UNIT 5

Fresh and Salt Water Systems

Water, water everywhere, but is it fit to drink? To wash our clothes in? To swim in? Think about how much we depend on fresh, clean water.

Most water on Earth is in the oceans. These huge bodies of water influence climate, affecting areas hundreds of kilometres inland. The oceans are also home to thousands of species of plants and animals, including the magnificent humpback whale shown here.

In this unit, you will discover how water — whether fresh, salt, or frozen — is distributed around the world. You will learn the many ways in which water affects our lives and the environment. You will also see how human activities influence not only the quantity of water but also its quality. As people use water — for drinking, agriculture, manufacturing, recreation, and other uses — they alter water systems. Some changes are obvious, such as irrigation and dam construction. These changes can lead to water shortages or to floods. Other changes are less obvious. For example, water may look fine to drink. However, it may contain harmful micro-organisms or toxic substances that have entered the water system from polluting sources.

By studying Earth's fresh and salt water systems, and the organisms that inhabit them, you will gain a greater appreciation for this precious resource. You will see the importance of monitoring and managing our water supplies in a way that ensures sustainability. Sustainability means meeting the needs of the present generation without hindering the ability of future generations to meet their needs, as well.

Unit Contents

UNIT 5

Preview

Focussing Questions

- What are the characteristics of water systems?
- How do water systems interact with the atmosphere and with Earth?
- How do water systems interact with human activities?

Where is water found on Earth? How much of Earth's water is fresh? Salty? Frozen? Topic 1 looks at the many ways in which we depend on water. Topic 2 examines icefields and icebergs. The Topic also examines the importance of those slow-moving rivers of ice known as glaciers.

In Topics 3-4, you'll explore the dynamics of fresh water systems and of oceans. You'll investigate the characteristics of surface water, groundwater, and seawater. You'll also find out how water, landforms, and climate are interrelated.

What do fresh water organisms need in order to survive? What do marine organisms need in their watery world? How can we monitor and protect aquatic systems, not only for ourselves, but for other living things as well? Find out in Topics 5-6.

Looking Ahead

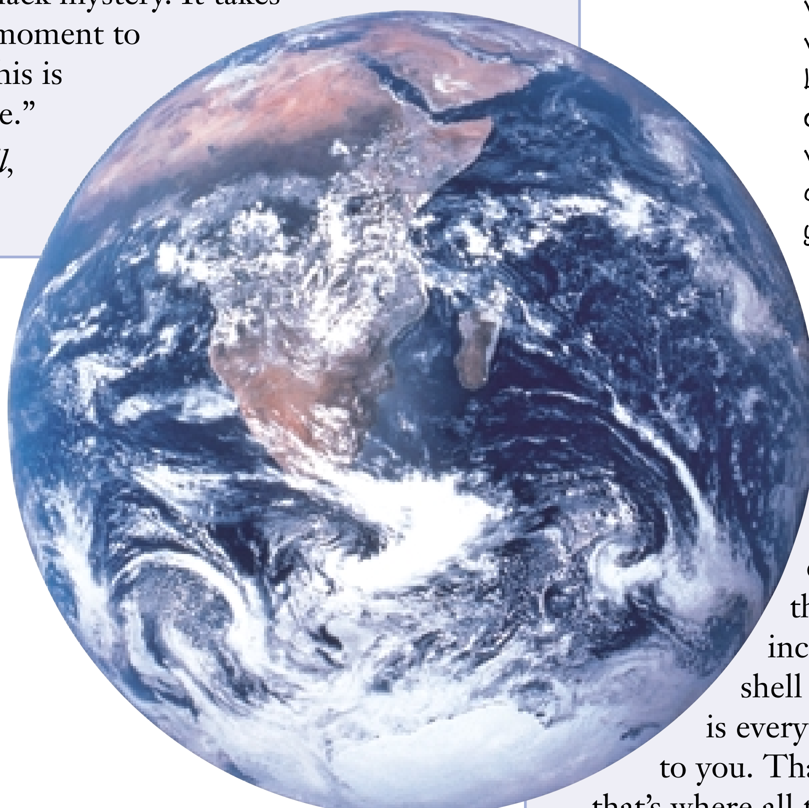
Read pages 472–473, "An Issue to Analyze: Water Watch." With your team members, you'll organize a local water action program. Collect information and resources now to prepare for this project.

- Save newspaper clippings related to water issues.
- Gather maps showing local water systems.
- Check out Internet sites related to water quality monitoring.
- Find out how to contact key people involved in water management.

TOPIC 1 A World of Water

"Suddenly from behind the rim of the moon, in long, slow-motion moments of immense majesty, there emerges a sparkling blue and white jewel, a light, delicate sky-blue sphere laced with slowly swirling veils of white, rising gradually like a small pearl in a thick sea of black mystery. It takes more than a moment to fully realize this is Earth ... home."

Edgar Mitchell, Astronaut



Science Log

What words and images come to mind when you think of water? In your Science Log, brainstorm a list of water-related words. You can also add illustrations if you like.

"Below was a welcoming planet. There, contained in the thin, moving, incredibly fragile shell of the biosphere is everything that is dear to you. That's where life is; that's where all the good stuff is."

Loren Acton, Astronaut

Word CONNECT

Most astronauts are scientists and engineers. However, when they express their feelings about Earth, astronauts often speak like poets. What evidence of poetic words do you see in the quotations on this page? Imagine you are an astronaut observing Earth from space. Create a poem or write a diary entry to record your thoughts, feelings, and impressions.

People who have seen Earth from space marvel at the beauty and majesty of our "blue planet." Our water-blue Earth, our home, is brimming with vibrant life. Water is the key to that life. More species of organisms inhabit water than any other places on Earth. Equally important, all organisms require water to survive. Scientists believe that life cannot exist unless there is water.

Most of the water on Earth, however, is salt water. **Salt water** is water such as ocean water and seawater that has a high salt content. About 97 percent of Earth's water is salt water, unfit for us to drink. Instead, we rely on a much smaller supply of **fresh water**. Fresh water is water such as lake water, river water, pond water, and well water that most organisms can drink or use for life functions. Find out how you use fresh water in the next investigation.

INQUIRY

INVESTIGATION 5-A

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Water at Home

How do you use water at home? How much of it do you use? In this investigation, you will chart the ways in which you use water. This is one way to observe your family's water use and to calculate how much water your family members use.

Question

How much water does your family use in one day, and what is it used for?

Procedure

1. **Identify** all the ways you and your family members use water at home. **Record** your ideas. You may want to use a graphic organizer such as a concept map. **Note:** For tips on using graphic organizers, turn to Skill Focus 2.

2. **Design** a summary chart like the one shown below. Give it a title. Use your list of ways to use water to fill in the first column.

3. **Design** small record sheets so you and your family can keep track of the length of time you use water during the day. Enter your family's data in your summary chart.

4. The table on the right lists average amounts of water used for some common activities. **Record** this data in the third column of your summary chart.

5. In the fourth column, **calculate** the total volume of water used for each activity.

Average Quantity of Water Used for Various Activities

clothes washer	230 L per use
dishwasher	65 L per use
toilet flush	20 L per use
bath	130 L per use
shower	25 L per min
faucet	12 L per min

Activity	Total time used	Rate of water use (see the table)	Total volume of water

Analyze

1. **(a)** Calculate the total amount of water used for *all* activities in your home in one day.

   (b) Calculate the average amount of water used for *each person* in your home in one day. (How can you get help for this question if you need it?)

2. Organize and graph the class data on home water use. Decide on a type of graph that you think will work best for showing your data.

Conclude and Apply

3. As a class, find the average quantities of water used, as well as the maximum and minimum quantities used. Use the average to calculate the total water consumption by the population in your town or city. How could you determine the accuracy of the figure you calculate?

4. The actual amount of water used in your home will vary, especially if you have water-saving devices such as low-volume toilets or showerheads. What are some other ways that you could reduce your water use?

How Do You Depend on Water?

Each of the trillions of cells in your body needs water to function. Fortunately, you are never very far from water in one form or another. In fact, about 65 percent of your body mass is water. Water is a part of all organisms. An apple is 84 percent water. If you were a watermelon, about 98 percent of your body mass would be water!

The amount of water in your body is not constant. Every breath you exhale releases gaseous water vapour into the air. Every cellular process uses up a tiny fraction of your body's water. To maintain a normal body temperature of 37°C, you give off water in the form of sweat. You lose water every time you eliminate wastes as well. You must replace the water you lose. To remain healthy, you need about 2.5 L of water each day. (How close to that amount were you in the previous investigation?)

Water is vital for survival. However, you depend on water for more than just basic, physical health. Water is vital, also, to the way of life and the quality of life of everyone in Alberta. You can see this for yourself in the next activity.

Pause & Reflect

How would your life be different if:

- you didn't have any saliva?
- your lungs weren't moist all the time?
- you couldn't sweat?
- you couldn't cry?

How is water connected to all of this? Write your ideas in your Science Log.

Find Out ACTIVITY

How Do We Use Water?

Do you like to swim, fish, ski, or skate? If so, then you depend on water. In what other ways do you depend on water? What about other people in your province?

Procedure

1. Study the illustration on these two pages. Identify all the uses of water that you can. Record them in a list.
2. There are many more uses of water. Add at least five more to your list.
3. Classify the water uses using an organizing system that makes sense to you.

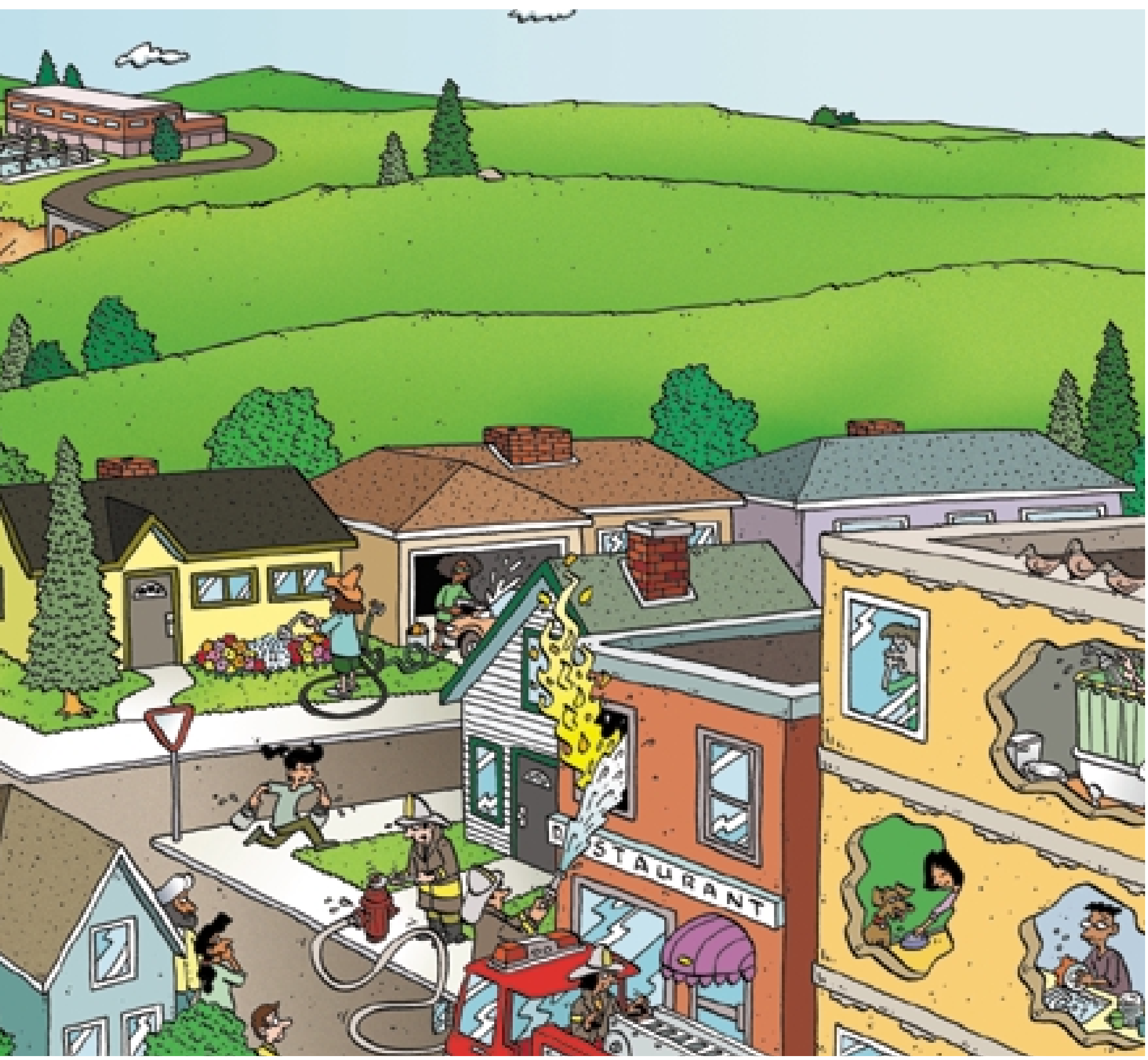
What Did You Find Out?

1. Compare your organizing system with others in the class. Reach a consensus on a useful system for classifying water uses.
2. "Water is vital to the quality of life of everyone in Alberta." What evidence do you have to support this statement? Write a short paragraph or draw an illustration to explain your answer.

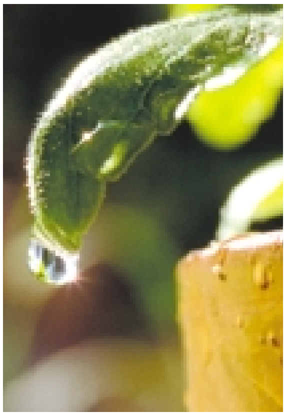
Extension

Analyzing and Interpreting

Agriculture, oil exploration, industry, cities, and thermal power stations are the five main users of water in Alberta. Do any of these surprise you? If so, explain why. If not, explain why not.



The Water Cycle



Have you ever gone for a walk in your neighbourhood just after a heavy rain? What do you notice? Water drips from leaves and runs along gutters or drainage ditches. There are puddles in parking lots and pastures, and footpaths across a playing field are muddy. A few hours later, the puddles are gone and sidewalks are dry. What has happened to the water?

Each drop of rain that falls must go somewhere. Some runs off the land into streams and rivers, and then pours into the oceans. Some soaks, seeps, and flows underground. Some goes into wetlands and lakes. Some appears to just "vanish" into the atmosphere.

Water is always on the move. The ability of water to "disappear" and to reappear somewhere else is not magic. It is the result of two common changes of state: evaporation and condensation. The continuous interaction of these two changes produces the water cycle (see Figure 5.1). The **water cycle** controls the distribution of Earth's water as it evaporates from bodies of water, condenses, precipitates, and returns to those bodies of water.

DidYouKnow?

If there were no water cycle, the current rate of evaporation of water from the oceans, lakes, rivers, and land would completely dry out Earth in about 3000 years.

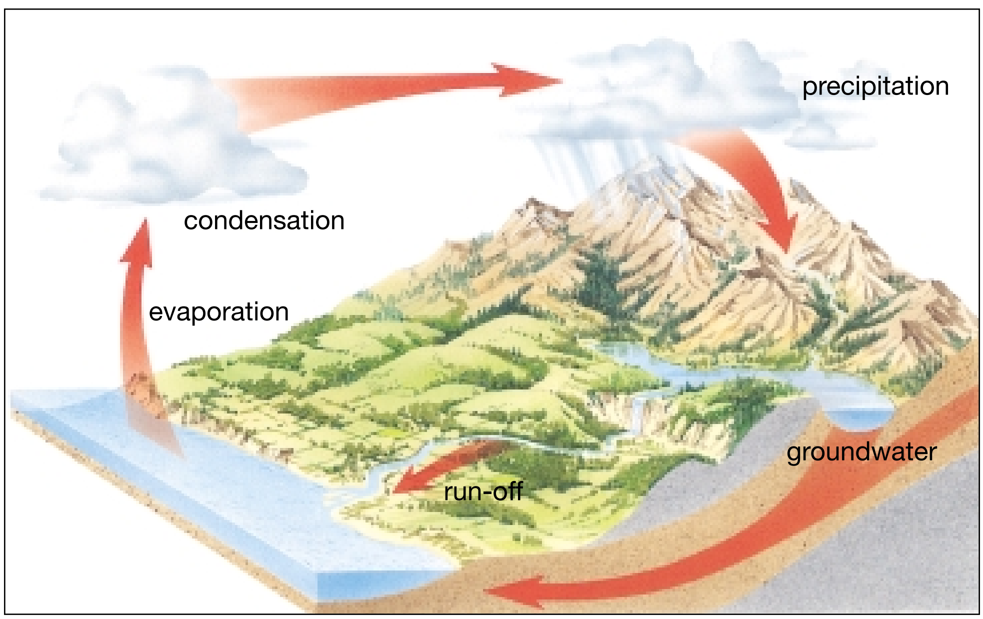


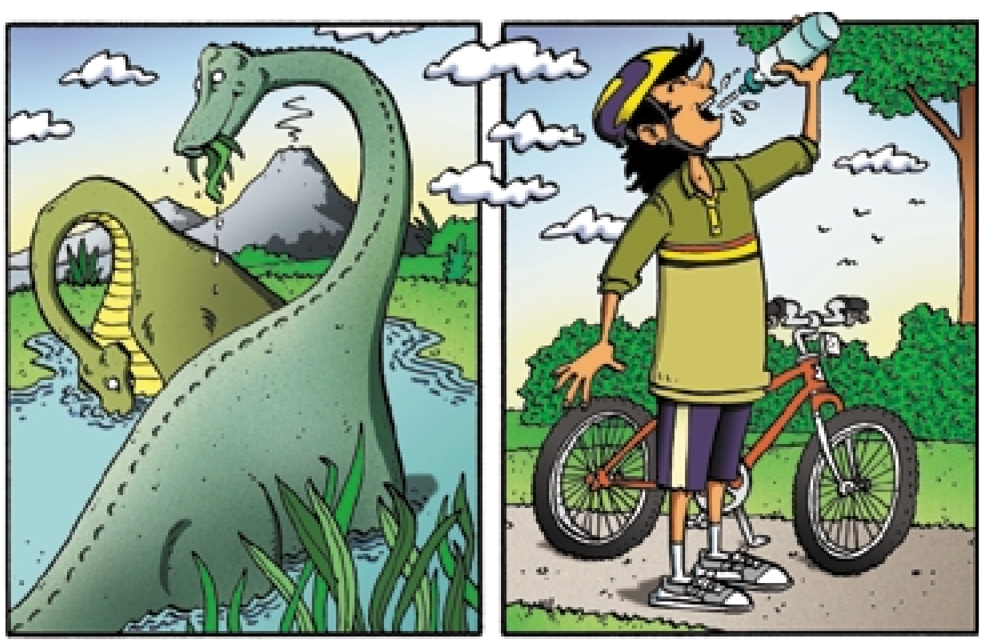
Figure 5.1 Water moves from Earth to the atmosphere and back to Earth again in the endless water cycle.

You may recall from previous studies that evaporation is the change of state from a liquid to a gas. Evaporation converts liquid water from Earth's surface into gaseous water vapour. There is always some water vapour in the atmosphere. Condensation is the change of state from a gas to a liquid. Gaseous water vapour remains in the atmosphere until it cools. As it cools, water vapour condenses to form clouds. Liquid and solid water fall from the clouds as precipitation — rain and snow.

STRETCH Your Mind

Just how big is 520 000 km^3? Imagine a much smaller space to start: 1 m^3. (Better still, why not make one out of metre sticks? How many do you need?) The space inside 1 m^3 can hold exactly 1000 L of water. Use that information to calculate the amount of water, in litres, in 520 000 km^3.

The Sun's energy drives the water cycle. Each year, about 520 000 km^3 of water from Earth's surface evaporates to form water vapour. Water vapour does not remain in the atmosphere for long, though. Eventually it condenses and falls to Earth. On average, there is enough water vapour in the atmosphere for only a ten-day supply of precipitation worldwide. About 78 percent of Earth's precipitation falls into the oceans.



Off the Wall

Water is always moving — flowing, evaporating, condensing. However, the overall amount of water on Earth is always the same. In fact, the total amount of the water on our planet and in the atmosphere has not changed for billions of years. A glass of water that you drink today may include some of the same water particles that cleaned and cooled a dinosaur's skin millions of years ago!

PROBLEM-SOLVING

INVESTIGATION 5-B

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

A Water Cycle Model

Reading about the water cycle can introduce you to the scientific ideas behind this important process. However, “getting your hands wet” can give you a much better understanding of how the water cycle works.

Challenge

Water is one of the few substances on Earth that can exist naturally in all three states: solid, liquid, and gas. Design a model to show water changing from a liquid to a gas and then back again. Then change the water to a solid and back again to a liquid.

Safety Precautions

- Be careful — you will be working with hot water and steam.
- Wear your safety glasses, apron, and gloves.
- Do this investigation only under the supervision of your teacher.

Materials

common items of your choice such as: electric kettle, bowls of various sizes, oven mitts or gloves, ice, hot plate, modelling clay, sand, soil, water, refrigerator, freezer

Design Specifications

A. Your model must demonstrate how water can exist in all three states.

B. Your model must demonstrate how water can change from a liquid to a gas, from a gas to a liquid, from a liquid to a solid, and from a solid to a liquid.

C. Your model does not need to be all in one location.

Skill FOCUS

For more information about the safety symbols used in this investigation, turn to Skill Focus 1.

Plan and Construct

1. With your group, plan how you will cause water to change state.
2. Draw a labelled sketch of your model, indicating what materials you will use.
3. Obtain your teacher's approval. Then construct your model.
4. Demonstrate how your model works.
5. Wash your hands after you complete this investigation.

Skill FOCUS

To learn more about how to use models in science, turn to Skill Focus 12.

Evaluate

1. **(a)** Did your model work as you expected?
   (b) What adjustments did you make so it would work, or work better?
2. **(a)** What scientific knowledge did you use to help you develop your model?
   (b) What scientific knowledge did your model help you develop?
3. How did the models constructed by other groups work? Did other groups have ideas that you would like to use? Did your group have ideas that others wanted to use?
4. What part did thermal energy play in this investigation? What part does it play in the water cycle?

DidYouKnow?

During lengthy periods of Earth's history, when the global climate was much colder, glaciers spread over as much as 28 percent of the land. You will investigate the links between water and climate in Topics 2 and 4.

Distribution of Water on Earth

In terms of the amount of water on this planet, the water you need to survive is actually in very short supply. As you read earlier, the vast majority of water on Earth, about 97 percent, is salt water (see Figure 5.2). You cannot drink salt water. Neither can other land-living organisms. You need fresh water to meet your water needs.

Figure 5.2 Most of Earth's water is frozen or is salt water.

Barely 3 percent of all the water on Earth is fresh water (see Figure 5.3). Most water is frozen in large masses of ice. These frozen expanses of water form ice sheets at the North and South poles, and glaciers in high mountaintops. Compressed sheets of snow and ice cover about 10 percent of Earth's land area and lock up about three-quarters of the planet's fresh water supply in the solid state.

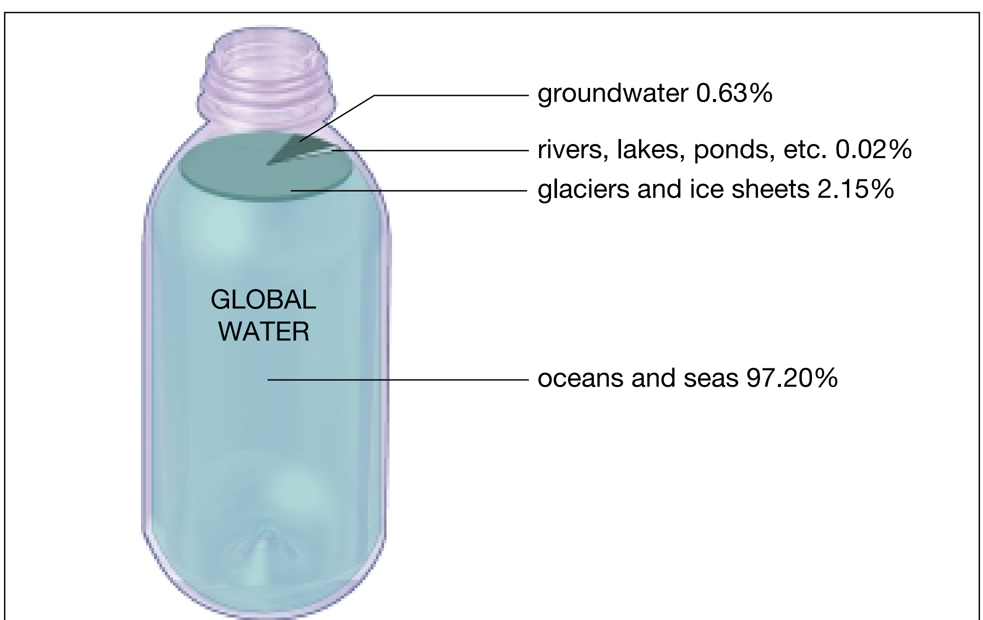


Figure 5.3 This "bottle graph" shows the distribution of water on Earth, by volume.

This means that little more than 0.5 percent of Earth's water is found as liquid fresh water. Believe it or not, nearly all of this water occurs below the surface as groundwater. The tiny remainder accounts for all the water on the land surface in rivers, streams, ponds, lakes, and freshwater wetlands.

In volume, this tiny remainder — about 270 000 km^3 of fresh water — seems like a large amount. It is. However, it must supply tens of *billions* of other organisms with the water they need to survive. This includes over six billion humans.

Water Enough for All?

The water cycle ensures that the total quantity of Earth's water stays the same. However, the distribution of fresh, usable water varies greatly from one part of the planet to another (see Figure 5.4). So, too, do our ways of using that water. We take water, as well as materials and organisms, from oceans, rivers, lakes, and underground. We use these resources for drinking, cooking, eating, washing, farming, manufacturing, and many other activities. Our activities add wastes — pollutants — to Earth's water resources.

Math CONNECT

Look at the percentages of water distribution in Figure 5.4. Draw a circle graph to represent these percentages.

Percentages of Earth's renewable fresh water

Country	Amount of fresh water (%)
Brazil	18
Canada	9
China	9
United States	8
Other countries	56

Figure 5.4 Four countries hold nearly half of Earth's renewable supply of fresh water. What factors do you think affect this uneven distribution of water?

Skill FOCUS

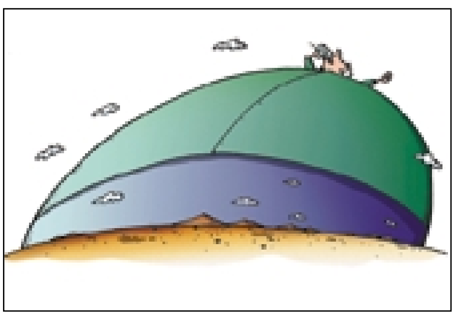
To review how to draw a circle graph, turn to Skill Focus 10.

