustion of fossil fuels (which emits gaseous nitrogen oxides), and the clearing of forests and grasslands. For example, farmers and gardeners use fertilizers to enhance the growth of their plants. However, not all the nitrogen in the fertilizers is used by the plants. Some stays in the soil. When it rains, or when fields are watered, some of the nitrogen is carried into aquatic ecosystems. This excess nitrogen can cause an overgrowth of algae called an algal bloom. **Figure 4.25** shows how an algal bloom can affect an aquatic ecosystem.

Figure 4.25 An algal bloom is caused by too much of a nutrient, such as nitrogen, entering an aquatic ecosystem.



- **A** Rain carries nitrogen from farms, gardens, and lawns into aquatic ecosystems.
- **B** Algae and plants at the water's surface grow quickly. This blocks sunlight from reaching deeper water.
- **C** Deep-water plants get no sunlight. They cannot carry out photosynthesis, so they no longer give off oxygen, and they soon starve to death.
- **D** When the plants die, decomposers have lots of food. The number of decomposers increases quickly. They use up the oxygen in the water as they carry out cellular respiration.
- **E** As oxygen in the water is used up, aquatic organisms that need the oxygen suffocate and die.

Before you leave this page . . .

1. Why are bacteria an important part of the nitrogen cycle?
2. How does excess nitrogen in the nitrogen cycle affect the biosphere?

CONCEPT 4

Phosphorus is cycled through interactions between living and non-living things.

Activity

Algal Blooms

Have you ever been near a body of water that is experiencing an algal bloom? If so, use your observations to help answer the questions in this activity. Whether you have or have not seen an algal bloom in real life, locate and study photos of algal blooms. How do you think the air smells during an algal bloom? Would you go swimming or fishing in water experiencing an algal bloom? Why or why not? How do you think an algal bloom might affect drinking water? What do you think happens after the bloom and fish kill are over? What happens to all of the dead fish? How does the body of water recover from an algal bloom?

Phosphorus is another nutrient that cycles in ecosystems. Phosphorus is essential for the growth and development of organisms. **Figure 4.26** shows that phosphorus is stored in the geosphere. When rock material is broken down through natural weathering processes, phosphorus is released into soil and water. Plants and plant-like organisms in water absorb the phosphorus, and animals obtain it when they eat plants, plant-like organisms, and other animals. Decomposers return phosphorus to soil and water as they break down dead organisms. Human activities also release phosphates into soil and water.

Connect to Investigation 4-G on page 338

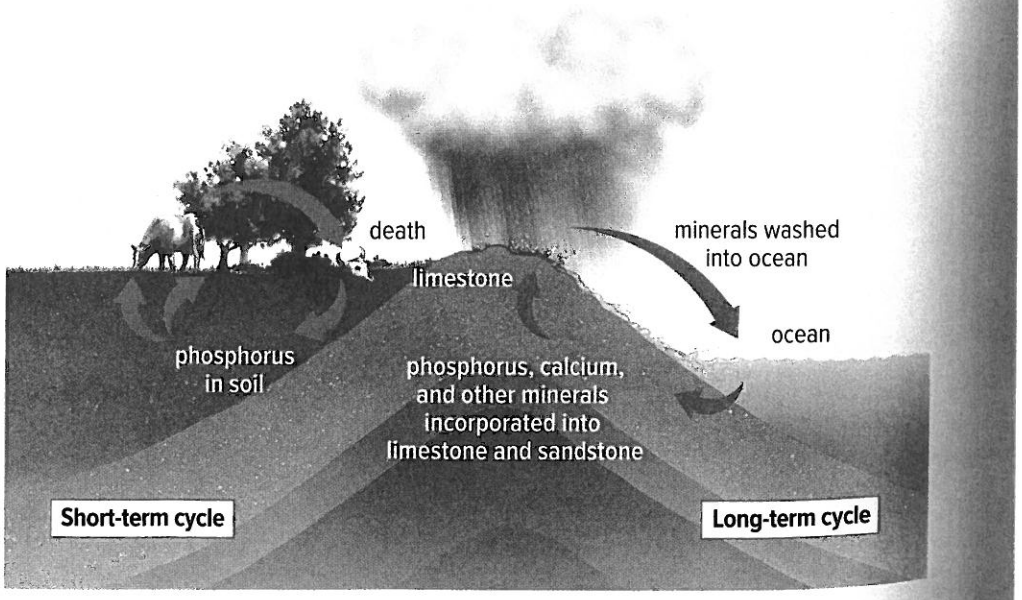


Figure 4.26 During the phosphorus cycle, phosphorus is exchanged among the biosphere, hydrosphere, and geosphere.