Water quantity — the amount of water — is only one concern we have for the water we depend on. An equally important concern is **water quality**: the characteristics of a water resource that make it suitable or unsuitable for various uses. You will learn more about water quality in Topic 6.

Off the Wall

If you wanted to drink all the water on Earth (about 1.35 billion km^3), you would need a stomach with a radius of about 680 km. Your head would sit about 14 000 km above your feet. You would stand 1600 times taller than Mount Everest, and Earth's atmosphere would be about level with your navel.

How long would it take to drink all that water? If you were able to consume 4 L per second, 24 hours a day, it would take you about 7900 years just to gulp down the first cubic kilometre! How long would it take to finish it all?



Managing Our Water Resources

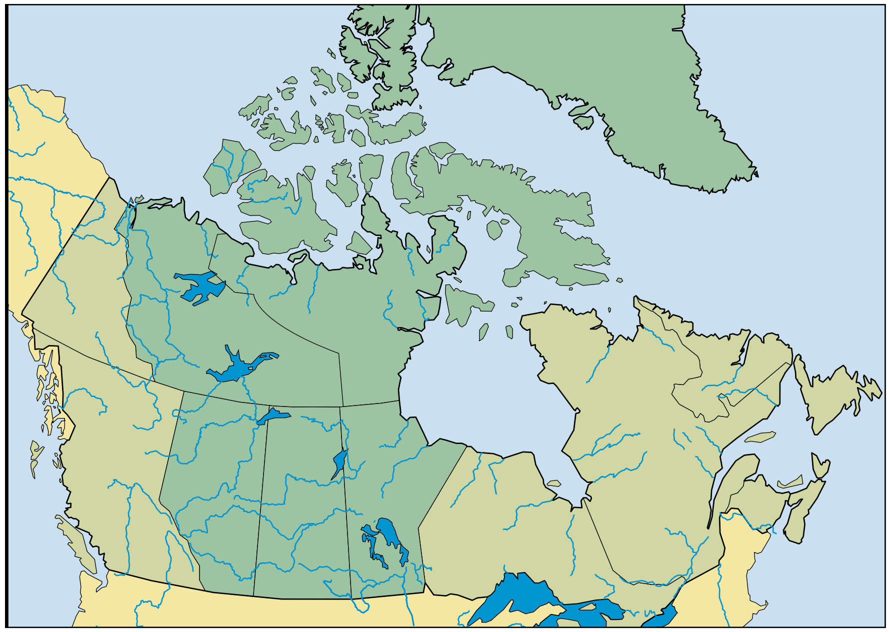


Figure 5.5 Nine percent of Earth's fresh water is found in Canada.

Pause& Reflect

Whether you get your drinking water from a tap, from a well, or from bottled spring water, it is all recycled. In your Science Log, write a paragraph or poem, or make a drawing that expresses the idea of water moving endlessly through the phases of the water cycle.

The map in Figure 5.5 shows the major rivers and lakes in Canada. Even though we are blessed with so much water, we still need to manage it carefully. Water management involves balancing the water needs of people, industries, wildlife, and the environment with the ability of fresh water systems to remain plentiful and clean. To manage water properly, we need to know how much water we have and where it comes from. We also need to know how water is used and how it can be negatively affected by pollution and overuse. Some people in Canada have jobs that help answer these questions. They gather the information we need to manage water properly to ensure it will be plentiful and safe forever. In the next two Topics you will explore some of this information too, as you learn where we have fresh water and how we use it.

TOPIC 1 Review

1. Puddles disappear and streets and fields dry out after a rain shower has ended. Explain why.
2. Design a concept map outlining different ways that we use water in our lives. Use your own topic headings or choose from among these: physical needs, economic needs, wildlife needs, agricultural needs, industrial needs.
3. **Apply** In Canada, water is fairly cheap and easy to obtain. How might it affect you if you had to pay a quarter from your allowance each time you used water, or if you had to travel many kilometres to obtain water?

TOPIC 2 Earth's Frozen Water

After ocean water, the next largest amount of water on Earth is frozen. Large masses of compressed snow and ice exist as ice sheets at the North and South poles, and in high mountaintops. These large areas of frozen water cover about 10 percent of Earth's land area. They lock up about three quarters of the planet's fresh water supply in its solid state. Let's look more closely at these masses of frozen water, starting with glaciers.

Did You Know?

Most of the fresh water on Earth is locked in glaciers.

What Is a Glacier?

In some areas of the world, it is so cold that snow remains on the ground year-round. When snow doesn't melt, it begins piling up. As it accumulates, the weight of the snow becomes great enough to compress the bottom layers into ice. Eventually, the snow can pile so high that the pressure on the ice on the bottom causes partial melting. Then, the ice and snow begin to slide downhill. This moving mass of ice and snow is called a **glacier**.

You may have heard the term "polar ice cap." An **ice cap** is a glacier that forms on an extensive area of relatively level land and that flows outwards from its centre.

In Canada today, the high basins of the Coast, Columbia, and Rocky Mountains are among the snowiest places on Earth. In these high mountains, the air is cool, and snow and ice melt slowly. Thus, conditions are ideal for the formation of icefields and glaciers. An **icefield** is an upland area of ice that feeds two or more glaciers (see Figures 5.6 and 5.7).

Off the Wall

The ice at the centre of the Columbia Icefield is as deep as the CN Tower in Toronto is tall (553 m). The icefield is so big that it creates its own winds and its own weather.

Figure 5.6 The Columbia Icefield is a high basin of accumulated snow and ice covering 325 km^2.

Figure 5.7 The Columbia Icefield is the largest of all the icefields in the Canadian Rockies. This icefield feeds six major glaciers, three of Canada's largest rivers, and three oceans.

How Does a Glacier Form?

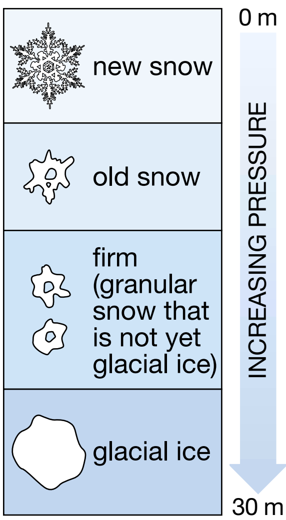


Figure 5.8 The weight of snow creates pressure, gradually changing crystals into glacial ice.

All glaciers begin as snow. Snowflakes accumulate and gradually become grains, then ice crystals, and finally ice. Figure 5.8 shows how glacial ice forms.

Over time, snow particles change from flakes to grains. Why? Snow crystals have a natural tendency to rearrange themselves into a circular form. The grains are compacted by the weight of more layers of snow. As a glacier melts, water trickles down and refreezes between the crystals. At the same time, air is slowly squeezed out of the snow mass. The snow gradually becomes ice. In a similar way, snow on city sidewalks becomes ice, under the constant pressure of people's footsteps. For pressure to turn snow to glacial ice in the mountains, at least 30 m of snow must accumulate in one place.

Valley Glaciers

A glacier that forms in a mountain range is known as a **valley glacier**. In high mountains, the average temperature is low enough to prevent snow from melting during the summer. Thus, valley glaciers grow and creep along. Figure 5.9 shows a valley glacier — the Athabasca Glacier — in the Columbia Icefield. This glacier covers about 6 km^2. Although not the largest one in the icefield, the Athabasca Glacier is the best known. This glacier is the only one accessible by road. The nearby but less accessible Saskatchewan Glacier is almost twice the size of the Athabasca Glacier (see Figure 5.10).

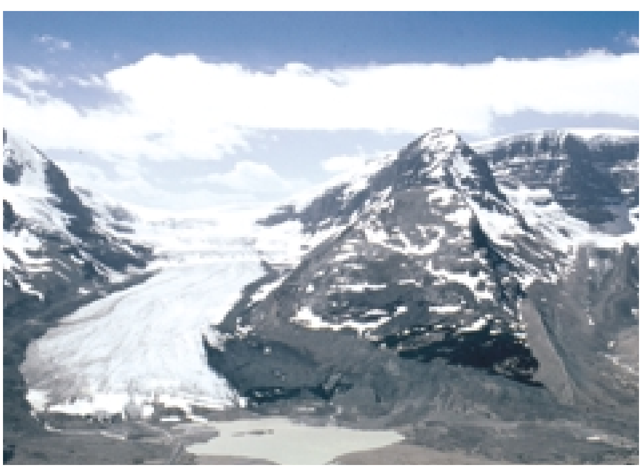


Figure 5.9 Valley glaciers, such as the Athabasca Glacier, are found around the world in mountain ranges at very high elevations.

Figure 5.10 The longest outflow from the Columbia Icefield is the Saskatchewan Glacier. It is nearly 7 km long.

Skill FOCUS

For tips on using the Internet, turn to Skill Focus 9.

INTERNET CONNECT

www.school.mcgrawhill.ca/resources/

There are 10 major types of glaciers in the world. Find out which five of these are found at the Columbia Icefield. Go to the above web site, then go to **Science Resources**. Go to **SCIENCEFOCUS 8** to find out where to go next. Report on your findings in class.

Continental Glaciers

A **continental glacier** is a huge mass of ice and snow (see Figure 5.11). Continental glaciers occur mostly near the North and South poles in Greenland and Antarctica. These glaciers are so thick that they can almost bury mountain ranges on the land they cover. Antarctica is a land mass covered by a continental glacier that is about 932 000 km^2. This is about one and one third times the area of Alberta.

Word **CONNECT**

A crevasse is a fracture in ice. Use a dictionary to find out how a crevasse differs from a crevice. Explain the difference in a sentence in your notebook.

Figure 5.11 Accumulation of snow and ice leads to the formation of continental glaciers.

Figure 5.12 This icefall is found in the Columbia Icefield.

Glacial Features

Ice is neither fluid, like water, nor solid, like stone. The shapes that develop in flowing ice are unique to glaciers. Two such features, shown in Figure 5.13, are icefalls and crevasses. Where a glacier flows over a steep cliff and breaks up, an **icefall** results (see Figure 5.12). A **crevasse** is a fissure, or crack, in the ice, as shown in Figure 5.14.

DidYouKnow?

The Athabasca Glacier is 6 km long when measured from its upper edge to its toe. Its average width is 1 km. In some places, this glacier is 300 m deep, which is as tall as the Eiffel Tower in Paris.

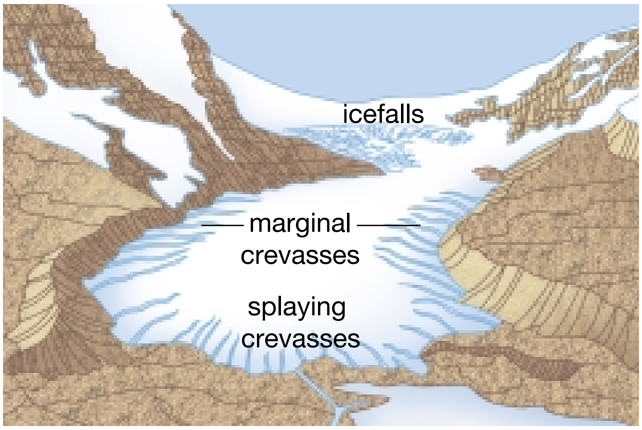


Figure 5.13 Crevasses are often covered by snow. Walking on an icefield can be treacherous.

Figure 5.14 Glacial ice can stretch. However, if a glacier stretches too much, it cracks and crevasses form.

Find Out ACTIVITY

How Does a Glacier Move?

Glaciers are moving rivers of ice. They move so slowly that it is difficult to observe their movement. In this activity, you can make a model glacier and "speed up" its movement.

Safety Precautions

- Wear gloves during this activity.
- Do not get the borax solution on your skin or in your eyes.
- Dispose of the mixture as instructed by your teacher.
- Wash your hands after doing this activity.

Materials

waxed paper
large spoon
measuring spoons
sponges
borax powder
2 mixing bowls
measuring cup
water
white glue
funnel

Procedure — Performing and Recording

1. Cover your work surface with layers of waxed paper.
2. Crinkle up some of the waxed paper to make a slight slope. Then cover the slope and the surrounding work surface with more waxed paper. **CAUTION** Be sure that the glue and the model glacier stay on the waxed paper throughout this activity.
3. In one mixing bowl, combine 250 mL water with 15 mL borax. Stir until the borax dissolves and there is some solid material at the bottom of the bowl. Add a little more borax, if necessary.
4. In the second bowl, mix 100 mL of water with 35 mL white glue. If necessary, pour off any excess water after you stir the mixture.
5. Stir the borax solution again. Then add about half the solution to the glue-and-water mixture. Stir until the mixture sets. (Add more small amounts of the borax solution if you need to, until the mixture sets.)
6. Remove the mixture from the bowl. Have a partner help you pour it into a funnel.
7. Pour the mixture through the funnel onto the waxed paper slope. Let it pile up on the paper and then spread out. Observe what happens and record your observations.

What Did You Find Out?

1. Performing and Recording — Draw and describe a series of diagrams to show what you observed.
2. Analyzing and Interpreting — From your observations, explain how your model glacier moves like valley and continental glaciers.

Off the Wall

Most glaciers move less than 1 m per day. A glacier in Alaska holds the record as the fastest glacier on Earth. In 1937, the Black Rapids Glacier advanced at the incredible rate of 30 m per day. Why do you think this glacier was moving so fast?

Glacial Movement

Because of the crushing weight of the layers above it, the ice deep in a glacier is flexible enough to bend, stretch, and flow. This flexibility allows the ice to flow away from areas of accumulation. The ice moulds itself to the shape of the rock over which it flows.

A glacier is like a river. It flows downhill. It also spreads and thins in wide areas and squeezes and deepens in narrow areas. Most glaciers tend to spread out at the toe where the ice thins.

DidYouKnow?

The middle of the Athabasca Glacier flows at an average speed of 80 m a year, or about 1 cm an hour.

Advancing or Retreating?

What happens when a glacier melts faster than it flows? It looks as though the glacier is going back uphill, even though it's still flowing downhill. This is called a retreating glacier. Many of the glaciers near Banff and Jasper are retreating. A few, such as the Columbia Glacier, are advancing.

If ice melts from a glacier faster than it is replaced by new ice, the glacier shortens and retreats. If ice builds up more quickly than it melts, the glacier lengthens and advances. No matter whether the toe of a glacier is retreating or advancing, the glacier as a whole is always moving downhill and forwards. The Athabasca Glacier is one example of how a glacier can retreat even while its ice is flowing downhill. In one year, the glacier's toe retreated 3 m, but the ice in the middle flowed forward at least 35 m! You can see how the position of this glacier's toe has changed over time in Figure 5.15.

Word CONNECT

The word retreat usually means that something moves away. Look up the word recede in a dictionary. Which word do you think best describes a glacier that is melting faster than ice is accumulating?

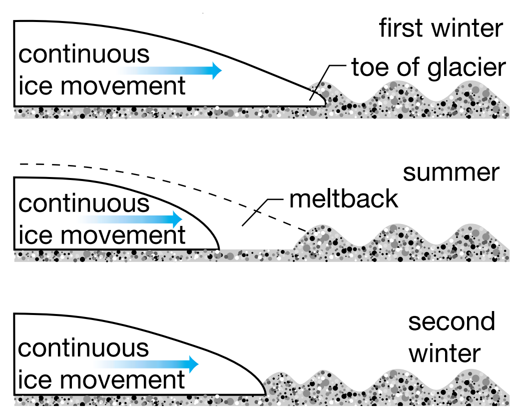


Figure 5.15 The position of the toe of the Athabasca Glacier has changed over the years.

Pack Ice and Icebergs

For most of the year, the surface of the Arctic Ocean is solid with pack ice. **Pack ice** is a sheet of ice rarely more than 5 m thick that breaks easily. It is formed from freezing sea water. Large pieces sometimes break off and melt as they move toward warmer waters.

Icebergs are large chunks of ice that break loose, or **calve**, from continental glaciers as the glaciers flow downslope into the ocean (see Figure 5.16). Each year, about 16 000 icebergs break loose from Greenland's glaciers. Some icebergs are several kilometres long and rise more than 100 m above the surface of the ocean. As these icebergs float, sun and wind melt the tops. The bottoms of the icebergs, submerged in the ocean, melt more slowly.

Figure 5.16 Calved icebergs stay in the pack ice until temperatures rise above freezing. Then they slowly move away and start to melt.

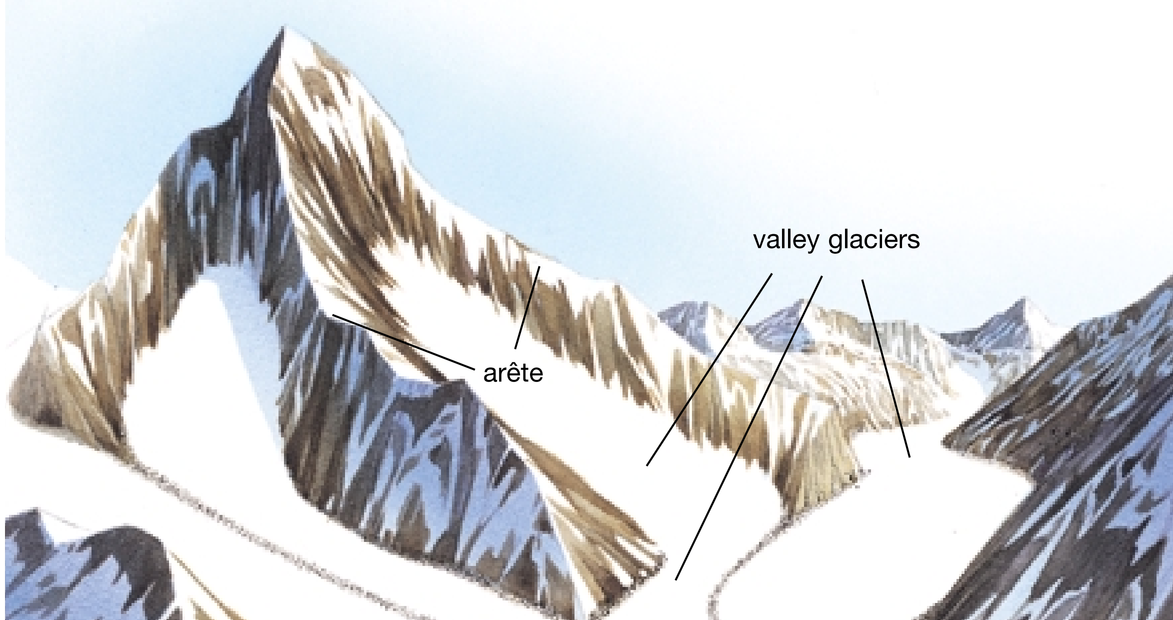
How Glaciers Shape the Land

Glacial Erosion

As they move over land, glaciers act like bulldozers. They push aside and forward any loose materials they encounter. Eroded sediments pile up along a glacier's sides, as shown in Figure 5.17. Glaciers also weather and erode rock. When glacial ice melts, water flows into cracks in rocks. Later, the water refreezes in these cracks, expands, and splits the rock into pieces. These rock pieces are then lifted out by the glacier. This process results in boulders, gravel, and sand being caught by the bottom and sides of a glacier.

As the glacier moves forward, rock fragments and sand at its base scrape the soil and bedrock. These rock fragments erode even more material than ice could alone. When bedrock is gouged by dragged rock fragments, marks are left behind. These marks, called **striations**, are parallel scars or scratches. Striations show in which direction the glacier moved.

Figure 5.17 The diagram and photographs show landforms characteristic of glacial erosion.



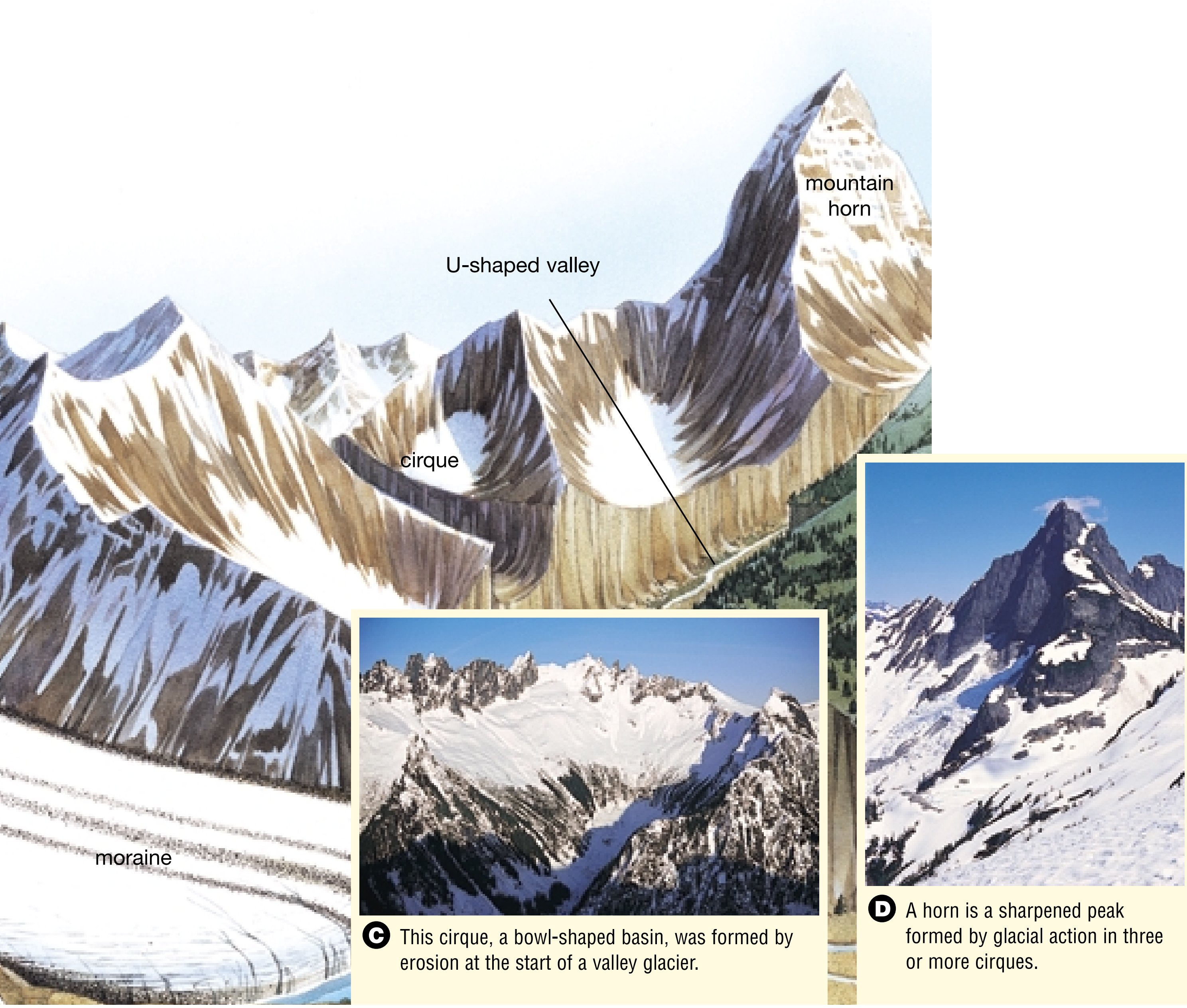
A Rocks stuck in glaciers can scratch and gouge underlying rock, resulting in striations or grooves.

B A large ridge of material left behind by a glacier is called a moraine.

Evidence of Valley Glaciers

If you visit the mountains, you can tell whether valley glaciers existed there. Valley glaciers erode bowl-shaped basins, called **cirques**, in the sides of mountains. Sometimes two or more glaciers erode a mountain summit from several directions. This can form a ridge called an **arête**, or a sharpened peak called a **horn**. Figure 5.17 shows all these land-forms. They are evidence of valley glaciers.

Valley glaciers flow down mountain slopes and along valleys, eroding as they go. Valleys eroded by glaciers are U-shaped because a glacier plucks and scrapes soil and rock from the sides as well as from the bottom (see Figure 5.17). In contrast, a valley eroded by a river is V-shaped.



C This cirque, a bowl-shaped basin, was formed by erosion at the start of a valley glacier.

D A horn is a sharpened peak formed by glacial action in three or more cirques.

Glacial Deposition

Figure 5.18 Till deposits can cover huge areas of land.

Figure 5.19 Glaciers pick up and deposit huge rock fragments called erratics. These erratics at Okotoks in Alberta were carried hundreds of kilometres by glacial movement.

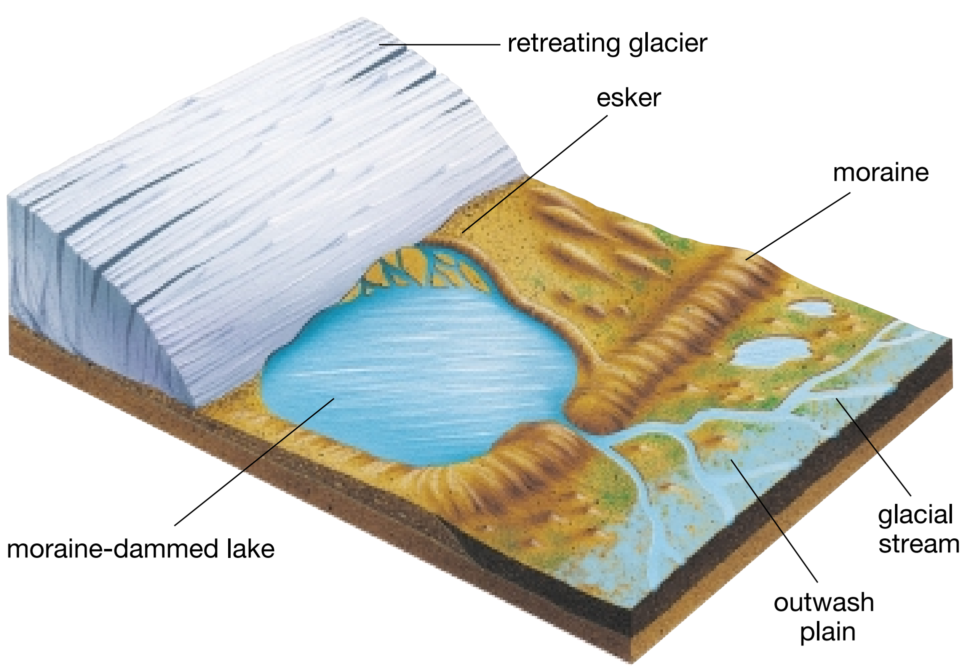
When glaciers begin to melt, they no longer have enough energy to carry much sediment. The sediment is deposited on the land. When the glacier slows down, a jumble of boulders, sand, clay, and silt drops from its base. This mixture of different-sized sediments is called **till** (see Figure 5.18).

Till is also deposited in front of a glacier when it stops moving forward. Unlike the till that drops from a glacier's base, this second type of deposit does not cover a wide area. Because it is made of the rocks and soil that the glacier has been pushing along, it looks like a big ridge of material left behind by a bulldozer. Such a ridge is called a **moraine**.

When more snow melts than accumulates, the glacier starts to melt and retreat. Material deposited by the meltwater from a glacier is called **outwash**. Outwash is shown in Figure 5.20. The meltwater carries sediments and deposits them in layers, sometimes in the shape of a fan. Another type of outwash deposit looks like a long, winding ridge. This deposit forms beneath a melting glacier when meltwater forms a river within the ice. This river carries sand and gravel and deposits them within its channel. When the glacier melts, a winding ridge of sand and gravel is left behind. This winding ridge is called an **esker** (see Figure 5.20).

In the next investigation, you will explore glacial erosion and deposition.

Figure 5.20 This diagram shows features of glacial deposition.



INQUIRY

INVESTIGATION 5-C

SKILLCHECK
- Initiating and Planning
- ✱ Performing and Recording
- ✱ Analyzing and Interpreting
- Communication and Teamwork

Glacial Grooving

Throughout the world's mountainous regions, there are 200 000 valley glaciers moving in response to local freezing and thawing conditions, as well as gravity. In this investigation, you will simulate the processes of glacial erosion and deposition.

Question

How is the land affected when a valley glacier moves?

Hypothesis

Form a hypothesis about the relationship between glacial movement and resulting landforms. Then test your hypothesis.

Safety Precautions

Apparatus

stream table (a homemade one will do)

2 or 3 books

metric ruler

overhead light source with reflector

Materials

sand

ice block containing sand, clay, and gravel

Procedure

1. Set up the stream table as shown.
2. Cut a narrow channel, like a river, through the sand. **Measure** and **record** its width and depth. **Draw** a sketch that includes these measurements.
3. Position the overhead light source to shine on the channel, as shown.
4. Force the ice block into the river channel at the upper end of the stream table.
5. Gently push the "glacier" along the river channel until it is halfway between the top and bottom of the stream table and is positioned directly under the light.
6. Turn on the light and allow the ice to melt. **Record your observations**. Does the meltwater change the original channel?
7. **Record** the width and depth of the glacial channel. **Draw** a sketch of the channel and include these measurements.

Conclude and Apply

1. Explain how you can determine the direction a glacier travelled from the location of its deposits.
2. Explain how you can determine the direction of glacial movement from sediments deposited by meltwater.

Analyze

3. How do valley glaciers affect the land surface over which they move?

Meltwater Features

In summer, **meltwater** — water formed by the melting of snow and ice — carves channels in and through glaciers. Some meltwater streams flow on the surface of the ice before disappearing into the mazelike network of streams beneath the glacier. Figure 5.21 shows a meltwater feature known as a **millwell**. This is a rounded drain in the ice chiselled by a stream as it plunges downward. The subglacial streams emerge, finally, from the toe of the glacier (see Figure 5.22).

Figure 5.21 Meltwater streams form millwells as they plunge into glacial ice.

Figure 5.22 A river emerging from glacial ice

The Importance of Glaciers

Icefields, glaciers, and the year-round snows in high mountains act as natural reservoirs. These reservoirs collect snow throughout the fall, winter, and spring. They gradually release this reserved water as meltwater in summer. Glaciers feed a constant supply of meltwater into the river systems of the Prairies. Water from the Columbia Icefield, for example, crosses all three prairie provinces. It helps run hydroelectric plants, irrigate crops, water cattle, and supply drinking water to many homes.

Glaciers exert a direct influence on the water cycle by slowing the passage of water through the cycle. Glaciers are excellent storehouses of vast quantities of fresh water. They release this water when it is needed most, during the hot, dry summer months.

Besides their importance as fresh-water storehouses, glaciers provide important clues to the past. Because of the way glacial ice accumulates and endures, glaciers offer an excellent source of information about Earth's past climates.

Ice Ages

Over the last several million years, Earth has had at least seven major periods of cooling called **ice ages**. The most recent ice age began about 120 000 years ago. It ended only about 11 000 years ago. During this period, the climate was very different from what it is today. Glaciers covered as much as 28 percent of the land.

During the last ice age, much of North America was as cold as Greenland is today. Glaciers covered the land from the Arctic to as far south as the Great Lakes (see Figure 5.23). How do we know this? You've seen how glaciers create distinct features in the land. For example, striations, moraines, U-shaped valleys, and erratics are all clues to the presence of glaciers. From evidence such as this, scientists can determine where glaciers have previously existed.

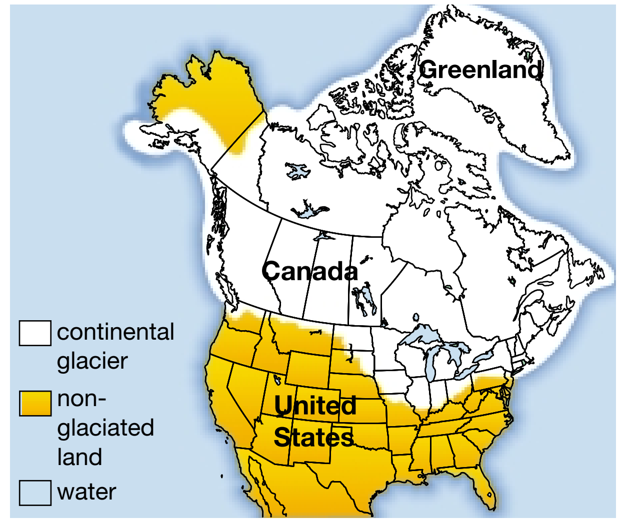


Figure 5.23 During the last ice age, glaciers in North America covered an area three times as large as they do today.

Off the Wall

At the peak of the last ice age, scientists estimate that average air temperatures around the world were about 5°C lower than they are now. This small difference is enough to start an ice age. A cooler-than-average summer does not produce enough heat to melt all the snow by summer's end. The next winter adds more snow. This makes it even harder for the following summer's heat to melt all the snow. When more of the land is covered with snow and ice, a greater amount of sunlight is reflected back into the atmosphere. This adds to the cooling. Over thousands of years, the snow piles up to heights of 1 km or more! The tremendous weight of the snow causes the lower layers to turn to ice, forming continental glaciers.

Cool Tools

Ancient ice provides important clues to the climates of earlier geologic eras. Scientists use an ingenious method called ice core sampling to study evidence imbedded in ice. They use long drills to remove cores of ice from the ice sheets of Antarctica and Greenland, and from glaciers. The long cylinders of ice provide a detailed record of what was taking place in the world over the past several ice ages. Each layer of ice in a core corresponds to a single year or season. Almost everything that fell in the snow that year remains behind. These remnants include wind-blown dust, ash, atmospheric gases, and even radioactivity. They provide a record of global climate change over millions of years.

By examining air bubbles trapped within ice cores, scientists have discovered that the amount of carbon dioxide varies within ice cores. No one knows the exact reasons for these differences, but scientists agree that carbon dioxide levels in the atmosphere are associated with climate changes.

Ice Ages and Climatic Change

A small change in average temperature is enough to start a chain of events that produces an ice age. Why might the temperature of Earth's atmosphere change in the first place? Here are some hypotheses scientists have suggested to explain why ice ages happen:

- There may be occasional reductions in the thermal energy given off by the Sun.
- An increase in volcanic activity may add large volumes of dust to the atmosphere. This might reduce the amount of the Sun's energy reaching Earth (see Figure 5.24).

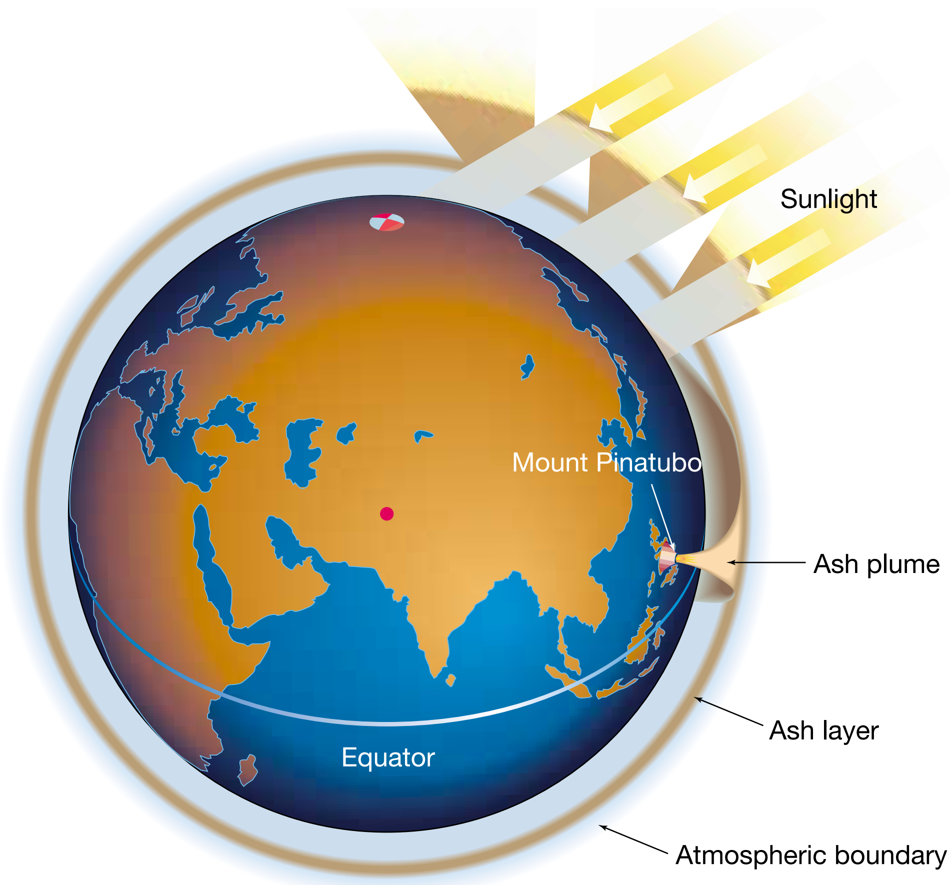


Figure 5.24 When Mount Pinatubo in the Philippines erupted in 1991, its volcanic ash cooled temperatures around the world.

- Periods of mountain formation would increase the area of high mountain ranges on Earth. The extra snow remaining on these cold peaks through the summer reflects sunlight and may reduce the temperature.
- The movement of Earth's tectonic plates alters the shape of the oceans. This change affects the flow of ocean currents. With less mixing between hot and cold waters, some regions might become cold enough to start an ice age.
- Changes in the tilt of Earth's axis, or in its orbit around the Sun, may produce colder climates.

Scientists are still gathering data to test these hypotheses.

Climatic Changes Today

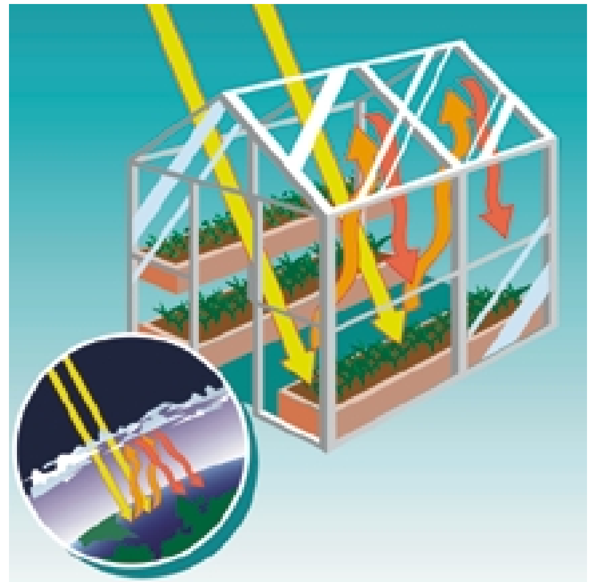


Figure 5.25 The Sun's radiation travels through our atmosphere and heats Earth's surface. However, the heat that is radiated from Earth cannot escape back through the gases of the atmosphere into space. This is similar to how a greenhouse warms.

Today, many newspaper and magazine headlines warn us about the greenhouse effect and global warming. These two events are related but are not the same.

As you learned in previous science studies, the greenhouse effect is natural warming caused by gases in our atmosphere trapping heat (see Figure 5.25). Carbon dioxide is the main greenhouse gas. It is important to realize that the greenhouse effect is not bad in itself. Without the greenhouse effect, life as we know it would not be possible on Earth. Like Mars, Earth would be too cold to support life.

Global warming means that global temperatures are rising. Many scientists hypothesize that one reason for global warming is the increase of greenhouse gases in our atmosphere. An increase in greenhouse gases increases the greenhouse effect. In the last 100 years, the mean surface temperature on Earth has increased 0.5°C. This increase may very well be due to global warming.

If Earth's mean surface temperature continues to rise, ice caps will melt. Low-lying areas might experience increased flooding. Already some ice caps are beginning to break apart and sea level is rising in certain areas. Some people believe that these events are related to Earth's increased temperature.

Find Out ACTIVITY

How Can Global Warming Be Slowed?

Human activities affect the air in our atmosphere. Burning fossil fuels and removing vegetation are examples of two such activities. Both activities add carbon dioxide to the atmosphere and may contribute to global warming. How can the amount of carbon dioxide in the atmosphere be reduced?

Procedure

Analyzing and Interpreting
Communication and Teamwork

1. In a group, brainstorm ways in which we rely on energy from burning fossil fuels. You might need to do some research in the library or on the Internet.
2. Now brainstorm some ways in which we can change our daily activities to reduce our reliance on energy from burning fossil fuels. (Hint: Think about transportation and how we heat or cool our homes, for example.)
3. Design a brochure or a web site informing people about steps we can take in our daily lives to slow down global warming.

Extension

4. Research some global actions that nations have undertaken to reduce the amount of carbon dioxide in the atmosphere. What further actions are required to prevent carbon dioxide from reaching dangerous levels?

Career CONNECT

What is this woman doing on this sea of ice? Believe it or not, she's at work! Trudy Wohhleben is a glaciologist, a research scientist who studies glaciers in the Canadian Arctic. Glaciologists are fascinated by what glacial ice can tell us. They study glaciers to find out how old they are. They also determine whether bacteria live within glaciers. They do research to find out how glaciers' movements over thousands of years have scraped away the bedrock surface of Earth and rock under and around them, and much more.

Trudy Wohhleben

Trudy's research focusses mainly on how glaciers affect the weather, and how weather affects glaciers. Throughout May and June, she works in the Arctic, taking measurements of temperature and of how fast the edge of a glacier moves forward or backward. She also gathers data on air temperature, wind, and snowfall, all year round, from three automatic weather stations located on the glacier. She uses the information to make a computer model — a sort of storyline of what has happened. This model can help her predict what might happen to the glacier and to the weather in the future.

Eventually, Trudy hopes to be able to answer questions such as: What will happen to the glacier if the summer melt period gets longer? Will the glacier get smaller? If more ice melts, will the added moisture in the atmosphere result in more precipitation? Could the glacier actually grow because of this increase in snow and rain?

Imagine that a research scientist working in your town or city wants to hire a student as a research assistant. Which skills do you have that might help you get the job? Make a list of your experience, skills, and interests. Decide which of these attributes you think will be most important to a scientist judging your application. Write a letter highlighting these points. Be sure to explain why you would like the job and what you hope to learn from it.

TOPIC 2 Review

1. Make a diagram to show how a glacier forms.
2. Explain the difference between a valley glacier and a continental glacier.
3. (a) What is meant by glacial erosion?
   (b) What is meant by glacial deposition?
4. Draw and label some landforms created by glacial action.
5. Give two reasons why glaciers are important.
6. Give two scientific hypotheses that could explain the origin of an ice age.
7. **Thinking Critically** Why do you think fossils of ocean fish are found on land far away from present-day oceans?

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

salt water
fresh water
water cycle
water quantity
water quality
glacier
ice cap
icefield
valley glacier
continental glacier
crevasse
icefall
pack ice
icebergs
calve
striations
cirques
arête
horn
till
moraine
outwash
esker
meltwater
millwell
ice ages

Reviewing Key Terms

1. In your notebook, copy each statement below. If it is true, write the letter "T" beside it. If it is false, write the letter "F" beside it. Then rewrite the statement to make it true.
   (a) Water vapour is water in the liquid state. (1)
   (b) Most of the world's water is fresh water. (1)
   (c) The repeated pattern of water evaporating, condensing, and precipitating is called the water cycle. (1)
   (d) Water quality involves balancing the needs of people, industries, wildlife, and the environment with sustainable water resources. (1)
   (e) Icebergs are large chunks of ice that break loose from valley glaciers. (2)
   (f) A glacier can retreat even while it is flowing downhill. (2)
   (g) Glaciers are an important storehouse of fresh water. (2)
   (h) The most recent ice age ended about 120 000 years ago. (2)
   (i) A decrease in greenhouse gases in the atmosphere may contribute to global warming.

Understanding Key Concepts

2. From where does most water vapour in the atmosphere evaporate? (1)
3. List four locations in which water is distributed on Earth. Sort your list in decreasing order of abundance. (In other words, list the locations from most plentiful to least plentiful.) (1)
4. List five purposes for which people use water. (1)
5. The data on the right show daily municipal water use between 1983 and 1994. Graph the data and answer the following questions. (1)
   (a) Name two likely uses for each of the three categories.
   (b) Which of the three categories of users experienced a decrease in water usage over this period? Which experienced an increase?
   (c) Suggest a reason for the trends (patterns) in water usage you observe in your graph for the first three categories.
   (d) Do you think these same trends apply today? Why or why not? How could you find out?
6. **(a)** Describe some landforms related to glacial erosion. (2)
   (b) Describe some landforms related to glacial deposition. (2)

Year	Municipal water use (in billions of litres/day)		
	Residential	Commercial	Industrial
1983	5.94	2.31	2.66
1986	6.08	2.48	2.86
1989	7.03	2.63	2.68
1991	7.13	2.71	2.49
1994	7.22	2.49	2.36

TOPIC 3 Fresh Water Systems

In Topic 1, you learned that less than one percent of Earth's total water supply is available for us to use for drinking, cooking, and other purposes. This small percentage is found in fresh water systems. Fresh water systems exist both above ground (as **surface water**) and underground (as **groundwater**).

This Topic looks at how fresh water systems are linked to one another. These links mean that damage to one system can cause damage to another. By understanding these links, we can take steps to try to minimize damage and maintain healthy water systems — for us as well as for other living things.

Word CONNECT

Find the precise meaning of each of the following words in a dictionary: marsh, bog, swamp, fen, and slough. Write a poem or a short story set in one of these wetland environments.

Lakes, Ponds, and Wetlands

A **lake** and a **pond** are basically large holes in the ground, filled with standing water (Figures 5.26A and B). A lake differs from a pond not in size, but in depth. In a pond, sunlight reaches all the way to the bottom. In a lake, sunlight does not reach the bottom. Thus, it is possible for a pond to be larger than a lake! The depth to which sunlight will penetrate depends on the water's clarity. **Clarity** is determined by the amount of matter suspended in the water.

Off the Wall

Some marshes can contain salt water rather than fresh water. Saskatchewan, for example, has both salt water marshes and salt water lakes. Lake Wakaw is a salt water lake in Saskatchewan. Try to locate it on a map. Why is its water salty? That's for you to find out!

Figure 5.26A Lake Minnewanka, Banff National Park, Alberta

Figure 5.26B A pond in Whiteshell Park, Manitoba

Wherever there is a low area in the land, **wetlands** can occur (Figure 5.27). There are many different types of wetlands. However, they have one characteristic in common. They are saturated with water all or much of the time. Marshes, for example, are shallow water wetlands (less than 1 m in depth). They usually remain wet throughout the year. You've probably seen small, marshy prairie sloughs. All wetlands provide habitats for an astounding diversity of plants and wildlife. You will learn more about life in fresh water systems in Topic 5.

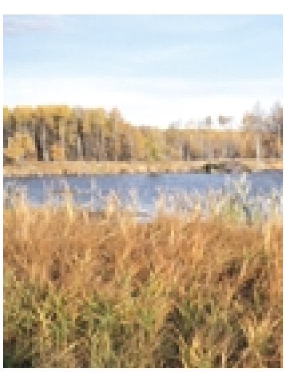


Figure 5.27 Wetlands such as this prairie slough are an important nesting area for ducks in North America.

Streams and Rivers

Streams and **rivers** are both fast-flowing waterways (Figure 5.28). However, their individual characteristics vary a great deal. Flowing waters differ greatly in speed, temperature, and clarity. They also differ in the nature of their banks and bottoms. All these factors affect the types of plants and animals that live in them. Fast-flowing waterways are usually rich in oxygen, which fish and other animals need to survive. Oxygen dissolves into water as it rushes through rapids, or plunges over waterfalls. You'll look more closely at streamflow and other characteristics later in this Topic.

DidYouKnow?

Cold water contains more oxygen than warm water. Trees overhanging a stream cool the water and help keep the oxygen levels high. This benefits trout, salmon, and other stream-dwelling creatures who need the oxygen to survive and reproduce.

Figure 5.28 Streams and rivers have flowing water.

Water Underground

Rivers and lakes are the most visible form of fresh water. However, another important source of fresh water lies beneath Earth's surface. In fact, most of the precipitation that falls on land sinks out of sight into the ground. Below the surface, this groundwater trickles downwards through connected pores and cracks (see Figure 5.29). Eventually, it reaches a layer of bedrock, such as granite. This bedrock layer forms a barrier. When groundwater cannot move any deeper, it begins to back up. It fills the pores in the material above the bedrock. You'll see later in this Topic how people drill down into these water-filled layers to make wells. They pump the water to the surface for use as drinking water, for factories, or for watering crops and livestock.

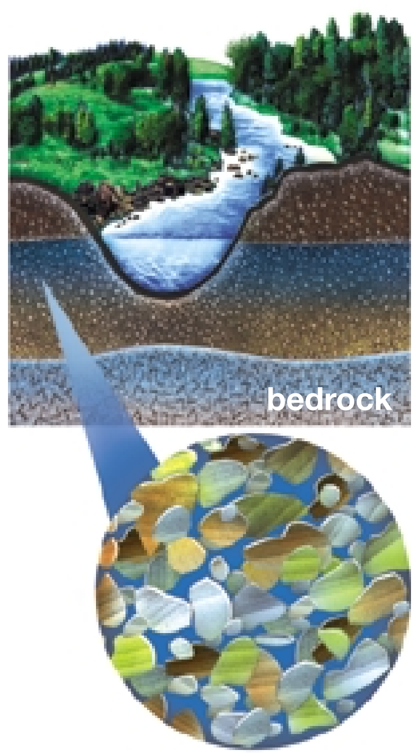


Figure 5.29 Groundwater is found under Earth's surface in small spaces between bits of soil and rock.

Fresh-Water Links: The Watershed Concept

Figure 5.30 This simplified drawing represents a watershed. A watershed is also known as a drainage basin.

Water is always on the move in the never-ending water cycle. No matter where a raindrop lands, it will eventually end up somewhere else. The same is true of ice and snow that melts. All fresh water on Earth — whether surface water or below groundwater — is part of a watershed. A **watershed**, or drainage basin, is the area of land that drains into a body of water (see Figure 5.30), such as a river, pond, wetland, lake, or ocean. When water hits the ground it either filters into the groundwater or flows downhill (of course, some also will evaporate). Water that doesn't soak into the ground or evaporate but instead flows across Earth's surface is called **run-off**.

The area of land within a watershed can be small or large. Within large watersheds, there are many smaller ones. For example, every stream is part of a large watershed. A small stream in your neighbourhood flows until it meets other small streams. The streams join larger rivers. Large rivers merge into major waterways.

A watershed includes both water and land. Each watershed has a variety of habitats. These range from rivers, streams, and lakes, to forests and farms. Cities are also part of watersheds.

In North America, a continuous ridge of mountain ranges divides the continent into two main drainage areas, as shown in Figure 5.31. On one side, water flows northeast to Hudson Bay or southeast to the Gulf of Mexico. On the other side, water flows west to the Pacific Ocean. This long ridge of mountains dividing North America is called the **Continental Divide**.

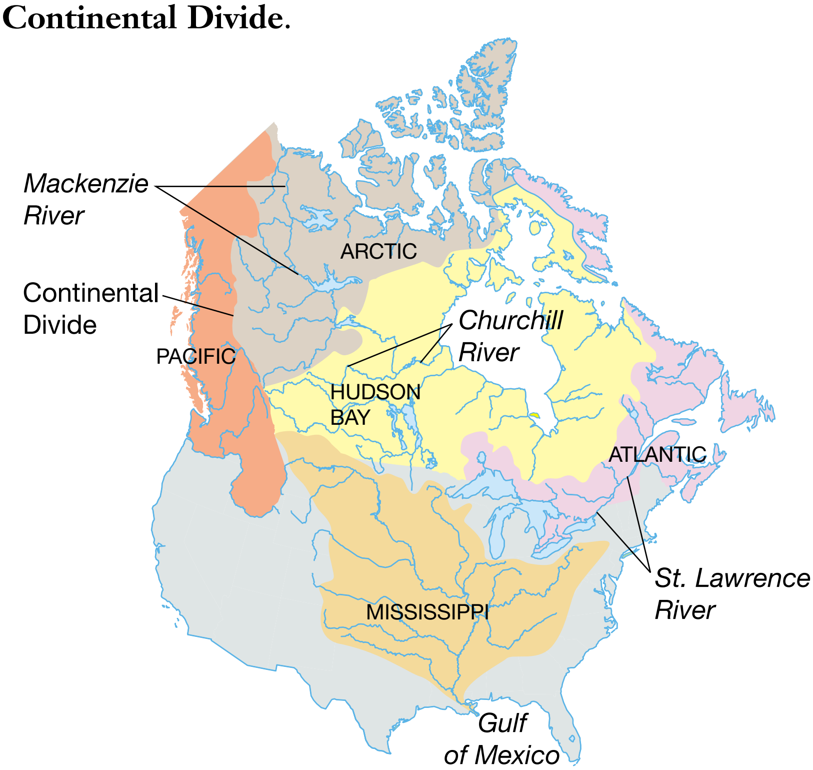


Figure 5.31 Canada has five major drainage basins. Most precipitation falling on Canada drains into the Pacific, Atlantic, and Arctic Oceans, and Hudson Bay. Interestingly, some of Canada's river water also ends up in the Gulf of Mexico.