Excess Phosphorus

Along with nitrogen, phosphorus is also a main ingredient in fertilizer. Excess phosphorus in run-off from agricultural fields contributes to algal blooms, like the one shown in **Figure 4.27**, and subsequent death of aquatic organisms. Phosphorus is also found in household cleaners and dishwashing and laundry detergents. Although that may sound like a minor source, scientists estimate that removing phosphorus from dishwasher detergents alone could reduce the amount of phosphorus in run-off by 10%. In 2010, Canada banned any household cleaners and detergents that contain more than 0.5% of phosphorus by weight.

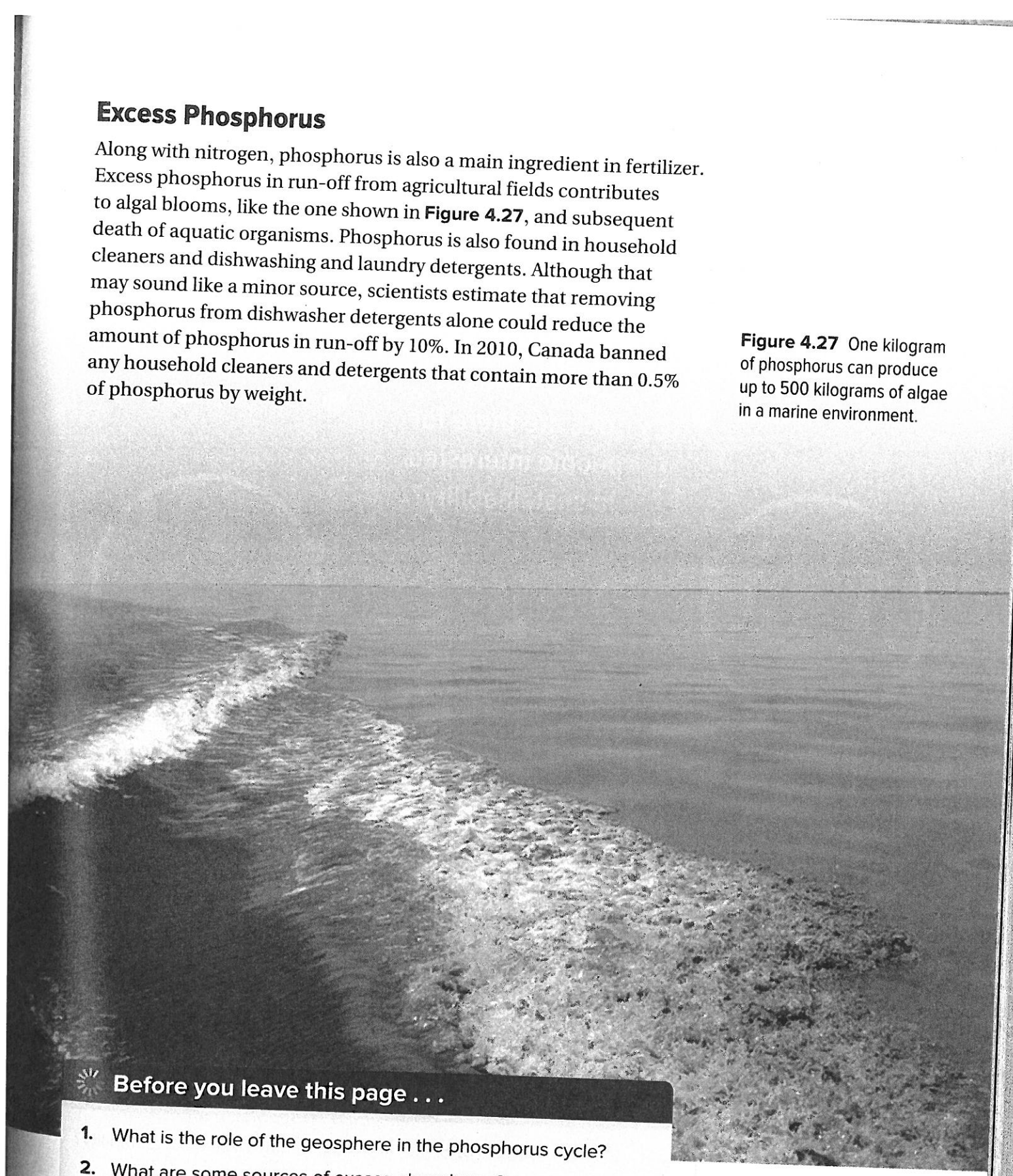


Figure 4.27 One kilogram of phosphorus can produce up to 500 kilograms of algae in a marine environment.