Watersheds in Alberta

Landforms determine the size of a watershed. They also determine the speed and direction of water flow. High ground, such as mountain ranges and hilltops, directs water one way or another. The upstream areas of a watershed are called the **headwaters**. The end point of the water flowing through a watershed is called the **outflow**. The outflow is usually a river mouth.

The geography of Alberta determines the direction water will flow. Generally, water located in northern and central Alberta moves towards the Arctic Ocean. East central and southern Alberta rivers flow into Hudson Bay. A very small amount of water in the southernmost area of Alberta ends up in the Gulf of Mexico.

Look at the drainage basin map of Alberta in Figure 5.32. How many different watersheds can you find on this map? In which watershed is your community?

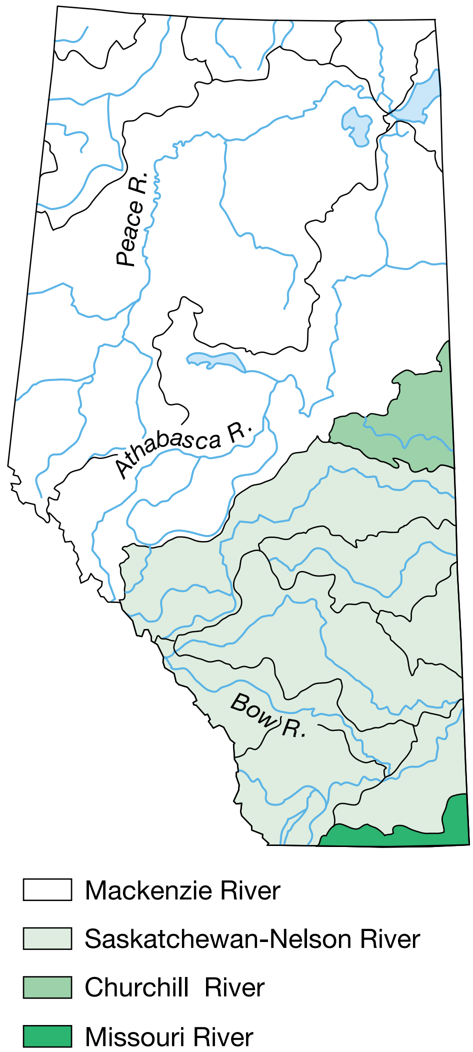


Figure 5.32 Watersheds of large rivers, such as the North Saskatchewan or the Athabasca, can cover many thousands of hectares.

Did You Know?

A raindrop falling in southern Saskatchewan or Alberta could eventually flow into the Mississippi River and south to the Gulf of Mexico. The same raindrop could be blown by a breeze from the south, however. Then it would land slightly farther north and would fall within the watershed boundaries of the South Saskatchewan River. The raindrop would then flow east and north to Hudson Bay and the Arctic Ocean.

Find Out ACTIVITY

Where's Your Watershed?

Your teacher will give you a copy of a map and some tracing paper. Work in a small group to locate your watershed.

Procedure

Analyzing and Interpreting
Communication and Teamwork

1. On the map, identify the major river in the area where you live.
2. Identify the boundaries of this river's watershed.
3. Find the local streams or rivers that drain into your major river.
4. Using tracing paper, trace the drainage from your local area to the ocean.

What Did You Find Out?

1. Where are the headwaters of your watershed?
2. Where is the outflow?
3. What major towns and cities are located in the watershed?
4. Approximately how many people do you think live within your watershed?
5. What types of habitats does your watershed have?

Figure 5.33 When it rains, water and all of the pollutants on land drain into ditches and storm drains.

Watersheds and Land Use

In the previous activity you located the watershed for the town or city in which you live. Think of what happens on the land around your city. What we do on the land can affect the water around us. If we spill gasoline when we are filling a car, pave over areas for new buildings and roads, or flush the toilet, our watershed is affected. For example, have you ever looked at the ditches or storm drains in your city after a heavy rainfall? (See Figure 5.33.) They are surging and full of water. This is because the watershed for a storm drain is a city, where most of the land is paved over. If the pavement wasn't there a lot of this water would soak into the soil. It would slowly seep into the groundwater or flow into rivers, lakes, or other bodies of water.

Paving over land is one way to change the run-off patterns in watersheds. Other land uses, such as logging, can affect watersheds too.

People who manage the water supply also have to consider what happens on the land in watersheds. One of the tools they use are Geographic Information Systems (GIS) that allow them to store data and generate maps electronically. For example, a water manager could generate a map that shows a river's watershed. Using GIS, they could then predict what might happen if run-off patterns change in the watershed. If part of the river was dammed, or an area was paved over, would another area flood?

The amount of water discharged by a watershed is influenced by soil conditions, vegetation, and human settlement patterns. How do you think run-off in urban areas compares to that in areas such as wetlands, forests, and prairies? What other factors affect run-off? Find answers to these questions in the next investigation.

Figure 5.34 When many trees are cut down, a river's flow pattern will change.

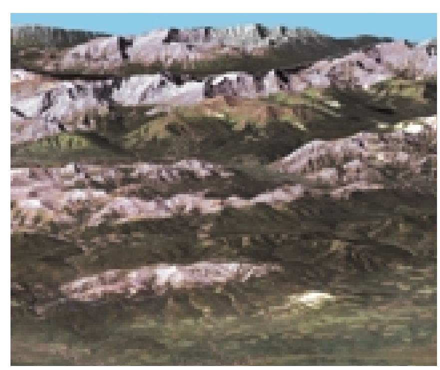


Figure 5.35 This GIS image of the foothills of Alberta was taken by satellite.

INQUIRY

INVESTIGATION 5-D

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

What Happens to Run-off?

How does Earth's surface affect what happens to rainwater falling on it? Consider the types of solid surfaces on which rain falls and the slope of the surface. Make a hypothesis and then test it by designing your own model and experiment.

Problem

How will run-off be affected by changes in land slope and land surface?

Hypothesis

Write a hypothesis related to how run-off will be affected by the slope and surface of a model landscape.

Apparatus

graduated cylinder
sink or basin
protractor
rigid piece of acrylic plastic
sponges
small blocks of wood
watering can

Materials

paper towels
water

Procedure

1. Before you begin to plan your group's investigation, consider these questions:
   (a) Your class is comparing three different surfaces: plastic, paper towels, and a sponge. What is different about each surface?
   (b) Which surface represents a parking lot? Sandy soil? A grassy area?
   (c) How does slope affect run-off?

Skill FOCUS

For tips on how to set up a controlled experiment using different variables, see Skill Focus 6.

2. Before carrying out your investigation, design a procedure and have your teacher approve it. Then prepare a table for recording your observations. What are you measuring? What are the variables? Which variable(s) stay(s) the same? Which variable(s) change(s)? How will you measure the effect of changing the angle of slope of each surface?
   (a) Wipe up any spills.
   (b) Wash your hands after this investigation.

Analyze

1. (a) Assess whether your procedure allowed you to make clear comparisons. What criteria did you use to make your assessment?
   (b) How might you improve the experimental design?
2. (a) What other variables could you have investigated?
   (b) What additional materials or procedures would you need to do this?

Conclude and Apply

3. This investigation is a model to show what happens to rainwater falling on land. Based on your observations, write three different outcomes for the following: A raindrop fell on ________ and it ________ because ________.

Run-off and Erosion

In the last investigation you explored the factors that determine whether rain soaks into the ground or runs off. The amount of rain and the time it takes it to fall are two factors. Another factor is the slope of the land. Gentle slopes and flat areas hold water (see Figure 5.36A). This gives the water a chance to evaporate or sink into the ground. On steep slopes, however, gravity causes water to run off before much evaporation or seepage can happen.

The amount of vegetation, such as grass, can also affect the amount of run-off. Just like spilled milk running off a table, water will run off smooth surfaces that have little or no vegetation (see Figure 5.36B). Plants and their roots act like sponges to soak up and hold water. By slowing down run-off, plants and roots help prevent the loss or **erosion** of soil.

Wetlands, forests, and prairies capture and store more water than paved roads and parking lots. Thus, urban areas have more run-off than areas covered with vegetation.

Figure 5.36A In areas with gentle slopes and much vegetation, there is little run-off and erosion.

Figure 5.36B Lack of vegetation can lead to severe soil erosion in some areas.

Deposition

Most rivers begin their journey on the steep slopes of a mountain range, as shown in Figure 5.37. Headwaters are usually narrow, straight, and fast-moving. They tumble down waterfalls and form white-water rapids. The water carries any loose rocks or boulders.

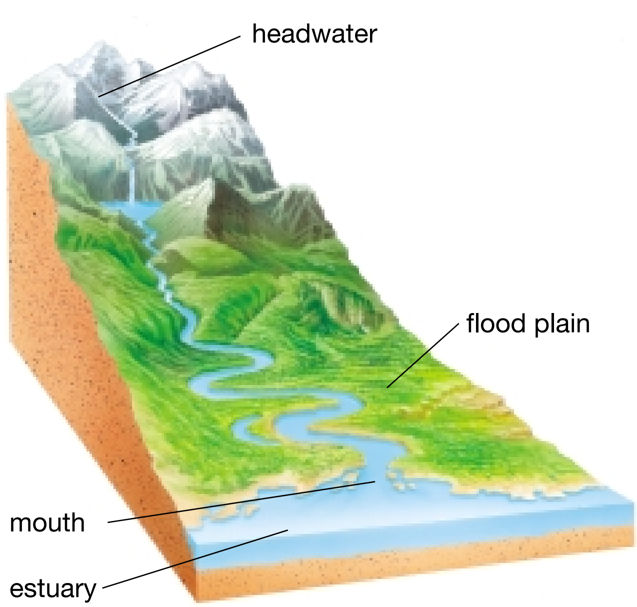


Figure 5.37 A river's journey

A river carries water downhill from the land back to a lake or ocean. As it flows, a river can erode materials from its bottom and banks. Where the river slope is flatter, the river slows down and deposits these materials. This process is known as **deposition**. This usually occurs in the lower reaches of the river, especially near the mouth.

A river can carve steep valleys, especially in higher parts of the drainage basin (see Figure 5.38). In the lower parts of the basin, deposits may cause fan-shaped deltas at the river's mouth (see Figure 5.39).

The volume of water flowing in a river determines how the river shapes the surrounding landscape. The speed and timing of the flow are factors, as well. Rainflow, snowmelt, and groundwater all contribute to the volume of flow. Streamflow varies from season to season and from year to year.

Explore stream erosion in the activity below and in the next investigation.

Figure 5.38 Fast-moving water has created a V-shaped valley.

Figure 5.39 This broad, wide river winds across a level flood plain.

Observing Stream Erosion

Take a closer look at stream erosion in this activity.

Materials

paint pan
soil
ruler or pencil
beaker
water

Procedure ✷ Performing and Recording

1. Fill a paint pan with 3 cm of soil.
2. Use the edge of a ruler or a pencil to level the soil. Use your hands to gently pack it down.
3. With your finger or a pencil, make a stream channel in the soil. Put several bends or turns in the channel.
4. Slowly pour water from a beaker into the channel from the higher end of the pan.
5. Wash your hands after completing this activity.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe where the stream erodes the most sediments.
2. Describe how the path of a stream of running water affects the rate at which erosion takes place.

INQUIRY

INVESTIGATION 5-E

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Stream Speed

Think about the various factors that might affect how fast a stream flows. Based on your prior knowledge and the materials listed, design your own experiment. With your group, plan how you can show the relationship between the speed of a stream and the stream's ability to erode.

Question

How does a stream's speed affect its ability to erode?

Hypothesis

Make a hypothesis about how the speed of a stream affects erosion. Then design an experiment to test your hypothesis.

Safety Precautions

- Wash your hands after you handle the sand.
- Wipe up any spills as wet floors are slippery.

Apparatus

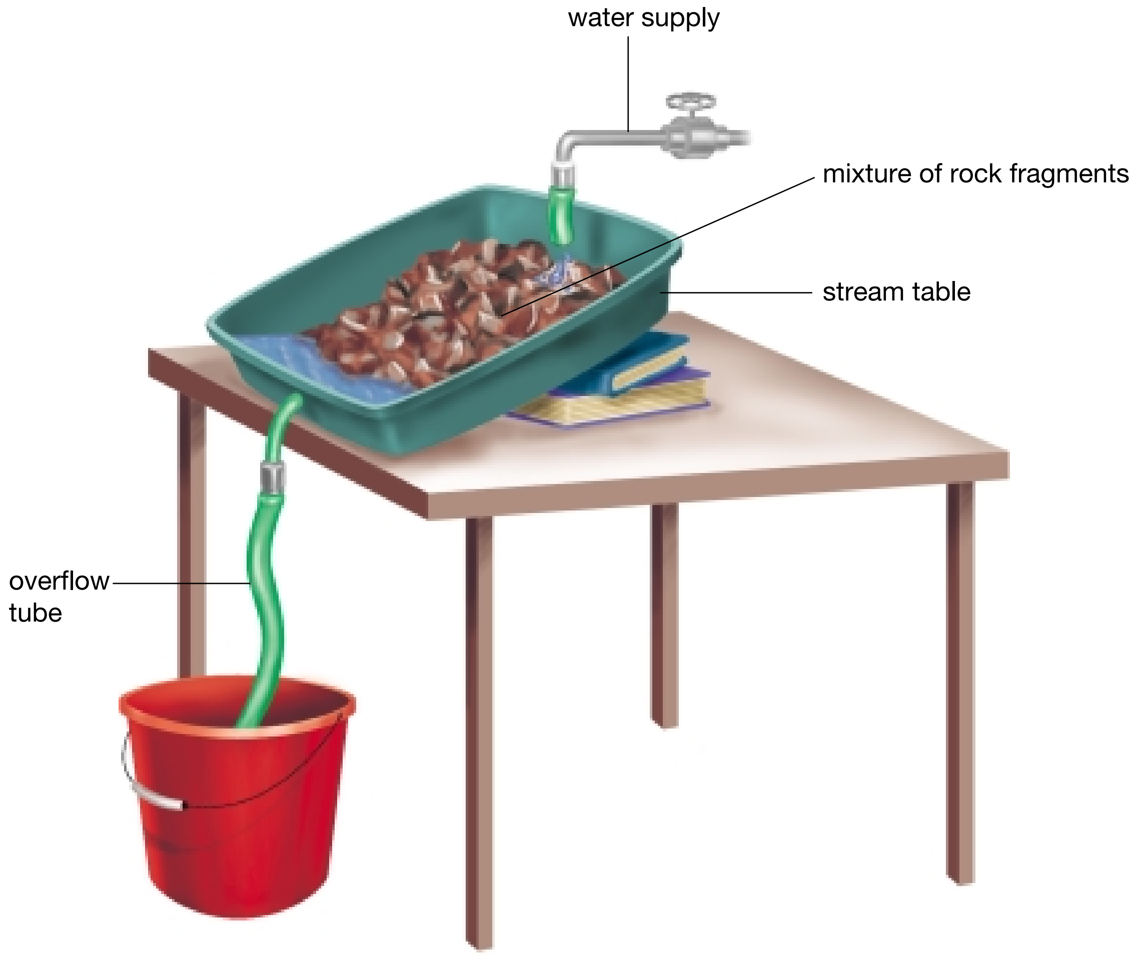
stream table
2 beakers
rubber tubing
metre stick
small piece of foam cup
stopwatch
funnel
hose clamp or clothespin

Materials

water
sand

Procedure

1. Work with your group to decide how to test your hypothesis. You should set a standard distance (e.g., 50 cm) that you will time the piece of foam.
2. List the steps you need to take to test your hypothesis. Include in your plan how you will:
   (a) make your stream channel;
   (b) adjust the height of the slope;
   (c) measure the length of the stream channel;
   (d) use tubing and one of the beakers to begin the water flowing down the stream;
   (e) catch the overflow water at the other end of the pan with the other beaker;
   (f) determine the time it takes the piece of foam to flow down the stream channel; and
   (g) observe the amount of erosion that takes place.
3. **Make a data table** so that it is ready to use as your group collects data. Will the data be summarized in graphs? Decide which type of graph to use.
4. **Identify** the manipulated and responding variables of the experiment. Have you allowed for a control in your experiment? Do you think you should run any tests more than once?



5. Make sure your teacher approves your plan and your data table before you proceed.

6. **Conduct** your experiment. **Record your observations** and **complete the data table.**

Skill FOCUS

For tips on designing your own experiment, turn to Skill Focus 6. For guidance on drawing graphs, turn to Skill Focus 10.

Analyze

1. Calculate the speed of your streams. Divide the distance by the time (speed = distance/time).
2. Were sediments carried along with the water to the end of your stream channels?
3. Did the slope affect the speed of the streams in your experiment?

Conclude and Apply

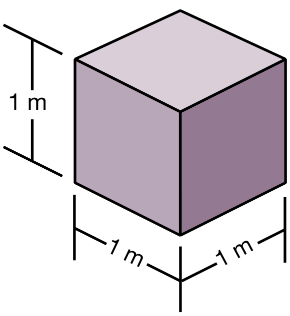
4. Did the streams with the greatest or smallest slopes erode the most sediments? Explain.
5. How would your results change if a stronger flow of water was used? How does this compare to flooding?

River Flow Monitoring

Figure 5.40 A researcher checks stream flow rate using a special meter.

One way watershed managers study drainage basins is by measuring streamflow (Figure 5.40). **Streamflow** is the amount of water discharged by a watershed. It involves measuring the amount of water (volume) that flows past a certain point over a period of time (velocity). Watershed managers measure the amount of water flowing through a stream channel over a period of years. In this way, they can calculate the average streamflow.

An important part of watershed management is knowing the amount of water that will be flowing through river channels at any given time. This information helps scientists to accurately analyze water quality and to prevent or warn people about floods. It also helps them predict drought conditions, and design irrigation and drainage projects. In some rivers and streams, the depth and flow rate of the water are monitored constantly by gauges. In others, a person measures the depth and flow from time to time.



The illustration on the left shows how flow rates are measured for rivers. The cube is 1 m long, 1 m wide, and 1 m high. Therefore, it is 1 m^3. If you filled this cubic metre with water, it would hold 1000 L. The rate at which a river flows is often measured in m^3/s (cubic metres per second). People who monitor rivers want to know how many cubic metres of water flow by in one second.

Another important part of river flow monitoring involves sediments. The greater a river's rate of flow, the higher its ability to transport sediment. When the river slows it does not have the energy required to carry the sediments, so they are deposited.

Sediment is measured and classified depending on whether it is suspended in the water, rolling or bouncing along the bottom, or stationary on the riverbed.

Figure 5.41 shows a cross-section of a typical stream channel. It contains all three types of sediments. Sediments carried by water have a variety of effects. What are they and why are they important?

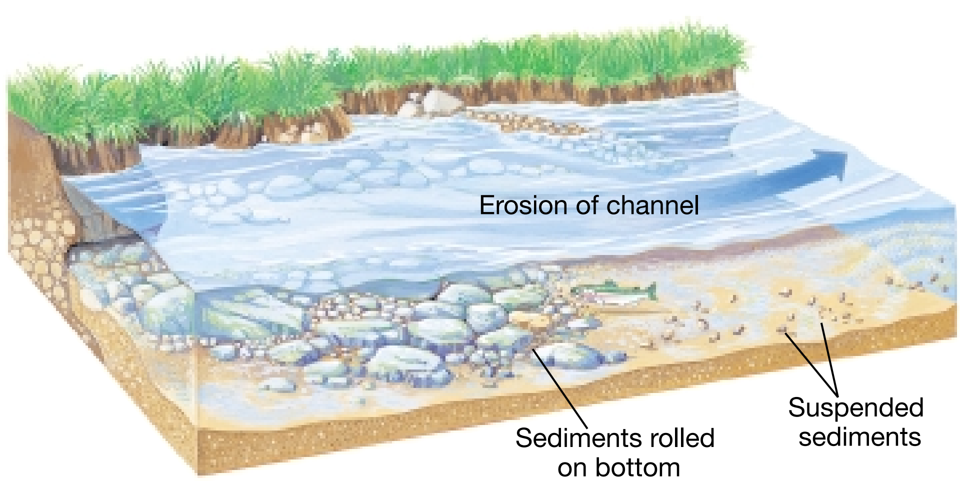


Figure 5.41 Cross-section of a typical stream channel. How will the shape of this channel change over time?

Why Is Monitoring Sediment Important?

Sediment plays a major role in the transport of pollutants. Toxic chemicals can attach themselves to sediment particles. The sediment particles then transport and deposit these toxic chemicals in other areas.

By studying the quantity, quality, and characteristics of sediment in a stream or river, scientists and engineers can determine the sources of the pollutants. They can also assess the impact of the pollutants on the aquatic environment. Once the sources and impact are known, steps can be taken to reduce the pollutants.

- Sediment particles released in fish habitats can carry toxic agricultural and industrial chemicals from run-off. These chemicals can cause abnormalities or death in fish.
- Some farming practices increase soil erosion and add sediment-borne toxic chemicals to the environment. Sediment data can help evaluate farming practices and their environmental effects.
- Deposition of sediment in rivers or lakes can decrease water depth. This can make navigation difficult or impossible.
- Sediment can affect the delivery of water. Water is often taken from streams and lakes for domestic, industrial, and agricultural uses. The presence of sediment in the water can wear out the pumps and turbines at the water supply station.

To find out how much material is transported by a river, scientists take samples and do calculations to measure sediment load (see Figure 5.42). Sediment load indicates the total amount of sediment transported over an hour, day, month, or year.

Figure 5.42 The apparatus shown here "grabs" samples of sediment so scientists can analyze them in a laboratory.

DidYouKnow?

Scientists have estimated that at Montréal the St. Lawrence River transports 2.3 million tonnes of sediment each year. This is the equivalent of 230 000 truckloads of soil. The Fraser River carries an average of 20 million tonnes of sediment a year into the Pacific Ocean.

INTERNET CONNECT

www.school.mcgrawhill.ca/resources/

The peak flow of the Peace River was once measured at 18 500 m^3/s. At this rate, an Olympic-sized swimming pool would fill in just 0.14 seconds! Calculate how long it would take your nearest river to fill an Olympic-sized swimming pool (2.6 million litres of water). To get flow rates for rivers in your area, visit the above web site. Go to **Science Resources**. Then go to **SCIENCEFOCUS 8** to find out where to go next.

Reducing Erosion and Stream Sediment Load

A great deal of sediment is lost from building sites during construction. This sediment can find its way into a sewer or stream system. To offset this problem, a de-sedimentation site can be built to prevent the sediment from entering waterways (see Figure 5.43). Rivers such as the Fraser in British Columbia are dredged from time to time to deepen the riverbed, clogged by sediment (see Figure 5.44).

DidYouKnow?

Alberta has lost more than 70 percent of its natural slough and marsh wetland area. A large part of this loss has occurred as farmers and landowners cleared their land to begin farming. As towns and cities grow, many more wetlands are filled in to provide land for buildings and roads.

Figure 5.43 A de-sedimentation site on the Fraser River

Figure 5.44 Dredging a river removes sediment.

One of the best ways to restore an eroded river is to plant native vegetation along its banks to stabilize the soil. This will lead to less erosion of the banks and less deposition. Where erosion is severe, it may be necessary to reinforce the banks with logs or other obstacles to decrease the current along the bank (see Figure 5.45). For extreme erosion, reinforced rock baskets, called rip-rap, may be necessary. To help deepen the river channel, "digger logs" are sometimes installed to force water down.

One of the major functions of wetlands is to reduce erosion. They do this by storing excess water and slowing the rate of run-off. They also trap and neutralize harmful chemicals in run-off.

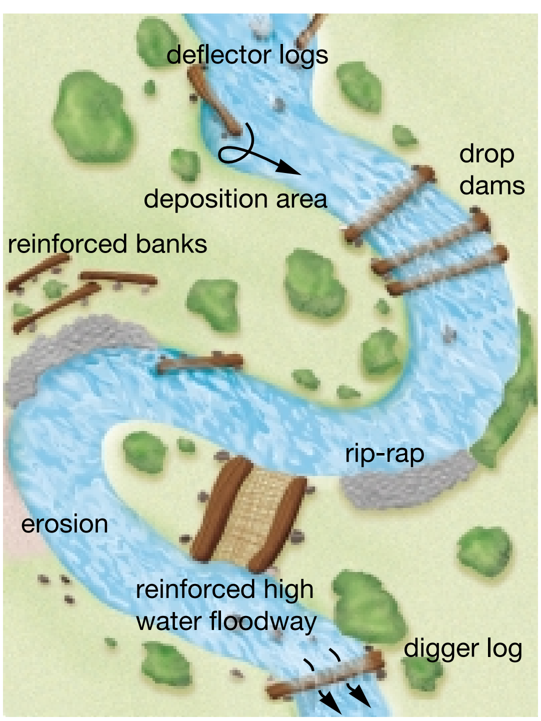


Figure 5.45 Ways of restoring an eroded river

Watershed Management and Groundwater

More than 25 percent of Albertans depend upon groundwater for their water supply. Much of this is related to agriculture. Farmers use this water for irrigation, domestic use, and livestock. Groundwater also contributes to the water level in some lakes. Some river systems also depend on groundwater to keep their channels from drying up during low flow seasons.

A groundwater system is similar to a river system. However, it does not have channels that connect different parts of the drainage basin. Instead, a groundwater system has connecting pores. Soil and rock are **permeable** if the pore spaces are connected and water can pass through them. Sandstone is an example of a permeable rock.

Soil or rock that has many connected pores is highly permeable. Water can pass through it easily. Soil or rock is less permeable if the connected pore spaces are fewer in number or if the pores are fewer or smaller. Some material, such as clay, has small pore spaces or no pores at all. This material is **impermeable**. Water cannot pass through it.

Some types of rock, such as sandstone, are full of pores and can hold a lot of water. As every space in the rock becomes filled, the groundwater forms a sort of underground river system, connected by pores instead of stream channels. This system of water flowing through porous rock is called an **aquifer**. Like rivers on the surface, the water in aquifers moves, although its flow is very slow. It might take 80 years or more to travel through 1 km of sand. The layer of porous rock in which all pores are full of water forms a **water table**, as shown in Figure 5.46. The level of a water table may change, rising closer to the surface in wet seasons and sinking lower in dry seasons.

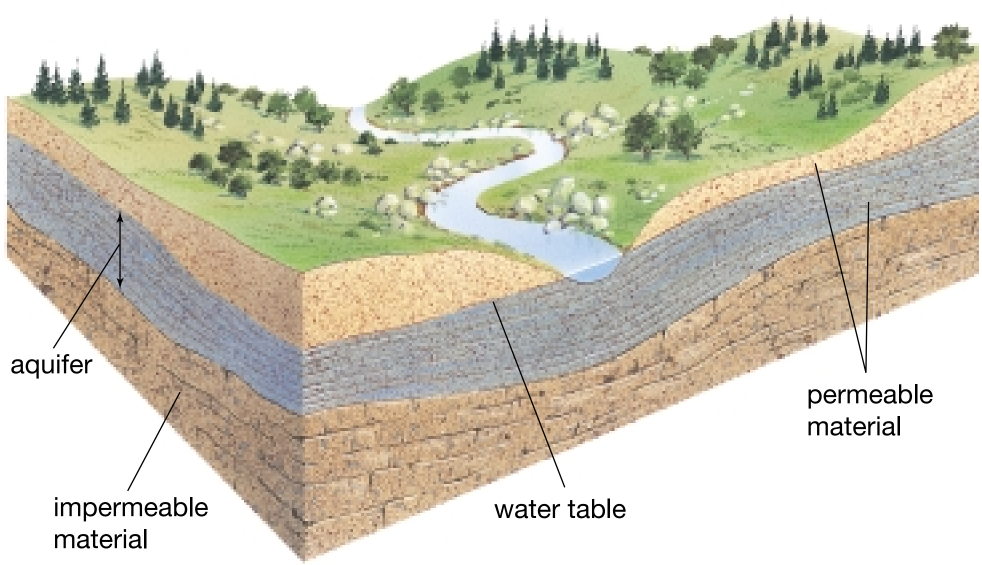


Figure 5.46 Cross-section of a groundwater system

Did You Know?

The amount of fresh water underground is about 37 times the amount on the surface in rivers and lakes. About half this underground water saturates the rock and soil to a depth of nearly 1 km. The remaining half of the water is even deeper — trapped 1–5 km below Earth's surface.

Pause & Reflect

What effects might plant roots and earthworms have on pore spaces in soil? In your Science Log, make a hypothesis and then describe how you could test it.

DidYouKnow?

The depth of wells in Alberta can range anywhere from 2 m to over 50 m.

Wells and Springs

Have you ever been to a beach and scooped out a hole in the sand? As if from nowhere, water appears in the hole. Water moves into the hole from the saturated sand surrounding it. In almost any part of the world, even in deserts, a hole dug deep enough will reach water from the reservoir under the ground. Wells are made by drilling a hole through the soil and rock to a point below the water table (see Figure 5.47). Water is pumped up to the surface. If too many wells are dug in one area, they may remove groundwater faster than it is replaced by precipitation. If that happens, the water table will drop and the wells may run dry.

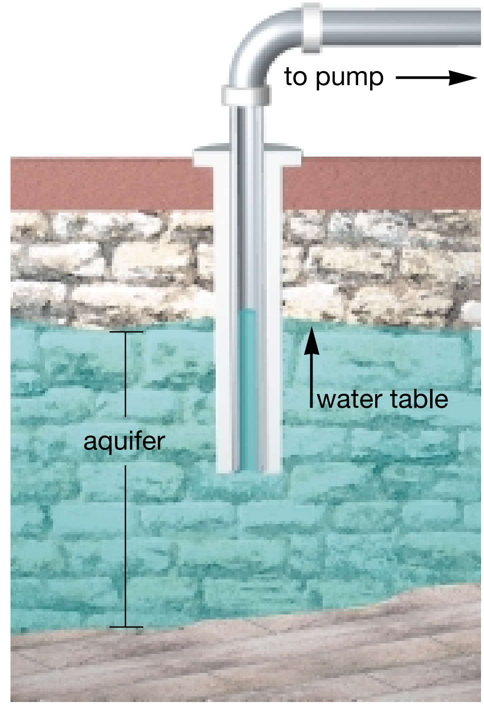


Figure 5.47 Wells are dug deep enough to reach a point below the water table.

Find Out ACTIVITY

How Much Pore Space?

Some materials have a greater volume of pore spaces in them than other materials. How can you measure pore space? Find out in this activity.

Materials

3 identical beakers	water
100 mL sand	graduated cylinder
100 mL gravel	100 mL clay

Procedure Performing and Recording

1. Take three identical beakers. Put 100 mL of sand in one, 100 mL of gravel in the second, and 100 mL of clay in the third.
2. Slowly pour 100 mL of the water from the graduated cylinder into the beaker of sand until the water just covers the sand. Record the amount of water used.
3. Repeat the procedure with the beaker of gravel and then the beaker of clay.

Wash your hands after completing this activity.

What Did You Find Out? Analyzing and Int

1. Which material has more pore space? Why?
2. How might the total volume of pore space change if you crushed the gravel into smaller pieces? Draw a sketch to explain your answer.
3. What variables did you need to keep constant in this activity?

Extensions

4. Is soil from your school grounds more porous or less porous than sand? Make a prediction, then repeat the activity using 100 mL of soil.
5. What criteria did you use to assess your solution in step 4?

In some areas, groundwater flows naturally out onto the surface, forming a spring. This usually happens on hillsides or in gullies, where the water table is exposed by a dip in the land. Some springs produce steaming hot water. Hot springs occur where groundwater is heated by rocks that come in contact with molten material under Earth's surface. A well-known hot springs area in Canada is Banff, Alberta.

Aquifer Depletion

Underground aquifers are essential water resources for people and nature alike. When too much water is withdrawn for cities, agriculture, or industry, these precious reserves can be depleted. Local supplies fall short. Creeks, springs, and wells for kilometres around can go dry. When this happens, people must truck water in or build pipelines. However, the local plants and wildlife are left without enough water.

Using less water is the reasonable response to aquifer depletion. Water conservation leaves more water in rivers, streams, and aquifers, which is good for wildlife. It is also good for us, since many regions experience water shortages during parts of the year. Conserving water also saves us money on water and sewage bills!

DidYouKnow?

In the twelfth century, in the French region of Artois, people began digging wells from which water flowed without any need of a pump. Such wells today are called *artesian wells*, after the name of the region in France.

Find Out ACTIVITY

Make a Model Aquifer

Use a small aquarium to create your own model aquifer system. You can demonstrate how permeable and impermeable layers below the ground can influence groundwater movement. Your model can also illustrate the conditions needed for an artesian well to exist.

Procedure ✷ Performing and Recording

1. Use the illustration shown here as a guide. The modelling clay represents the impermeable layer. The coarse gravel represents the aquifer. Use dry sand for the surface layer.

2. Now make an artesian well. Remove some of the sand at the bottom of the hill to expose the clay. Using a pencil, make a hole through the clay. Place a medicine dropper (with the bulb removed) upside down in the hole.

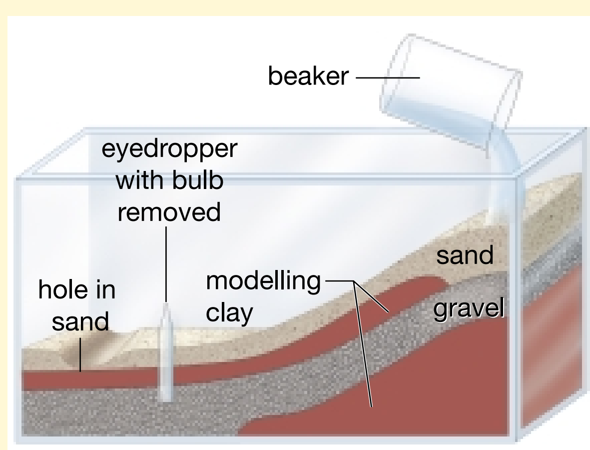
3. Before covering the well with sand, make sure you reseal the hole around the tube with modelling clay.

4. Add water, but pour very slowly. Observe the movement of the water as it travels along the aquifer. Wash your hands after completing this activity.

What Did You Find Out? ✷ Analyzing and Interpret

1. What is happening at the artesian well site once the aquifer is filled with water?

2. How are artesian wells different from other wells?



Groundwater Contamination

Looking Ahead

How could you use your understanding of groundwater contamination? Record your ideas. You may wish to use them in "Water Watch" at the end of the unit.

Groundwater carries with it any soluble (dissolvable) contaminants that it encounters. Any addition of undesirable substances to groundwater caused by human activities is considered **contamination**. Groundwater can spread the effects of dumps and spills far beyond the site of the original contamination.

Sometimes hazardous wastes, chemicals, heavy metals, oil, and other contaminants collect on the surface of the ground. Rain or run-off seeping into the soil can carry these substances into the groundwater. When water quality specialists analyze the quality of groundwater, they consider land use practices in the watershed and in the vicinity of the well.

Groundwater contaminants come from two categories of sources. These are point sources and non-point sources. **Point sources** are those where the source of a pollutant is from a small, defined area. Leaking gasoline storage tanks, leaking septic tanks, and accidental spills are examples of point sources. So are municipal landfills and industrial waste disposal sites (see Figure 5.48). **Non-point sources** are those where a pollutant comes from a wide area. Run-off from farm land treated with pesticides and fertilizers is an example of a non-point source.

Hydrogeologists are scientists who study groundwater (see Figure 5.49). To learn about the characteristics of an aquifer, they drill wells. The drill passes through different rock formations. The driller records the depth of each formation, and collects samples of the rock material penetrated (sandstone, sand, clay, etc.). These data provide valuable information for determining groundwater availability, movement, quantity, and quality.

Figure 5.48 Municipal landfills such as this one are point sources of groundwater contamination.

Figure 5.49 These researchers are testing groundwater samples for possible contamination.

Too Little Water

There is a water dilemma in Alberta. Often there is too much water in the large flowing rivers of northern Alberta. This rapidly flowing water can destroy and erode agricultural land. In the south, Alberta's rivers carry smaller volumes of water. At the same time, the agricultural, industrial, and municipal demand is very high. Some river channels are in danger of drying up during the hot summer months.

Managing water in southern Alberta is different from managing water in the north. Much of the water that is used in Alberta is for agriculture, particularly irrigation. Almost 40 percent of Alberta's population lives in southern Alberta. Nearly 50 of their urban communities rely on irrigation systems for domestic water supply.

One example of a water management project is the Western Irrigation District. This water delivery system uses 1200 km of canals east of Calgary (Figure 5.50). It delivers water to farmers, to acreage owners, and to various industrial customers. In addition, it supplies storm water removal systems and municipal water for several towns.

Many people using irrigation canals are helping to conserve the limited water resources by using more efficient irrigation equipment. Look at the map of amount of annual rainfall in Canada in Figure 5.51. Can you see how the amount of water available to Canadians depends on where they live?

DidYouKnow?

The irrigated parts of Alberta make up 4 percent of the province's total cultivated land base. However, these areas generate 16 percent of the province's total agricultural production. Irrigation protects the farmers against drought. It also ensures that high-value crops such as beans, peas, sugar beets, potatoes, ginseng, and mint can grow in Alberta.

DidYouKnow?

Canada diverts more water through the use of dams and canals than any other country in the world.

Figure 5.50 An irrigation canal in Alberta

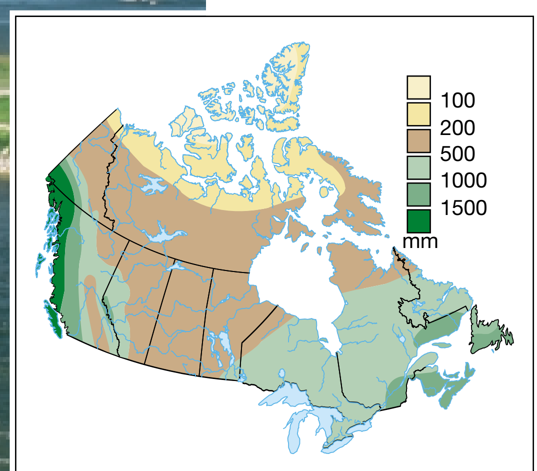


Figure 5.51 Average annual precipitation in Canada. How much rainfall does your area receive?

DidYouKnow?

When hydroelectric projects are built, the size of the areas flooded is sometimes huge – larger even than some countries. This has a major impact on habitats.

Too Much Water

What happens when a river system has too much water in it? If spring melting occurs rapidly, together with heavy spring rains, large volumes of water can enter a river channel in a very short time. A river may then overflow its banks and spill out over a wide area of the valley floor. This part of the river valley is called the **flood plain**, as you saw in Figure 5.37. A river that overflows its banks can bring disaster if cities, homes, and farms are built on flood plains (see Figures 5.52 and 5.53).

Figure 5.52 People build walls of sandbags in an attempt to hold back flood water.

Figure 5.53 In 1997, the Red River flood in Manitoba caused great social and economic damage. The rising flood waters forced more than 28 000 people to evacuate their homes.

Dams are built for many reasons, including irrigation and flood control. Large dams may be used to supply water to a city. They may also be used to generate hydroelectricity. A dam might be placed across a river to store water for the dry southern Alberta summers.

Figure 5.54 A hydro-electric dam at Ghost Lake, Alberta

Many environmental considerations go into building a dam. All dam projects in Alberta require approval from Alberta Environment before construction begins. Alberta Environment consults other agencies such as Alberta Resource Development to ensure that certain environmental standards are met. These standards are designed to protect rivers and streams and their habitats. The steady flow and water level produce a relatively constant environment throughout the length of the river downstream from the dam. However, the constancy of the altered river often reduces the diversity of organisms that were present before the dam was built. Short-term and long-term impacts must be evaluated before a dam is built.

Predicting Floods

Each year, floods claim hundreds of lives, drive people from their homes, and cause millions of dollars in property damage. That's why flood prediction is so important. To accurately predict floods, a lot must be known about the drainage basin of a particular river. One important piece of data is how fast water drains from the basin.

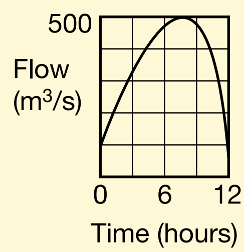
Imagine that it rains on a parking lot with a drain near one end. All of the water does not reach the drain at the same time because it takes longer for the water at the far end of the parking lot to travel to the drain. Also, the parking lot is probably not level, so some areas drain more quickly than others. This is similar to run-off from a drainage basin flowing into a stream channel.

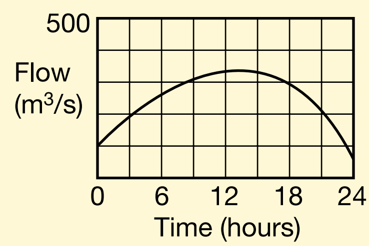
The graphs show run-off of two drainage basins after a 3 cm rainfall. The graphs show the volume of the flow over time. Study the graphs and interpret the data to explain the differences.

Find Out ACTIVITY

What Did You Find Out? Analyzing and Inter

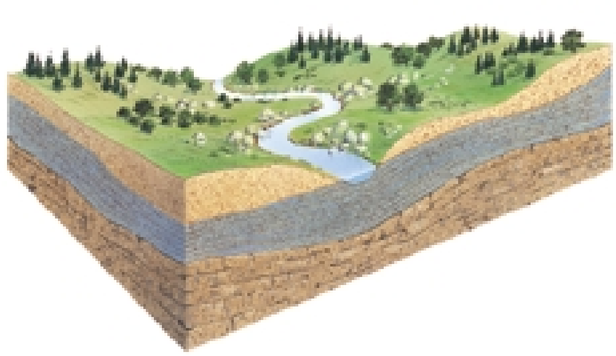
1. Which of these two drainage basins will most likely flood?
2. What might be different about the two drainage basins that would explain the differences in their flow rates?





TOPIC 3 Review

1. Imagine you are a watershed manager. Describe some of your tasks and responsibilities.
2. Make a sketch of the drawing below into your notebook. Label the parts of a groundwater system.



3. **Design Your Own** You can make a homemade stream table by using a section of eavestrough and covering the bottom with soil. Build a stream table. Then design an experiment to find out what happens to the rate of erosion if you use different types of soil. (Remember to specify your variables, and a control.)
4. Explain what is meant by "aquifer depletion." How can this problem be solved or reduced?
5. Rainwater in southern Alberta can end up in the Gulf of Mexico. How is this possible?
6. **Thinking Critically** "A watershed reflects the health of the surrounding ecosystem." Do you agree or disagree with this statement? Explain your answer.

TOPIC 4 The Oceans

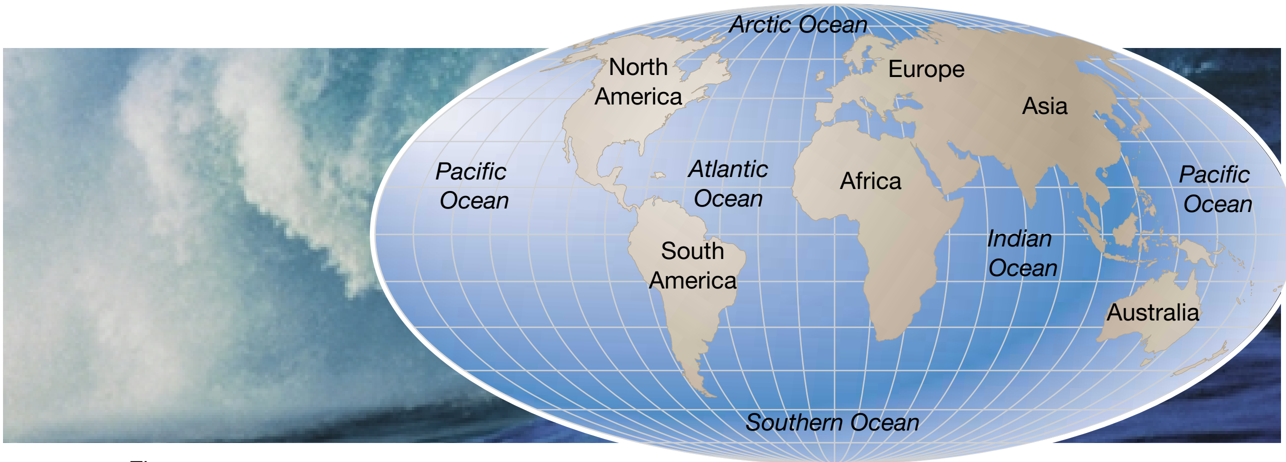


Figure 5.55 The oceans cover about 70 percent of Earth's surface, or 360 million square kilometres. The total volume of the oceans is about 1.35 billion cubic kilometres.

The ocean is never still. You can see it moving in the waves that crash ashore. On the open water, sailors witness broad, slow-flowing "rivers" at the ocean's surface. These movements carry enormous amounts of water over hundreds of kilometres from one part of the ocean to another. The ocean is in constant motion below the surface, too. Huge masses of cold water creep along the ocean floor, then rise from the depths to the surface.

If you live far from the ocean it may be hard to imagine how the ocean affects your life. No matter where you live, though, you cannot escape the influence of the ocean. The weather is affected each day by Earth's oceans. Its waters provide us with food, and its floor holds resources of oil, gas, and minerals. Many of the items you buy in a store were transported across oceans from other continents.

Since we live on dry land, we may not always realize the importance of the oceans to life on Earth. Oceans cover two thirds of Earth's surface. When you look at a map of the world, you can see that oceans dominate the planet. Trace your finger through all of the world's oceans on the map in Figure 5.55. You can see that there is really only one ocean in the world — all of the world's ocean water is connected. Can you see why some people think that our planet is misnamed? Perhaps it should have been called Ocean instead of Earth.

INTERNET CONNECT

www.school.mcgrawhill.ca/resources/

How deep is the ocean? How can whales dive to such great depths? What do jellyfish eat? No doubt, you have lots of questions about the ocean. To have your ocean-related questions answered by a marine scientist, visit the above web site. Go to **Science Resources**. Then go to **SCIENCEFOCUS 8** to find out where to go next. Use the information you find to prepare a short illustrated report.

A Sea Full of Salt

Rivers, like British Columbia's Fraser River in Figure 5.56, flow down from mountains and across the land before finally pouring their waters into oceans. Traces of muddy water from the largest rivers can be detected as far as 1000 km out from the coastline. Ocean water, however, is not the same as river water. Ocean water is salty.

Off the Wall

If the total amount of salt in the oceans were dried and spread over the whole Earth, it would produce a layer 45 m thick. This is deep enough to bury a 15-storey apartment building.

Figure 5.56 The Fraser River flows from its headwaters near the Alberta border to empty into the Pacific Ocean. Each year it dumps 20 million tonnes of sand, silt, and mud. All of these materials contain salts.

On average, 1000 g of seawater contain 35 g of dissolved salts. This is usually expressed as 35 parts per thousand (ppt). By far the most common material in this solution is sodium chloride. This is the same chemical substance as the table salt you use to season food. The next most plentiful salts are composed of sulphates, magnesium, calcium, and potassium (see Figure 5.57). The measure of the amount of salts dissolved in a liquid is known as **salinity.**

Where do the salts in the ocean come from? Most started out in rocks on land. Rivers and groundwater flowing over the rocks pick up the salts and carry them to the ocean. Fresh water, in fact, contains many of the same dissolved substances as seawater, but in far smaller proportions. For example, the concentration of sodium in seawater is about 16 000 times greater than in fresh water.

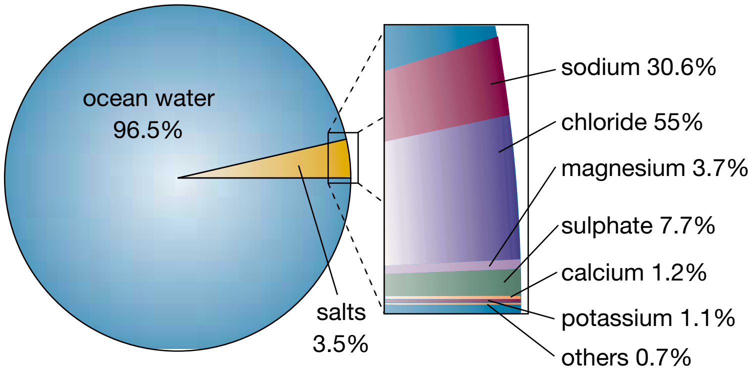


Figure 5.57 Ocean water contains about 3.5 percent salts. Traces of almost every chemical substance on Earth can be found in seawater, including gold and silver. Most of these substances, however, occur in extremely small quantities.

Pause& Reflect

If the ocean is continually fed salt from the land, why isn't it getting saltier? In your Science Log, make a prediction that explains this phenomenon. You will learn more about salt in the ocean in Topic 5.

Although rivers from different areas of land may carry different salts into the seas, the motion of sea water mixes them together. Thus, samples of water from any part of the ocean generally contain similar substances.

Another source of chemicals in seawater is volcanoes. Molten lava and gases from volcanic eruptions on the sea floor add materials such as chlorine and sulphur to seawater. Gases from volcanic eruptions on land circulate first in the atmosphere. From there, they may dissolve directly in the surface waters of the ocean, or be carried from the atmosphere in rainfall.

Find Out ACTIVITY

How the Ocean Gets Its Salt

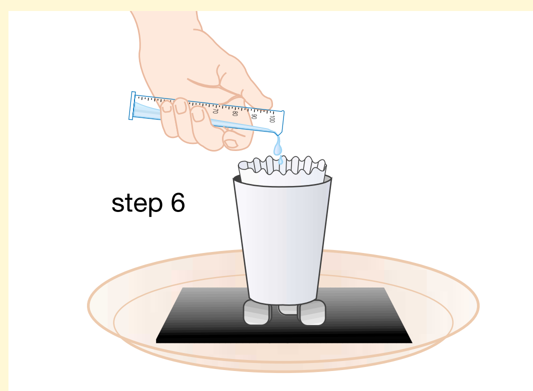
Why is the ocean saltier than the rivers that flow into it? Where does the salt come from? Why does the ocean level not rise as rivers continually pour water into ocean basins? This activity provides clues that help answer these questions.

Materials

- graduated cylinder
- 2 paper cups
- paper coffee filter
- 15 mL salt
- 15 mL soil
- sharp pencil
- sheet of black construction paper
- modelling clay
- large plate or tray
- water

Procedure — Performing and Recording

1. Use the point of the pencil to punch five holes in the bottom of the paper cup. **CAUTION** Be careful as you punch the holes.
2. Place the coffee filter inside the cup.
3. Make short legs of modelling clay for the cup. Set up your materials as shown.
4. In the empty cup, stir together the soil and the salt.
5. Pour the soil/salt mixture into the coffee filter.
6. Pour 20 mL of water onto the soil/salt mixture. Allow the liquid to drain through the holes in the cup onto the construction paper.
7. Allow the paper to dry. Record your observations.
8. Wipe up any spills and wash your hands after this activity.



What Did You Find Out? — Analyzing and Interpreting

1. Why does salt move from the soil mixture onto the construction paper?
2. Why is salt left behind on the paper after it dries?
3. What process causes water to leave the ocean? (This process balances the water entering the ocean, and explains why the ocean level does not rise.)
4. Why is river water not salty?

Ocean Basins

The oceans form the largest ecosystem on Earth. Oceans are vast, and much remains to be discovered about what lies below the ocean surface. Beneath the waves, most of the ocean is pitch-black. Visible light does not penetrate the water beyond a depth of about 100 m. Starting with simple techniques, and later using advanced technology, scientists have come to learn more and more about the amazing undersea world.

A Journey on the Ocean Floor

Imagine you could empty the oceans of water and take a journey along the sea floor. What would you see? For one thing, features in the ocean basins are much bigger than on land. There are mountain ranges, steep valleys, and vast plains (see Figure 5.58). The forces that shaped these features are different from those that shaped rivers and lakes. There are no winds, rivers, rain, or ice on the seabed to erode and carve the rock. Instead, the origin and formation of the ocean basins are due mainly to the movements of Earth's tectonic plates.

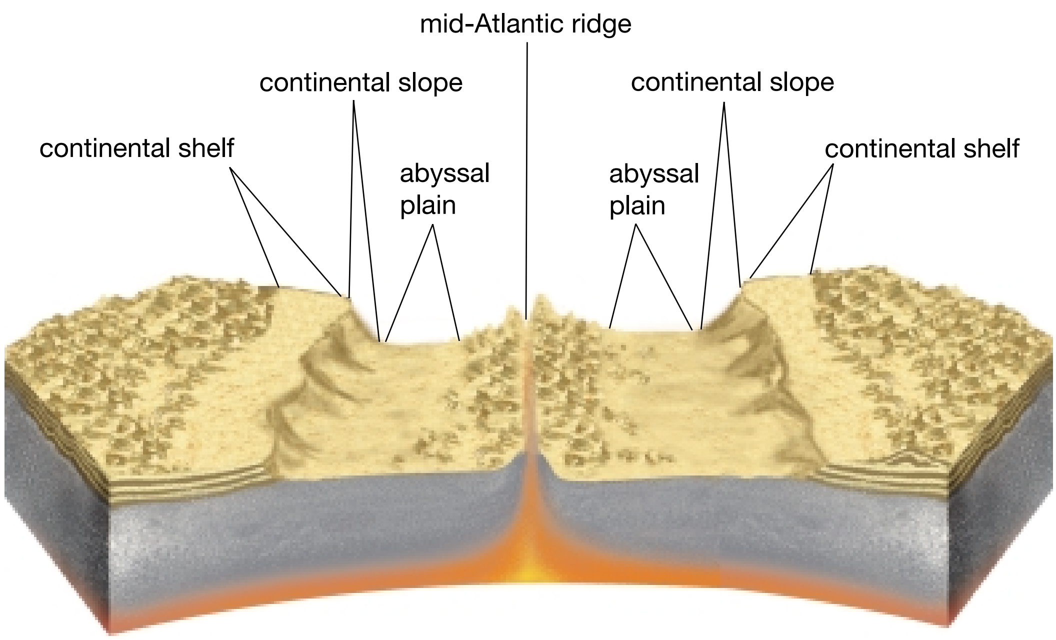


Figure 5.58 The ocean basins contain mountain ranges, deep valleys, and wide plains.