Before you leave this page . . .

1. What is the role of the geosphere in the phosphorus cycle?
2. What are some sources of excess phosphorus?
3. What actions could you take to help reduce the amount of excess phosphorus entering the phosphorus cycle?

Connect to Investigation 4-E on page 336

INVESTIGATION
4-E

OPEN INQUIRY

Where Do You Fit into the Nutrient Cycles?

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to online or print resources
- computer software for drawing or creating animations
- drawing materials, such as coloured markers, pens, or pencils, posterboard, and/or construction paper
- scissors
- tape

You have just read about the water, carbon, nitrogen, and phosphorus cycles—the sources and sinks in each and how humans and excess nutrients can affect the balance of the cycles. In this investigation, you will think about these cycles and your role in them on a more personal level.

Question

How do you fit into and affect each nutrient cycle?

Procedure

1. Your goal for this investigation is to create a representation of each of the four cycles listed above and show how you fit into each cycle and how you impact it.
2. Determine how you would like to represent each cycle.
3. Determine how you fit into each cycle. Decide how you will show that in your representation.
4. Determine how you impact each cycle. Decide how you will show that in your representation.
5. Share your ideas with your teacher.
6. Once approved, create your representations of each cycle.
7. Share your representations with other students.

Process and Analyze

1. What realizations did you make about your actions in relation to the cycles while completing this investigation?
2. How did your representations compare to other students? What did you learn from studying their representations?

Evaluate and Communicate

3. How could you change your actions to reduce your impact on each cycle? How could you show this in your representations?

Apply and Innovate

4. How could you use your representations to raise awareness about the impact of humans on each cycle?

INVESTIGATION
4-F

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Greywater: Recycling Household Wastewater

Greywater is household wastewater except for water from toilets and kitchen sources. Although not yet approved in all jurisdictions in Canada, there is a growing trend to recycle greywater for certain uses.

Question

What are important features of a greywater recycling system?

Procedure

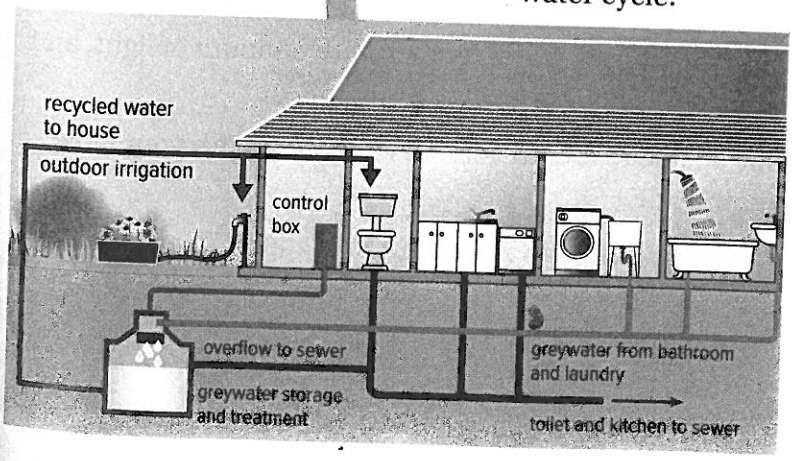
1. Analyze the schematic below, which shows a complete household system that uses greywater from all suitable sources.
2. Make a list of the key features of the system. For example, identify the sources of greywater, what is done with the greywater, and how it is used.

Analyze and Interpret

1. What is the recycled greywater used for?
2. For the system shown, is the recycled greywater used directly or is some type of treatment performed first? Why do you think it is set up this way?

Conclude and Communicate

3. In a chart format, list some benefits and risks of using recycled greywater.
4. Explain how greywater recycling fits into and benefits the water cycle.



5. Research the status of greywater use in your area. Is it legal? If so, what regulations are in place for its use?
6. Develop a design for a bathroom-specific system that uses greywater from the sink as a source of water to flush the toilet. Include a labelled sketch of your design to explain how it works.