Recall from your earlier studies that Earth's crust is made of large plates of rock that move slowly. One result of this movement is that the oceans have not always been shaped as they are today. As tectonic plates move apart or together, some oceans expand, while others shrink.

www.school.mcgrawhill.ca/resources/
To learn more about satellite imagery and to view images of the ocean floor, visit the above web site. Go to **Science Resources**, then to **SCIENCEFOCUS 8** to find out where to go next. Construct your own images of a part of the ocean floor.

DidYouKnow?

The ocean basins are no older than 200 million years! By determining the age of fossils found on the ocean floor, scientists can estimate the time at which the ocean floor was formed.

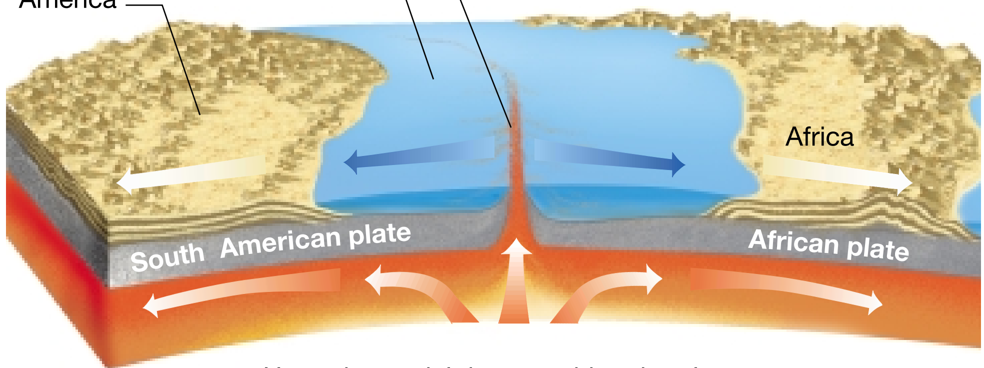


Figure 5.59A The Atlantic Ocean is expanding. North America and Europe are being carried about 3 cm further apart each year.

Pause& Reflect

Put your hands on a globe of the world, placing one hand on either side of the Atlantic Ocean. Imagine your hands are tectonic plates, and begin to move them slowly apart. What would happen at either side of the Pacific Ocean as you do this? In your Science Log, write a short paragraph or draw a sketch to explain why trenches are located around the rim of the Pacific Ocean.

What features of the sea floor are related to plate movements? Long undersea mountain chains called **ocean ridges** run along the centre of the oceans. These ridges are the youngest areas of the sea floor and are still being formed by volcanic eruptions. Molten lava flows from these ridges, quickly hardening into new plate material that pushes tectonic plates farther apart. Ocean ridges are more than 1000 km wide and rise 1000–3000 m above the sea floor.

Along some margins of the sea floor, narrow, steep-sided canyons, called **trenches**, are formed where the edge of an ocean plate pushes against the edge of a continental plate (see Figure 5.59B). As the plates move together, the ocean plate is forced to bend steeply down beneath the heavier continental plate. Most trenches occur around the margin of the Pacific Ocean. The deepest trench, called the Marianas Trench, extends 11 km below sea level. This distance is deep enough to submerge an object as tall as Mount Everest.

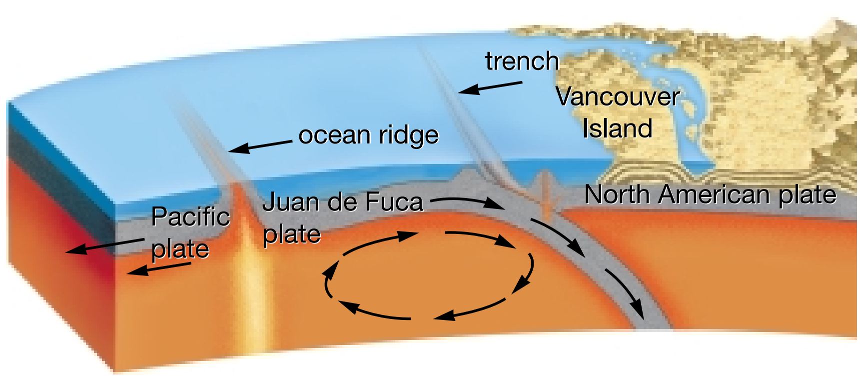


Figure 5.59B Coastal British Columbia is an earthquake-prone area. Earthquakes result as the small Juan de Fuca plate slides beneath North America.

Between the high mountain ranges at their centre and the deep trenches at their edges, the ocean floors are remarkably flat. These wide, open features of the deep sea are called **abyssal plains** (see Figure 5.58). They are formed of thick deposits of sediment, up to 1 km deep in places.

The sediments come from the continents, brought to the ocean edge by rivers. How do they reach the deep sea floor? They are carried there in great underwater landslides. These landslides are started by earthquakes, or simply by the force of gravity. From time to time, massive volumes of mud and sand slump down the slopes at the edge of the continents. Dropping to deeper waters, mud-filled currents spread their deposits evenly over the abyssal plains.

Continental Shelf and Slope

Ocean basins do not begin at the coastline. Instead they begin many kilometres out at sea. The area between the coast and the edge of the ocean basin is actually a submerged part of the continent, called the **continental shelf** (see Figure 5.60).

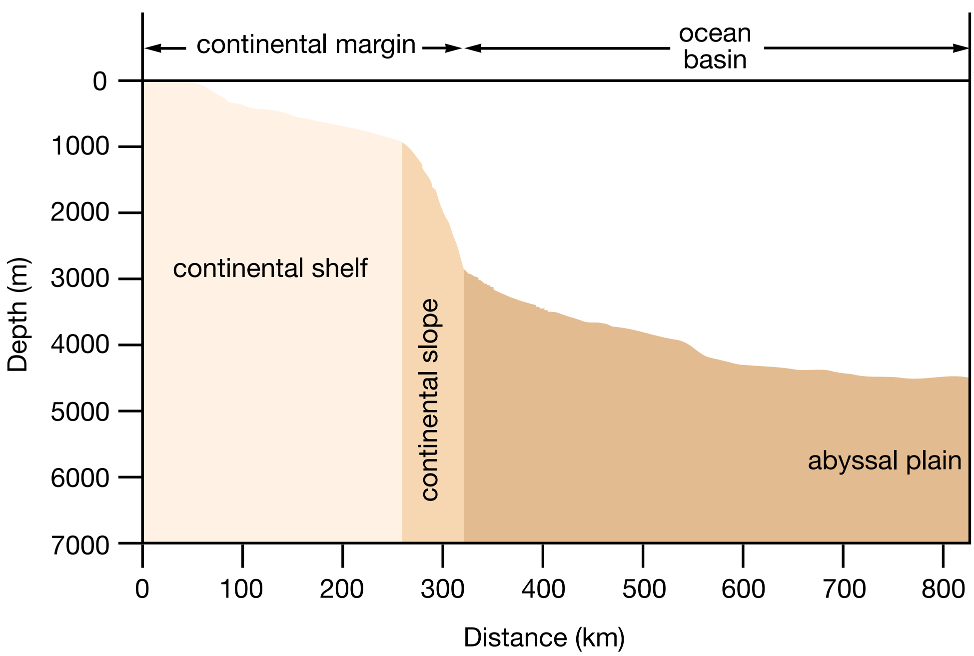


Figure 5.60 The ocean floor is divided into two main regions — the continental margin (the continental shelf and slope) and the ocean basin.

Continental shelves slope gradually away from the land before dropping steeply downward at the shelf edge. The narrowest continental shelves occur along coastlines with high mountains, where plates are moving together. The width of these shelves is usually less than about 30 km. Along other coastlines, the continental shelf is much wider. It may extend more than 300 km out into the sea.

From the edge of the shelf, the **continental slope** plunges at a steep angle to the sea floor. Continental slopes are usually less than 200 km wide and descend to about 3 km. Beyond the base of the continental slope lies the floor of the ocean basin.

THINK & LINK

INVESTIGATION 5-F

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

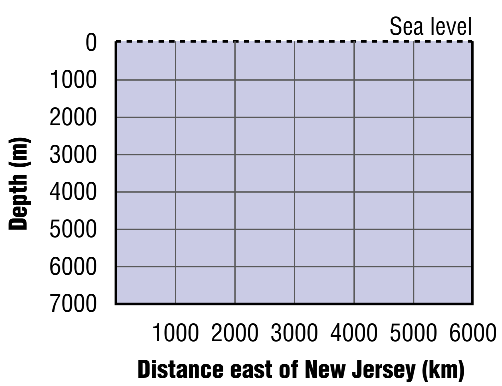
Mapping the Ocean Floor

Think About It

What does the ocean floor look like? Use these real data that were collected by a ship during a research voyage between New Jersey and Portugal to draw a profile of the sea floor under the Atlantic Ocean. Identify the location of New Jersey and Portugal on a map before you begin.

What to Do

1. Make a graph like the one shown below. Give your graph a title.
2. Study the data in the table shown on the right. It lists a series of depths to the ocean floor. The measurements were taken at 29 different points along a line.
3. Plot each data point on your graph. Connect the points with a smooth line.



Analyze

1. List the sea floor features that occur east of New Jersey
   (a) between 160 and 1050 km
   (b) between 2000 and 4500 km
   (c) between 5300 and 5600 km

2. Does your profile give an accurate picture of the sea floor? Explain. (Hint: Consider the distance between the two locations and the water depth shown on your graph.)

3. Why do you think the depth of the ocean floor is 0 for station 20? What feature do you think this might be? (Hint: Look in an atlas and predict what might be in this location.)

Data for Sea-Floor Profile

Station number	Distance east of New Jersey (km)	Depth to ocean floor (m)
1	0	0
2	160	165
3	200	1800
4	500	3500
5	800	4600
6	1050	5450
7	1450	5100
8	1800	5300
9	2000	5600
10	2300	4750
11	2400	3500
12	2600	3100
13	3000	4300
14	3200	3900
15	3450	3400
16	3550	2100
17	3600	1330
18	3700	1275
19	3950	1000
20	4000	0
21	4100	1800
22	4350	3650
23	4500	5100
24	5000	5000
25	5300	4200
26	5450	1800
27	5500	920
28	5600	180
29	5650	0

Skill FOCUS

For guidance on drawing line graphs, turn to Skill Focus 10.

Ocean Waves

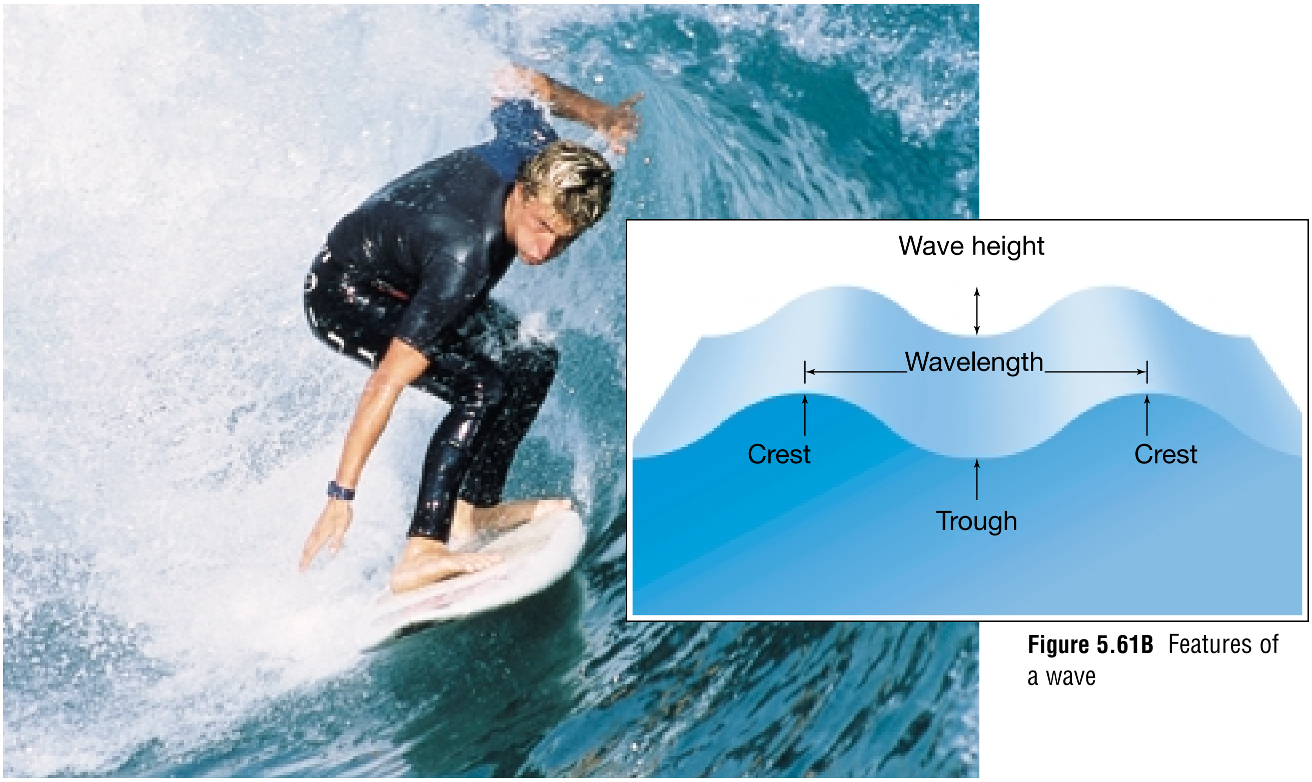


Figure 5.61B Features of a wave

Figure 5.61A Some of the largest waves occur along the coasts of California and Hawaii. The waves in these places have been blown by wind over thousands of kilometres of open ocean.

Surfers ride ocean waves, using the motion of the water to carry them to the shore (Figure 5.61A). What causes waves? You can find the answer in a bowl of hot soup! If you blow on the soup to cool it, your breath makes small ripples on the surface of the liquid. Ocean **waves** are just large ripples, set in motion by steady winds.

Waves begin on the open sea. Their height depends on how fast, how long, and how far the wind blows over the water. An increase in any one of these variables can cause an increase in wave height. Normal winds produce waves of 2–5 m in height. Hurricane winds can create waves 30 m high — two thirds the height of Niagara Falls! Even on a calm day, there is a steady movement of smooth waves near the shore. These smooth waves are called **swells**. They are caused by winds and storms far out at sea.

Whether large or small, waves on the water have features in common with all the other types of waves studied by scientists — such as sound waves, light waves, and radio waves. First, waves have height, as shown in Figure 5.61B. As you learned in Unit 3, a wave's height is measured from its crest (the highest part of the wave) to its trough (the lowest part of the wave). Second, waves also have a wavelength, which is the distance from one crest to the next. Third, waves have a speed of motion, which is measured by the time required for one wave to pass a given point.

Breaking Waves

Near the ocean surface, water particles move in a circular motion as a wave passes. As you learned in Unit 3, the particles end up in nearly the same position as where they started. As each water particle moves, it bumps into the next particle and passes its energy along.

When a wave reaches shore, it changes shape (see Figure 5.62A). As the trough of the wave touches the beach, it is slowed down by friction. The crest of the wave, however, continues moving at the same speed. The wavelength shortens, and the wave height increases. The crest of the wave eventually outruns the trough and topples forward. The wave collapses onshore in a tumble of water called a **breaker** (see Figure 5.62B). A surfer can use the forward motion of the crest to ride a wave to shore.

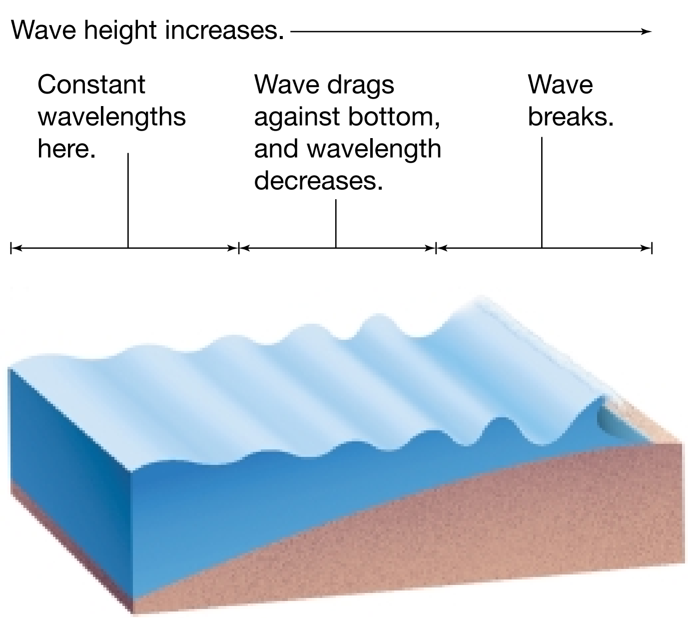


Figure 5.62A The movement of waves as they approach the shore

Figure 5.62B As a wave approaches the shore, its wavelength decreases and its height increases. It collapses onshore as a breaker.

DidYouKnow?

Some of the highest ocean waves are not caused by winds but by earthquakes, volcanic eruptions, or landslides on the sea floor. These events give the ocean water a push, just as you can make a wave in a bathtub by pushing with your hands underwater. Sea-floor events sometimes produce giant waves called *tsunamis*. The wavelength of a tsunami may be 150 km. It may travel over the open ocean at a speed of up to 800 km/h. When a tsunami approaches land, the speeding water is pushed up into a towering, destructive wave with a height of 15 m or more.

DidYouKnow?

Humans aren't the only animals that like to surf. Sea lions, seals, sea ducks, river otters, and even whales have been known to catch a wave or two.

How Waves Change Shorelines

The energy in waves shapes and reshapes shorelines around the world. Along some shorelines, churning waters swirl rocks and pebbles on narrow strips of land between steep sea cliffs and the ocean. On other shorelines, gentle waves lap broad, gently-sloping beaches of fine sand. Why does one shoreline have a sandy beach while another does not? You can find answers in the type of rock in each area and in the shape of the shoreline.

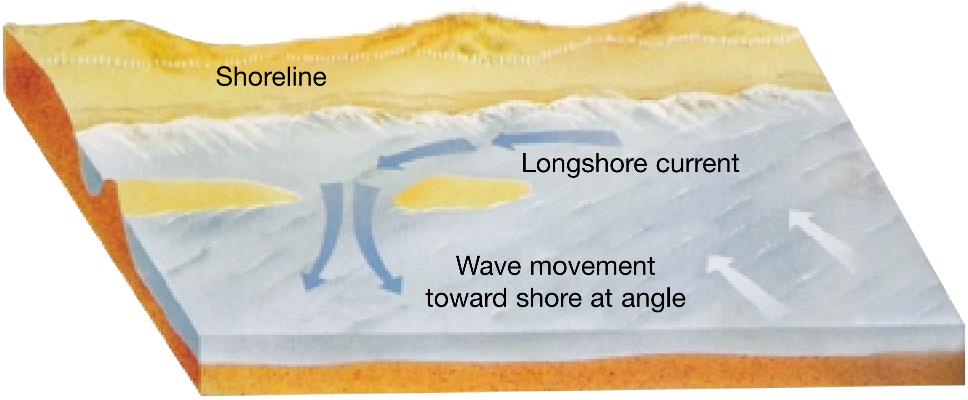


Figure 5.63A Along shorelines, waves move sediments back and forth.

Waves shape shorelines by eroding and redepositing sediments. Waves usually collide with the shoreline at slight angles. This creates a longshore current of water that runs along the shore (see Figure 5.63A). **Longshore currents** carry many metric tonnes of loose sediment. They act like rivers of sand in the ocean. What do you suppose happens if a longshore current isn't carrying all of the sand it has the energy to carry? It will use this extra energy to erode more shoreline sediments.

Along many shorelines, rocks and cliffs are the most common features. Waves slowly wear away the rocks and eventually form hollows. Over time, these hollows enlarge and become sea arches or caves (see Figure 5.63B). When too much erosion occurs, overhanging rock may fall off into the ocean. Rock fragments broken from the cliffs are ground into sediments by the endless motion of waves. These sediments are transported by longshore currents. Seawater can also dissolve certain minerals in rock, increasing erosion by chemical action. The combined action of waves and chemical processes can erode areas of rocky shorelines by as much as 1 m in a year.

Do the investigation on the next page to see for yourself how waves affect beaches.

Pause & Reflect

Imagine being an animal such as a barnacle, mussel, or sea star that lives on a stretch of rocky coastline. Predict how you would cope with the crashing waves that pound your home hour after hour. Describe or illustrate your ideas in your Science Log.

Figure 5.63B Sea caves and arches are formed by erosion by waves and wind.

INQUIRY

INVESTIGATION 5-G

SKILLCHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

Waves and Beaches

What happens to the material on a beach when waves strike it? Depending on the type of rock and the slope of the coastline, waves can either erode the land or build it up.

Question

How do waves affect beaches?

Hypothesis

Form a hypothesis about how the slope and materials of a beach will affect its size and shape.

Safety Precautions

Apparatus

beaker or measuring cup (500 mL)

clear plastic or glass pan or small aquarium

ruler

small block of wood

clock or watch

plastic pail or container

Materials

beach mixture 1
(450 mL sand + 150 mL gravel)

beach mixture 2
(450 mL gravel + 150 mL sand)

water

Procedure

1. Using beach mixture 1, build a small beach at one end of the pan or aquarium. Use your ruler to **measure** the height of the beach at the top of the slope. **Record** the measurement.

2. Then **measure** the width of the beach (from the top of the slope to the bottom of the slope). **Draw** a side view of the beach to scale and **record** your measurement.

3. Carefully pour water into the other end of the pan or aquarium until the water level reaches about one third of the way up the beach.

4 Make waves by holding the block of wood in the water and quickly moving it up and down for 2 min. Try to keep the speed and size of the waves constant.

5 After 2 min, **draw** a side view of the beach to scale. (Use your ruler to measure its dimensions and **record** this measurement.)

(a) **Label** the position of the sand and the gravel.

(b) Carefully pour off the water into a container provided by your teacher.

Skill FOCUS

For tips on estimating and measuring, turn to Skill Focus 5.

6 Rebuild a beach with a slope twice as steep as the first. **Measure, record,** and **sketch** the dimensions of the beach.

7 Repeat steps 3 to 5. Then empty the water and beach materials into a container provided by your teacher.

8 Repeat steps 1 to 7, using beach mixture 2.

(a) Wipe up any spills as wet floors are slippery.

(b) Wash your hands after this investigation.

Analyze

1. Based on your models, describe the effect that wave action has on a beach made mostly of sand compared with a beach made mostly of gravel.
2. How does the slope of a beach affect erosion by waves?
3. How do the materials on a beach affect erosion by waves? Explain your observations by referring to the difference in the mass of grains of sand and pieces of gravel.
4. Which variable was the responding variable in this investigation? Which variable was manipulated?

Conclude and Apply

5. Based on the results of this investigation, what effect do you think a large storm at sea might have on a sandy beach?
6. Beach erosion is a problem for many seaside communities. Suggest what might be done to prevent a beach from eroding.

How Beaches Are Formed

What happens to all the fragments of rock carried from the coast by crashing waves? As they rub against each other in the surging water, rock fragments are smoothed and ground down into smaller pebbles and grains of sand. Along steeply-sloping shorelines, these rock fragments wash back into the sea. This leaves a shoreline of only bare rock, with scattered boulders and larger stones. Where the shoreline has a gentler slope and calmer waters, smaller rock fragments can settle and build up, forming a broad beach (see Figure 5.64A).

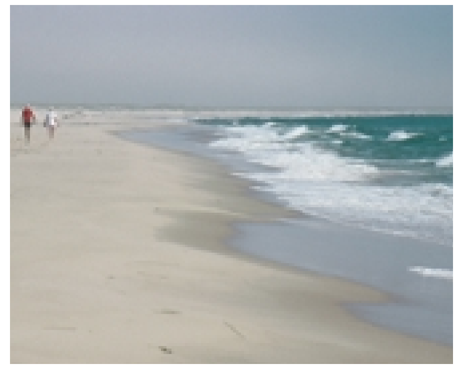


Figure 5.64A Ocean waves are a powerful and constant agent of change along coastlines. Like the fingers of a sculptor, they poke and probe the land, taking away bits here and adding pieces there. The result can be a sandy beach like this one.

Beaches are deposits of sediment that run along the shoreline. The materials that form a beach range in size from fine grains of sand less than 2 mm in diameter to pebbles and small boulders. Most beach sediments are fragments of hard minerals such as quartz. Beaches can also include other minerals of various colours, or fragments of seashells and coral.

Due to the continuous action of waves, beaches are in a constant state of change. In winter, strong winds bring larger waves that remove more sediment from the beach than they deposit. The beach erodes and becomes narrower. Calmer summer weather produces low, gentle waves that deposit sediments on shore, rebuilding the beach.

Many seaside communities spend a great deal of money to preserve their beaches. They may build seawalls and breakwaters, as shown in Figure 5.64B. These barriers of concrete and steel help slow down the speed and force of waves. Jetties are walls that extend from the land into the ocean. They are built to prevent sand from blocking the mouth of a river or harbour. Along some sandy beaches, rows of short walls called groins are built at right angles to the beach. They help reduce the movement of sand along the shoreline. However, most of these structures are only temporary solutions.

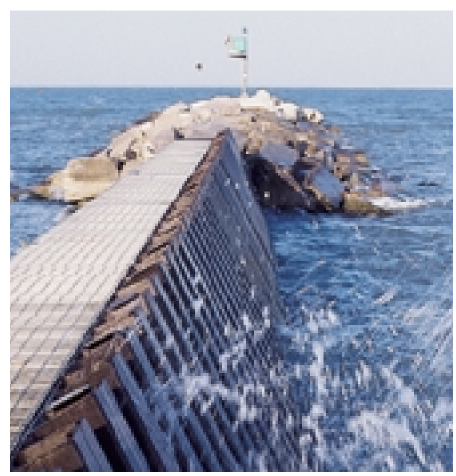


Figure 5.64B Barriers are used along some shorelines to protect beaches from erosion.

DidYouKnow?

In a few places in the world — including areas in Nova Scotia — there are "singing sands." These special sands make a fiddle-like sound when they are rubbed. Scientists think that a gel-like substance coating the sand grains helps produce the sounds.

Word CONNECT

A poem about the sea written by Canadian poet E.J. Pratt (1882–1964) has these lines:

It took the sea a thousand years,
A thousand years to trace
The granite features of this cliff,
In crag and scarp and base.

Explain what the poet is describing. Write your own short poem or haiku describing ocean waves.

Tides

Ocean beaches are sometimes covered by water, and sometimes they are not. They are covered and uncovered in regular daily cycles by the slow rise and fall of the ocean, called **tides**. The upper and lower edges of a beach are determined by the high-tide mark and the low-tide mark.

Centuries ago, people realized that the cycle of tidal movement is linked to the motion of the Moon. The largest tidal movements (called **spring tides**) occur when Earth, Moon, and Sun are in a line (see Figure 5.65A). At these times, tides are extra high and extra low. The smallest tidal movements (called **neap tides**) occur when the Sun and Moon are at right angles to each other (see Figure 5.65B). On these days, there is little difference in depth between high and low tides. The difference in level between a high tide and a low tide is called the **tidal range**.

Word CONNECT

Spring comes from the German word *springen*, which means to leap up. How does the origin of the word spring help describe spring tides?

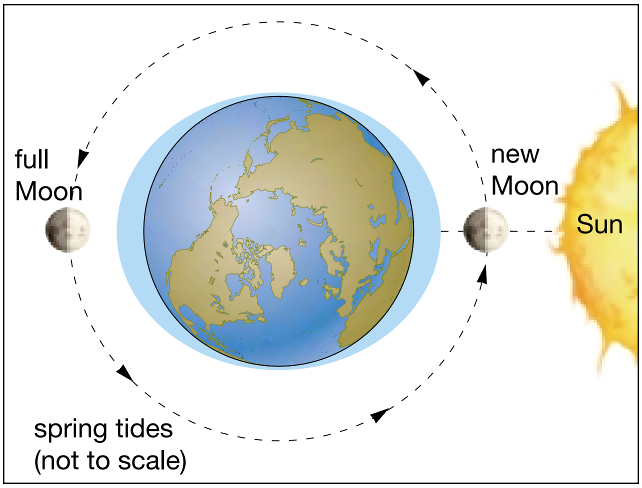


Figure 5.65A Spring tides occur twice per month, at full Moon (when Earth is between the Moon and the Sun) and at new Moon (when the Moon is between Earth and the Sun).

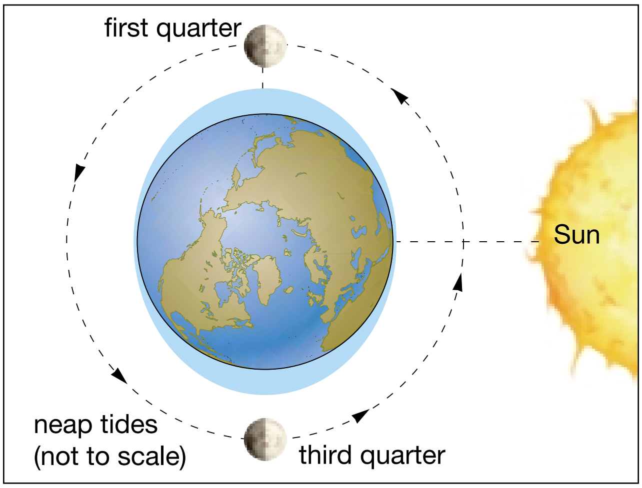


Figure 5.65B Neap tides occur twice per month, during the first-quarter phase and third-quarter phase of the Moon.

The link between Earth, the Moon, the Sun, and tides is gravity. Gravity is the force of attraction between two masses. Tidal movements result mainly from the pull of the Moon's gravity on the ocean. The Sun is much farther from Earth than the Moon is. The Sun has less than half as much influence on the tides as the Moon does, despite the Sun's much greater size.

During spring tides, the Sun adds its gravitational pull to the Moon's, producing a large tidal range. During neap tides, the Sun's pull works against the Moon's. This produces high tides that are not very high and low tides that are not very low.

If you look at the water moving up a beach as the tide rises, you may think that the volume of the ocean is increasing. However, the bulge of water that produces a high tide along one coastline draws water away from the other side of the ocean, just like water sloshing from one end of a bath tub to the other.

A tide is a giant wave, 1 or 2 m high and several thousands of kilometres long. As the crest of this wave approaches the shore, sea level appears to rise. This is high tide. A few hours later, the sea level appears to drop. This is low tide. In your Science Log, describe how tides are similar to waves produced by wind.

This movement of water causes a low tide along the opposite coastline (see Figure 5.66A). As Earth turns on its axis, different locations on Earth's surface face the Moon. The result is a sequence of high and low tides that follow each other around the world. On many of Earth's shorelines, tides rise and fall about twice a day (see Table 5.1).

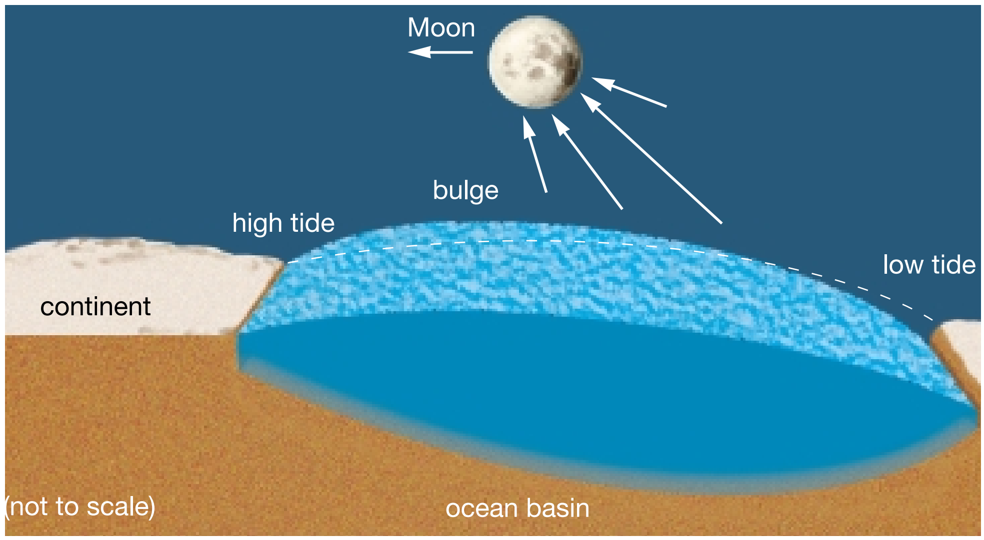


Figure 5.66A The gravitational pull of the Moon shifts water from one side of the ocean to the other.

Look at Figure 5.66B. The Moon's pull causes the ocean to bulge on the side of Earth facing the Moon. At the same time, there is a second bulge of water on the side of Earth that faces away from the Moon. This second bulge occurs partly because the Moon pulls more strongly on Earth itself than on the ocean on the far side. This leaves a bulge of ocean behind. The two areas of high tide on opposite sides of the planet draw water away from the areas in between them. In these in between areas, the ocean's surface falls.

STRETCH Your Mind

The times of each tide have a pattern that follows the cycle of the Moon. Study Table 5.1. What is the time interval between one tide and the next? Predict the time of the next low tide on July 2.

Table 5.1
Sample tide table

Date	Tide	Time
July 1	High	1:00 a.m.
	Low	7:13 a.m.
	High	1:25 p.m.
	Low	7:38 p.m.
July 2	High	1:50 a.m.
	Low	

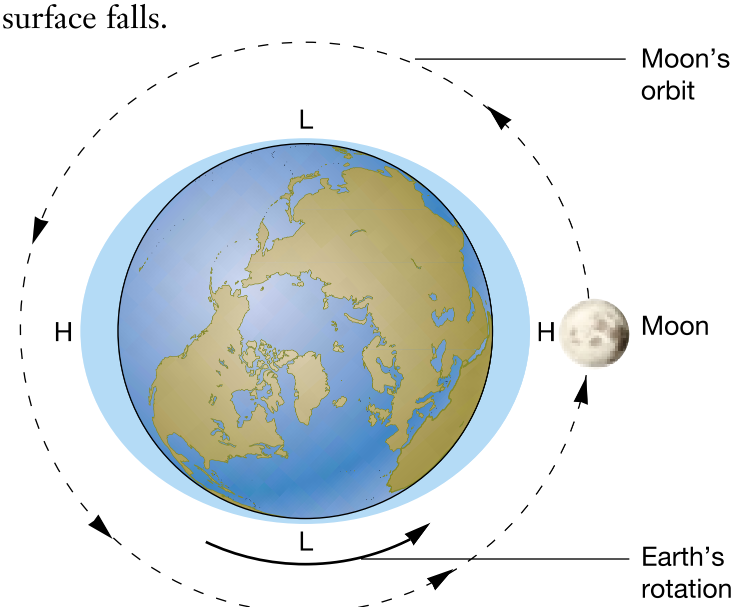


Figure 5.66B High tides occur on the side of Earth closest to the Moon and on the side farthest away.

In mid-ocean, the rise and fall of the ocean averages less than 1 m. Along shorelines, the tidal movement is more noticeable. The shape of a shoreline can have a great influence on the size of the tidal range. For example, in the Gulf of Mexico the tidal range is only about 0.5 m. The Gulf has a narrow passage, or mouth, to the open ocean, and a long, curved coastline (see Figure 5.67A). A rising tide that enters the narrow mouth spreads out around the bay, giving a small tidal range. In the Bay of Fundy, on Canada's east coast, the opposite occurs. The bay there is long and V-shaped (see Figure 5.67B). Tides enter the wide mouth of the V and pile up as they are funnelled down to the narrow end of the bay. The tidal range in the Bay of Fundy can be as great as 20 m.

Did You Know?

Lakes also have tides, but the change in water level is usually too small to be noticeable. In a very large lake, such as Lake Superior, the tidal range is only a few centimetres.

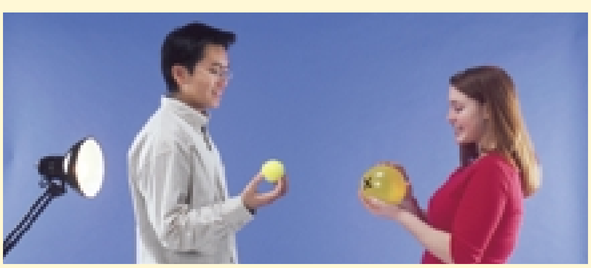
Figure 5.67A The Gulf of Mexico has a small tidal range.

Figure 5.67B The narrow Bay of Fundy produces a large tidal range.

Find Out ACTIVITY

Tidal Tales

Assess your understanding of how tides work by acting out the movement of Earth and Moon.



Materials

balloon
waterproof felt marker
lamp or flashlight with support stand
sink
tennis ball

Procedure

Performing and Recording
Communication and Teamwork

1. Place the balloon on the end of a water tap. Gently turn on the water and partially fill the balloon. Tie a secure knot. This is Earth.
2. Put an X on Earth to represent a coastal town such as Vancouver or Halifax.
3. Set up the lamp or flashlight in a secure place. This is the Sun. The tennis ball represents the Moon.
4. With a partner, use the tennis ball and the balloon to show how tides are created. You can gently squeeze the balloon to represent the "bulging" of ocean's tidal wave. Position the balloon and ball to show a high tide and low tide at town X. Position the balloon and ball to show the position of Earth, Moon, and Sun during spring tides and neap tides.

What Did You Find Out?

Analyzing and Interpr

1. Explain why town X has two high tides and two low tides each day.
2. Explain why there are two spring tide cycles and two neap tide cycles each month.

DidYouKnow?

Some scientists study ocean currents by tracking objects that are lost in shipping containers far out at sea. Over the years they have monitored running shoes, rubber ducks, and even hockey equipment. As long as these scientists know where and when the items were lost, they can predict how long it will take for the items to come ashore, and what current they might take.

Ocean Currents

Strange things sometimes wash up onto beaches with the waves. A message in a bottle is not very common, but many objects lost or thrown from ships far out at sea eventually make their way to land. Floating objects are carried over thousands of kilometres of ocean by broad, continuous movements of ocean water called **currents**. An ocean current is like a massive river within the ocean. Like a river, a current flows in one direction and connects one place with another.

Find Out ACTIVITY

Winds and Currents

How do winds affect surface currents? If you turn a skateboard upside down and run your hand across a wheel, friction between your hand and the wheel starts the wheel moving. The direction in which you move your hand determines the direction in which the wheel spins. In the same way, winds blowing over the surface of the ocean cause the surface waters to move. The surface currents flow in the same direction as the wind. What happens when a moving ocean current reaches land?

Materials

- rectangular pan
- water
- drinking straw
- stone
- 10 small circles of paper from a hole punch

Procedure

Performing and Recording

1. Fill the pan with water. Float the paper circles along one long edge of the pan.
2. Hold the straw with one end just above the paper circles and blow slowly and steadily through the other end. Observe and record what happens.
3. Place an object in the centre of the pan, such as a stone, to simulate an island. Repeat the activity.
4. Wipe up any spills as wet floors are slippery.
5. Wash your hands after this activity.

What Did You Find Out?

Analyzing and Interpre

1. How does moving air affect the surface water in the pan?
2. How does the shape of the pan affect your results?
3. How does the "island" affect your results?

Surface Currents

Currents of water at the ocean surface are driven by winds. Most surface currents flow in the top 100–200 m of water. The steady flow of currents results from major wind patterns. These wind patterns blow in fairly constant directions around the world (see Figure 5.68).

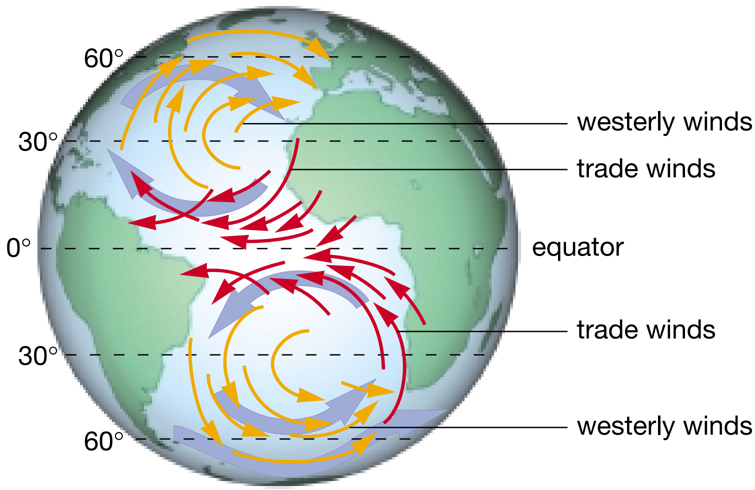


Figure 5.68 Winds (red and orange arrows) travel in a clockwise direction north of the equator and counterclockwise south of the equator. Ocean currents (blue arrows) move in the same direction as the winds.

Pause& Reflect

In your Science Log, make a prediction on how Earth's rotation affects wind direction. Then try this simple experiment. Poke a pencil through the middle of a paper plate. Place a drop of liquid, such as paint, on the circle next to the pencil. Hold the pencil between the palms of your hands and twirl it rapidly in a counterclockwise direction. Does the liquid move in a straight or curved line?

Note: Take care to protect your eyes and clothing from the paint.

Three factors influence the direction of winds and surface currents: uneven heating of the atmosphere; rotation of Earth; and the continents.

All winds begin as a result of uneven heating of the atmosphere. Warm air expands upward and outward as its particles move farther apart. This produces an area of low air pressure. Cool air, with a higher pressure, moves into the area of low pressure. The moving masses of air create winds.

The rotation of Earth produces a deflection (bending) of moving currents. As wind and water currents flow over Earth's surface, the planet turns beneath them from west to east. This motion causes currents in the northern hemisphere to turn to their right relative to the Earth's surface. In the southern hemisphere, the effect causes currents to turn to their left (see Figure 5.68). The overall result is that winds along the equator blow from the east. These winds, called **trade winds**, push ocean currents toward the west. Toward the polar regions, **westerly winds** drive currents the opposite way, from west to east, as shown in Figure 5.68.

The third influence on ocean currents is the continents. As you observed in the Find Out Activity on page 426, moving currents are forced to turn when they meet a solid surface. Continents deflect east-west currents either north or south. The combined influence of winds, continents, and the Earth's rotation keeps ocean currents circulating clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

Pause & Reflect

As water gets colder, its density increases. However, this is true only up to a certain temperature. Water achieves its maximum density at a temperature of 4°C. When water is cooled to 0°C, its density decreases. Therefore, bodies of water freeze from the top down rather than from the bottom up. Imagine if these differences in water density did not exist. How would life on Earth be affected if water bodies froze from the bottom up?

Ocean Temperature and Currents

Suppose you are on a boat in the middle of the ocean near the equator. You lower a thermometer over the side of the boat and record the water temperature at different depths until the thermometer reaches the sea floor. How would you expect the temperature to change, and why?

Figure 5.69 shows the results of such measurements. You can see that water temperature does not decrease steadily with depth. It changes sharply to form three distinct layers. As you might expect, water is warmest near the surface.

Almost all the heat in the ocean comes from the Sun. Winds and waves mix the heat evenly through the surface waters, forming a mixed layer. Because the Sun's energy does not penetrate very far, however, the water temperature begins to drop rapidly below a depth of about 200 m. Between 200 m and 1000 m, the temperature may fall from 20°C to a chilly 5°C. This region of rapid temperature decline is called the thermocline. Below the thermocline, ocean water remains very cold down to the ocean floor, where its temperature is close to the freezing point.

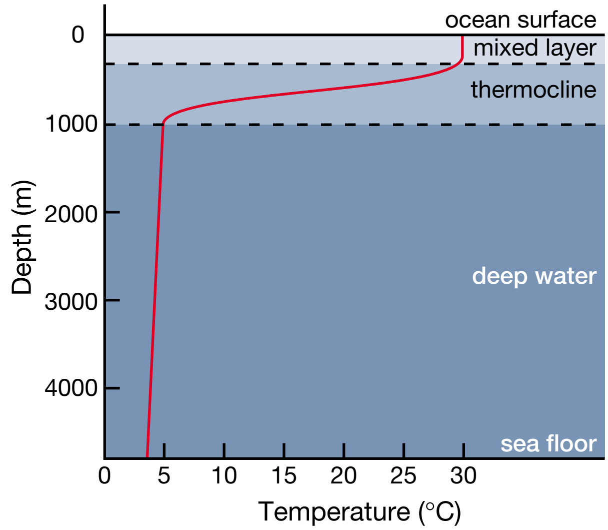


Figure 5.69 Temperature zones in the ocean

Oceans and Climate

To warm a bath of cool water, you must turn on the hot-water tap and stir the bath water with your hand. As the bath water circulates, you can feel the heat move from one end of the bathtub to the other. Similarly, surface currents in the ocean carry heat from one place to another. Warm currents begin near the equator, where the Sun's heat is most intense. As these warm currents circulate, they affect the climate and sea life of the regions to which they move.

Did You Know?

Large lakes can affect climate, too. The Great Lakes and other large lakes, such as Great Slave Lake, affect winds and levels of rain, snow, and fog in areas nearby.

Warm and Cold Currents

If you study a map of the world, you will see that Britain is as far north as Hudson Bay. However, Britain's climate is much milder. In southwest England, the winter seasons are mild enough to allow subtropical palm trees to grow! This mild climate is mainly due to a current of warm water called the Gulf Stream. The Gulf Stream starts in the Caribbean Sea and flows north along the east coast of North America. Then it turns northeast and crosses the Atlantic Ocean. The Gulf Stream carries warm water to Iceland and the British Isles (see Figure 5.70).

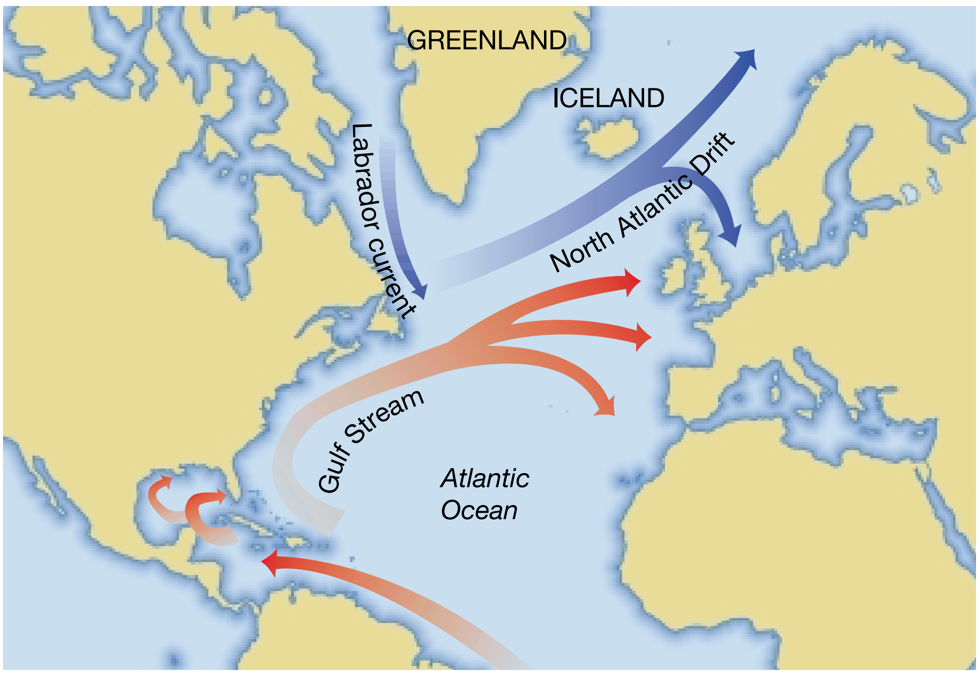


Figure 5.70 Map of the North Atlantic Ocean showing major currents (not to scale)

Warm ocean currents affect climate by transferring their heat to the atmosphere. Water has a very high **heat capacity**, which means that it takes a relatively long time to heat up or cool down. As a result, large bodies of water act as heat reservoirs in the winter, remaining warmer than the land nearby. The difference in temperature between the water and land affects the weather systems near the shoreline. These systems produce breezes that alter the processes of evaporation and condensation near the shoreline.

While warm currents flow from the equator, cold currents flow from the Arctic and Antarctic regions. Cold currents also affect the climate, by drawing heat from the air. For example, the Labrador Current on Canada's east coast flows south from Baffin Bay along the east coast of Newfoundland (see Figure 5.70). The icy cold water carries icebergs from the far north into the North Atlantic Ocean. On the west coast of Canada a warm current flows northwards from California, resulting in mild, but wet, winters.

Pause & Reflect

In your earlier science studies, you learned to distinguish between "climate" and "weather." In your Science Log, write clear definitions for each of these terms. Check your definitions against those in the Glossary at the back of this textbook.

Did You Know?

The volume of water in ocean currents makes even the mightiest rivers appear tiny by comparison. For example, the Gulf Stream moves about 26 000 000 m^3 of water per second, or about 1000 times more than the Mississippi River!

TOPIC 4 Review

1. Name a substance in seawater that comes from (a) the land, and (b) the atmosphere.

2. Describe how (a) ocean ridges, and (b) trenches are formed.

3. Name three factors that determine the height of a wave.

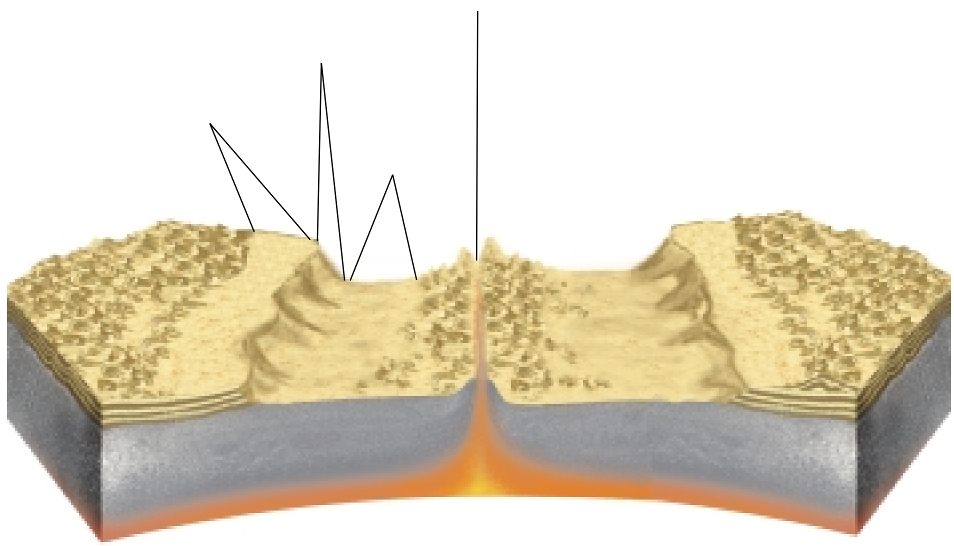
4. Explain the difference between spring tides and neap tides.

5. Explain how surface currents are produced.

6. Why are some currents warm and others cold?

7. How does a tidal wave differ from a tsunami?

8. Copy the following diagram into your notebook and supply the missing labels.



9. **Design Your Own** Using materials and procedural steps similar to those in Inquiry Investigation 5-G, design your own investigation to determine the most effective types of barriers in protecting beaches from erosion. In a group, brainstorm how to construct models to represent various types of jetties and sea walls. Have your teacher approve your experimental design before you proceed.

Wrap-up TOPICS 3-4

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

surface water
groundwater
lake
pond
clarity
wetlands
streams
rivers
watershed
run-off
Continental Divide
headwaters
outflow
erosion
deposition
streamflow
permeable
impermeable
aquifer
water table
contamination
point sources
non-point sources
flood plain
salinity
ocean ridges
trenches
abyssal plains
continental shelf
continental slope
waves
swells
breaker
longshore currents
tides
spring tides
neap tides
tidal range
currents
trade winds
westerly winds
thermocline
heat capacity

Reviewing Key Terms

1. Each phrase below describes a term from the list above. Write the term that matches the phrase describing it. (3)

(a) water that flows over Earth's surface

(b) water that soaks into the ground

(c) land area from which a stream or river gets its water

(d) dropping of sediments when an agent of erosion can no longer carry its load

2. Copy the following sentences, adding the correct words from the key terms listed above. (4)

(a) ______ and ______ are both produced by winds.

(b) ______ are produced by Moon's gravitational effect.

(c) ______ and ______ are produced by undersea volcanic activity.

(d) ______ are produced where one tectonic plate moves under another.

3. Make a bird's-eye sketch of a watershed and label the headwaters and the outflow. (3)

4. Explain the difference between a continental shelf and a continental slope. Use a drawing if you like. (4)

Understanding Key Concepts

5. How can a knowledge of local watersheds help a resource manager to assess land use? Give some examples. (3)

6. Describe two or more reasons to monitor streamflow. (3)

7. (a) Identify some point sources of groundwater contamination. (3)

(b) Identify some non-point sources of groundwater contamination. (3)

8. In a drawing, show the motion of water particles in a wave. (4)

9. What causes breakers to form? (4)

10. What causes high tides? (4)

11. Where does the sediment on abyssal plains come from? (4)

12. Explain how oceans and large lakes can affect climate and weather.

13. Apply Suggest some possible ways to reduce groundwater contamination. (3)

TOPIC 5 Living in Water

Pause& Reflect

How many aquatic habitats can you think of? In your Science Log, list and briefly describe four different aquatic habitats and the animals and plants that might live there.

Not all aquatic environments, or habitats, are the same. Some are salt water, some are fresh water, and some are fresh and salt water mixed. Aquatic habitats may be warm or cold, shallow or deep, light or dark. The water in the habitat may be moving, as in a stream, or motionless, such as water deep in a lake.

The **diversity**, or variety of life, varies from habitat to habitat. The ocean environment, for example, is vast. More than one million species of plants and animals are distributed throughout its various habitats, from tidepools, to kelp forests, to coral reefs, to hot vents in the deep sea. In this Topic, you will learn about the differences in three of the most common aquatic habitats and the diversity of life in each one.

Lakes and Ponds

Lakes and ponds are bodies of fresh water that collect in low areas of land. A pond is a small, shallow, calm body of water. Light can reach the bottom of a pond and rooted plants can grow there. The water temperature in a pond is quite constant from top to bottom and the temperature can vary as air temperature changes. A lake is usually larger than a pond. The water in a lake is too deep for plants to grow anywhere but along the shoreline. In the shallow water where light can penetrate, plants such as rushes, cattails, and water lilies grow. The temperature in a lake is quite constant, although surface waters are usually warmer than deeper, colder waters. You will learn more about the temperature layering in lakes on page 441.

Lakes and ponds are affected by local climate. For example, in cold locations, the surface of these habitats can freeze during winter months. In the summer, however, the surface waters will be much warmer than deep, colder waters. Lake and pond creatures include fish, insects, and amphibians such as frogs (see Figure 5.71A). As well, many larger animals, including beaver, muskrat, ducks, and turtles, may make their home in a pond or lake.

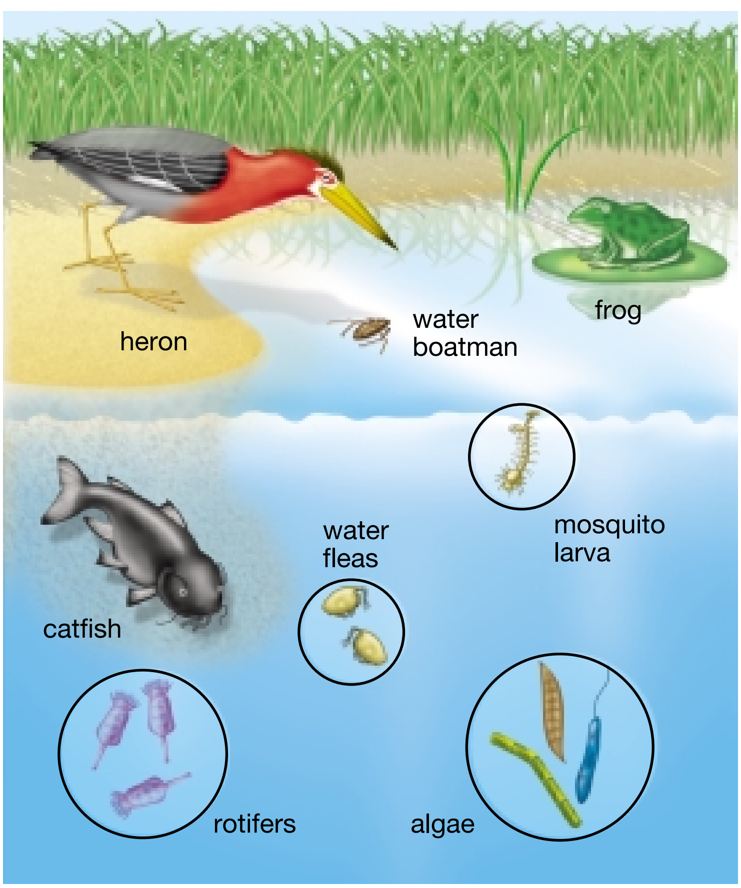


Figure 5.71A Lake habitat

Rivers and Streams

Figure 5.71B River habitat

You learned about rivers and streams in Topic 3. Most rivers and streams are quite shallow and often contain sediments eroded from the land. Some rivers are clear, while others are so murky that you cannot see the bottom. Streams and rivers usually alternate between areas where the water is calm (pools) and areas where water is moving quickly (riffles).

Can you imagine living in a home that is constantly moving? This is the challenge for creatures living in rivers and streams. Unless they are good swimmers, as fish are, most animals that live in these habitats attach themselves to the rocks on the river or stream bottom (see Figure 5.71B). The next time you are in a stream, turn over a rock. You may be surprised to see insects such as caddisflies or stonefly larvae clinging to the rock. Even the plants in rivers and streams, such as algae and moss, are small and attached to the rocks.

Oceans

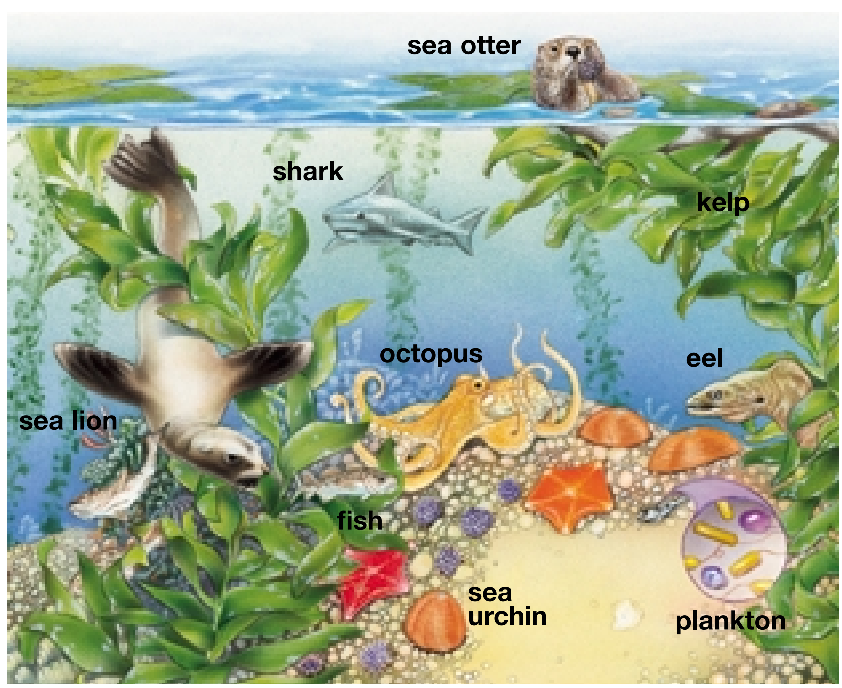


Figure 5.71C Ocean habitat

Oceans form the world's largest aquatic habitat. Oceans differ from lakes not only because they are salty, but also because oceans are deeper and have much more water movement due to tides, currents, and waves.

Even though there is life throughout the ocean and in a variety of ocean habitats, the greatest abundance of marine organisms are found in the top 180 m of water (see Figure 5.71C). This is the average depth to which light can penetrate in the ocean. Aquatic plants can grow only in the part of the water where light can penetrate. As a result, most marine organisms live on the continental shelf where the greatest source of food is located. In fact, more than 90 percent of marine life occurs here.

Adaptations for an Aquatic Life

Did You Know?

When you breathe, you exchange about 15 percent of your lung volume. When a whale or dolphin surfaces, however, they exchange about 90 percent of their lung volume to take advantage of the short time they are at the surface.

What special adaptations do aquatic animals have for life in the water?

Most aquatic animals use gills, organs that enable them to get oxygen from the water. You are probably familiar with fish gills (see Figure 5.72A), but gills come in all shapes and sizes. The frills on the mayfly nymph (Figure 5.72B) and marine tubeworm (Figure 5.72C) are gills, as well.

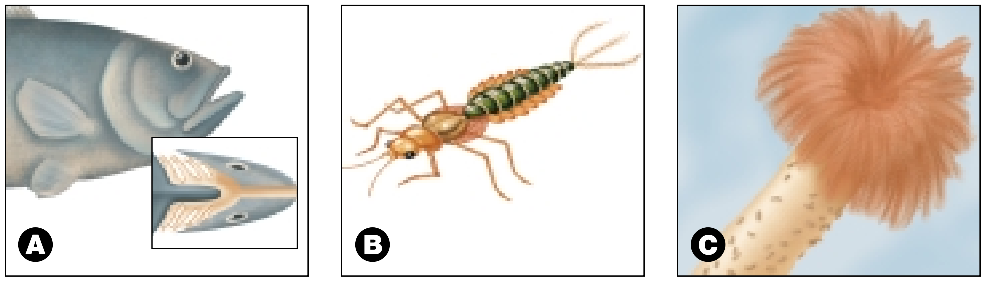


Figure 5.72 Gills are adaptations to an aquatic environment.

Did You Know?

Animals that live in habitats where the water moves very quickly are often small and flat. These adaptations prevent them from being swept away in the current. Many of these animals cling to rocks or hide under stones.

Some aquatic animals gather their oxygen at the water surface. For example, mosquito larvae have a tube-like siphon that they reach above the water surface. Some diving beetles trap an air bubble under their wing covers when they are at the surface and use this air like a miniature air tank.

Marine mammals, such as whales, use lungs to breathe, just like land mammals do. This is why we see marine mammals "blowing" at the ocean's surface. They are grabbing a breath or two of air.

On seashores and rivers, where the water is constantly moving, aquatic animals need to avoid being swept away. Some will tuck themselves into nooks and crannies on the bottom. Some, like the clam in Figure 5.73A, burrow down into the mud or sand. Other animals use special appendages, like the sea star's tube feet (Figure 5.73B) or the suction-cup-like foot of a freshwater snail (see Figure 5.73C).

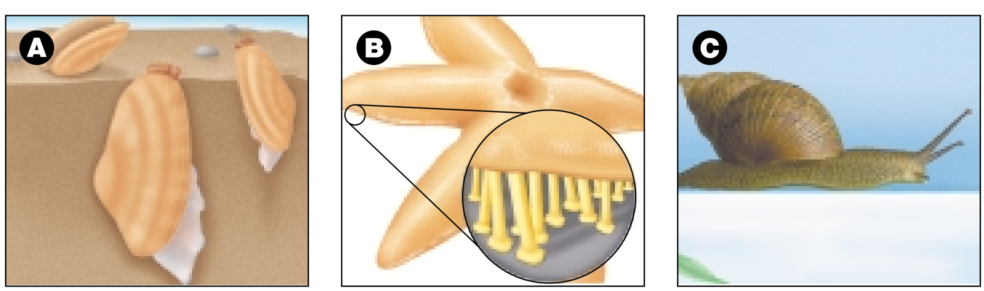


Figure 5.73 These aquatic animals have adapted to life in constantly moving water.

Is it easier to push your hand through water using a flat palm, or with your hand flat and pointed forward? When you slice a flat hand through water, your hand has a sleeker or more streamlined shape. Larger aquatic animals, such as fish and whales, have a streamlined shape to help them move easily through the water. Their fins and tail are thin and flat and their body is tapered at the front end to reduce water resistance as they swim.

Many aquatic animals use the buoyancy of water to help them move. Water striders, for example, can skate and jump on the surface film of the water (see Figure 5.74A).

Water in lakes and oceans is full of floating plants and animals called plankton. These buoyant, drifting organisms are moved around by water currents. They are an important source of food for animals in fresh water and salt water systems. Plant plankton is called phytoplankton (see Figure 5.74B), and animal plankton is called zooplankton (see Figure 5.74C). Zooplankton are usually small and they often have spines or other appendages to help them stay afloat. As well, they are often clear, with little colouration on their body. Why do you think this would be a good adaptation for a life in water?

DidYouKnow?

Not all plankton is microscopic. Jellyfish, for example, are a type of plankton. Although they can swim, their movements are not strong enough to compete with the surging currents and waves that move them around the ocean.

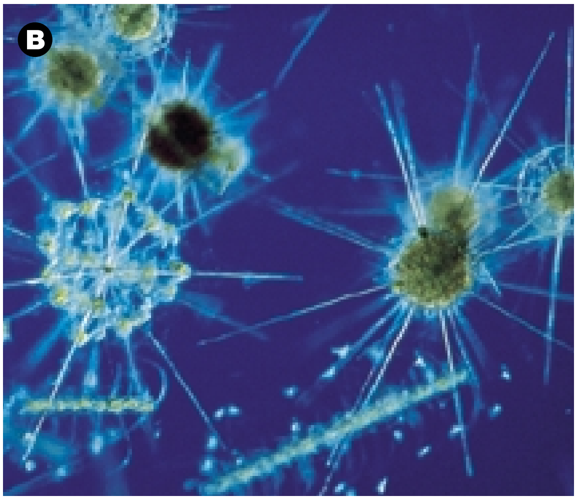


Figure 5.74 A. Water striders, B. phytoplankton, and C. zooplankton have adapted to life on or near the water's surface.

INTERNET CONNECT

www.school.mcgrawhill.ca/resources/

Glimpse life in a pond or in the ocean by going to the above web site. Go to **Science Resources**, then to **SCIENCEFOCUS 8** to find out where to go next. Write a short story or poem about what you see.

Some aquatic animals, such as fish, seals, and predatory insects, pursue food, catch it, and then eat it. Many other aquatic animals filter their food out of the water. The water flea in Figure 5.75A, for instance, sweeps food into its mouth by waving its legs. Barnacles (as shown in Figure 5.75B) wave their feathery appendages in the water to filter food from the ocean. Even the world's largest animals—the great whales—use filters called baleen to strain plankton out of the water. Baleen is visible in Figure 5.75C.

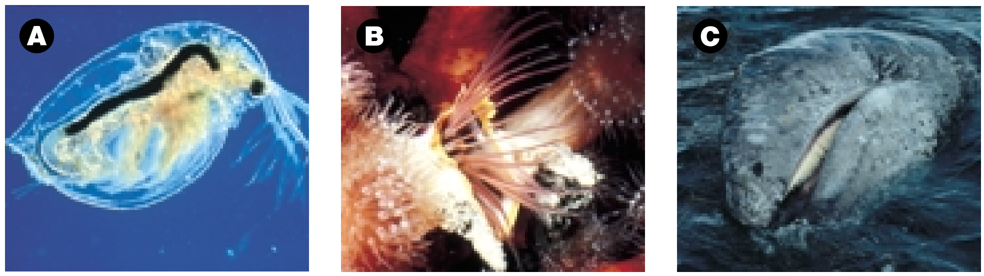


Figure 5.75 The water flea, barnacle, and grey whale all filter food out of water.

Pause & Reflect

In your Science Log, sketch a fish, insect, or other aquatic animal of your choice. Label all the adaptations that it has for a life in water. Use resources on the Internet or in the library to assist you if you need more information.

Skill FOCUS

For tips on using technology tools to conduct research, turn to Skill Focus 9.

Find Out ACTIVITY

A Wise Move?

Would a marine creature survive if you put it in a lake? Make a prediction about what you think might happen and then try this activity to test your prediction.

Materials

two glasses	water
spoon	salt
table knife	cucumber

Procedure ✷ Performing and Recording

1. Half fill both glasses with water. Add 15 mL of salt to one glass and stir until the salt is dissolved.
2. Cut three slices of cucumber, each approximately 0.5 cm thick.
3. Place one slice in each glass and set the third slice aside.
4. Wait a minimum of 30 min. Then remove the slices from the glass. (If you have time, wait an hour or longer.) Compare the three slices.

What Did You Find Out? ✷ Analyzing and Int

1. Describe any differences among three slices of cucumber.
2. Explain how this experiment might replicate what would happen if you placed a real marine creature in a fresh water environment.
3. What is the purpose of the third slice of cucumber that you did not place in a glass of water?

Aquatic Plants

There are two types of aquatic plants: those that are attached to the bottom, and those that float freely in the water (phytoplankton). Like land plants, aquatic plants need nutrients and sunlight to grow. Since aquatic plants require sunlight to photosynthesize, they can only grow in depths where the sunlight penetrates. This is why you find aquatic plants in shallow water in ponds, at the edges of lakes, and in the upper layer and at the edges of oceans (see Figure 5.76). How do you think land plants and aquatic plants differ? Try this Find Out Activity to discover the differences for yourself.

Figure 5.76 How have these aquatic plants adapted to a life in water?

Did You Know?

While most aquatic creatures cannot tolerate changes in salinity or temperature, salmon can move between fresh and salt water. They are born in fresh water and spend their first year or two in fresh water streams. Salmon spend their adult life in salt water, and return to fresh water to reproduce. Their kidneys are specially adapted to allow them to move between two aquatic habitats with different salinities.

Find Out ACTIVITY

Plant Adaptations

Land plants and aquatic plants have similar requirements — they both need sunlight, nutrients, and water to grow. However, they live in very different habitats. Can you spot some of the adaptations that aquatic plants have developed for a life in water? If possible, try this activity outside where you can find aquatic plants. If you cannot go outside, your teacher will provide you with the two types of plants you will need.

Materials

land plant and aquatic plant of similar size

magnifying glass

(**Note:** Choose an aquatic plant that is submerged, rather than one that has only its roots and lower stem in the water. The leaves and/or flowers may be floating on the water surface, but the rest of the plant should be submerged.)

Procedure — Performing and Recording

1. Examine the roots, stem, leaves, and flowers (if present) of the two different plants. Make a scientific drawing of both plants and label each part.
2. Create a data table to record the similarities and the differences between the two plants.

What Did You Find Out? — Analyzing and Interpreting

1. What are the challenges that aquatic plants have for living in water?
2. What are some adaptations of aquatic plants to a life in water?

Extension

Do research on the Internet or in the library to find out more about the plants that you examined in this activity. Write a paragraph about your plant. Include information on the plant's habitat, and how it is adapted to life in the water. (Hint: How does it reproduce? How does it keep its leaves near the surface of the water? Is too much water a problem for this plant?)

Attached Plants

Attached plants may be rooted in the soil in the bottom of a pond, or at the edge of a lake. Seaweeds are simply attached to the bottom. (Seaweeds do not have roots; they attach themselves to the ocean bottom using a structure called a holdfast.) Plants in very shallow water often have roots just like land plants, which they will use to anchor themselves and to gather nutrients from the soil.

Sometimes too much water can be a problem for aquatic plants. The plants need a way to get oxygen into their waterlogged roots. To do this, many aquatic plants, including the water lily in Figure 5.77A, have long, open channels in their spongy stems to carry air to their underwater roots.

Stomata (singular stoma) are tiny holes on leaves where water and air can pass in and out (see Figure 5.77B). While most land plants have stomata on the underside of their leaves, aquatic plants have stomata on the top of their leaves. These stomata enable their floating leaves to get more air.

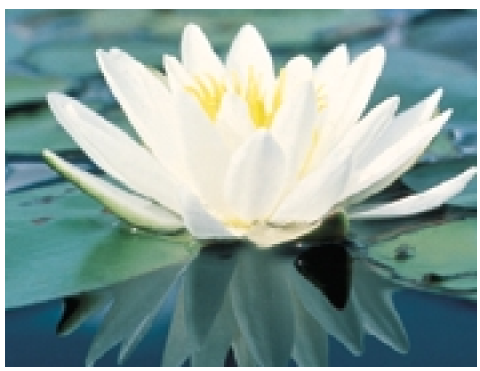


Figure 5.77A Water lily

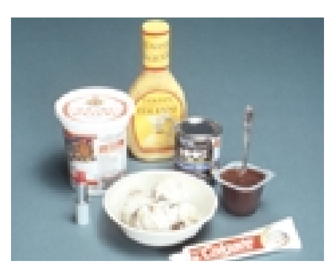
Figure 5.77B Open leaf stoma

When you did the previous Find Out Activity, you probably noticed that aquatic plants are much more flexible than land plants. A flexible stem allows the plants to move with currents and waves. Since water supports aquatic plants, they don't need to grow the strong, thick stems that you see in other plants. In fact, aquatic plants will usually collapse when you take them out of the water.

On land, plants generally use insects or the wind to spread their pollen or seeds. Many aquatic plants use the same strategy but first must push their flowers above the surface of the water.

DidYouKnow?

What do all of these products have in common? They all contain products from seaweeds. Carrageenan, algin, and agar are three extracts that come from seaweeds. They are used in hundreds of products from jellied candies to cosmetics. These extracts help to thicken and stabilize products. A stabilizer helps prevent a product from changing during storage. Have you had any seaweed today?



Find Out **ACTIVITY**

Dissolved Gases

As well as using light and nutrients, plants need carbon dioxide for photosynthesis and oxygen for respiration. Land plants obtain these gases from the atmosphere. In water, plants use gases dissolved in the water. How might water temperature affect the amount of gases available?

Materials

2 new, unopened containers of carbonated soft drink

refrigerator

Procedure

Performing and Recording

1. Make a hypothesis about the effect of temperature on dissolved gases. (In other words, does a liquid dissolve more gas when it is warm or when it is cool?)
2. Describe a method of comparing the amounts of dissolved carbon dioxide in carbonated soft drinks.
3. Place one container of soft drink in a refrigerator and leave the other at room temperature for at least 3 h.
4. Open both containers and compare their amounts of dissolved carbon dioxide gas using the method you described in step 2. Record your observations.
5. Wipe up any spills and wash your hands after this activity.

What Did You Find Out?

Analyzing and Inter

1. Was there more dissolved gas in the cold liquid or the warm liquid?
2. Based on your observations, would you expect warm water or cold water to hold more dissolved gases?
3. Based on your answer to question 2, would you expect warm water or cold water to have a greater number of organisms? Why?
4. **Critical Thinking** Describe the relationship between temperature and plant growth
   (a) on land
   (b) in water
   If your answers to (a) and (b) are different, explain why.

Seaweeds

Seaweeds are marine plants. They differ from land plants and other aquatic plants in that they do not have roots, flowers,or leaves (Figure 5.78). They dophotosynthesize, however, and use the energy of the Sun to create food. Almost all seaweeds are attached to the ocean bottom using a hold-fast. They get their nutrients from the water in which they live.

Figure 5.78 Like other marine plants, Kelp can produce food by means of photosynthesis.

Pause& Reflect

Read some labels on the foods you have at home. Can you find any products that contain carrageenan, algin, or agar?

Did You Know?

Single-celled organisms called *diatoms* make up more than half the plankton in the ocean. Phytoplankton may increase by as much as 300 percent in one day. A cubic metre of ocean water may contain 700 000 organisms!

Phytoplankton

The surface waters of lakes and oceans are full of tiny plants called phytoplankton. The majority of these plants range in size from 0.002 to 2 mm. Nearly all marine life depends on these tiny plants. In fact, much of life on Earth depends on phytoplankton since, like other plants, they produce oxygen that all animals need to survive.

Phytoplankton need light to grow and photosynthesize. Thus it is vital that they remain in upper surface waters where sunlight can penetrate for as long as possible. A small, light body, an irregular shape, and long spines are some adaptions that phytoplankton use to help slow their sinking. The diatoms in Figure 5.79A are one type of phytoplankton. As well, they are made of a glass-like substance called silica, which keeps them light and buoyant.

Skill FOCUS

For tips on scientific drawing, turn to Skill Focus 11.

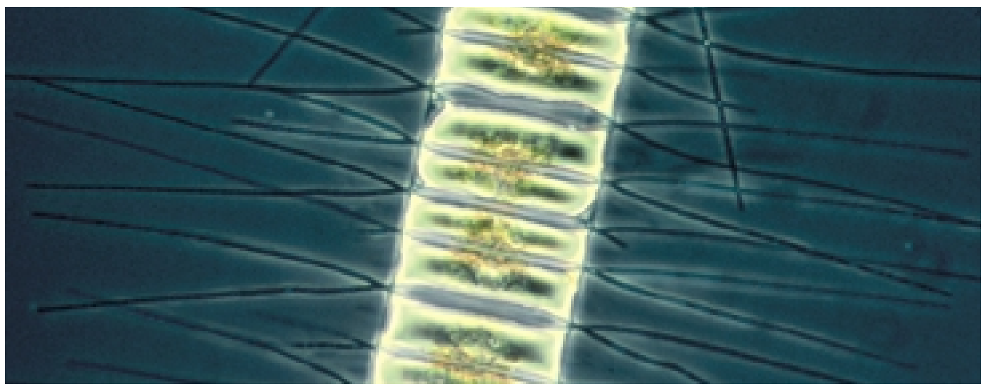


Figure 5.79A Diatoms can form long chains. They often have a small droplet of oil to help them float.

Find Out ACTIVITY

Design a Drifter

Phytoplankton are found in lakes and oceans throughout the world. The challenge of these tiny plants is to remain near the surface waters so that they can absorb the sunlight and photosynthesize. While they need to stay near the surface, they must be submerged to avoid the potentially harmful effects of the Sun. (They can get a "sunburn".) Can you design a drifter that will float but remain submerged?

Materials

variety of materials such as corks, empty pill bottles or small plastic containers, toothpicks, clay, pipe cleaners, twist-ties, rubber bands, and metal washers

bucket of water or a sink

Procedure ✷ Performing and Recording

1. Use the materials to design a type of phytoplankton that can float but remain submerged.
2. Sketch and label your phytoplankton.
3. Look at the designs of your classmates and note different strategies used to keep the plants buoyant.

What Did You Find Out? ✷ Analyzing and Interpr

1. What strategies did you and your classmates use when you designed your phytoplankton?
2. How do these strategies compare to the actual strategies that phytoplankton use?

Nutrients in Water

All aquatic plants need nutrients, such as nitrates and phosphates, to survive. Where do these nutrients come from? Originally nutrients are washed into the water from the land. They also come from **detritus**—the decaying bodies of dead plants and animals.

At certain times of the year, nutrients are very abundant. In the spring, for example, when snow starts to melt high in mountains, more water enters streams and rivers, and carries nutrients through to lakes and eventually to the ocean. In water, as on land, spring is a time of abundant plant growth because of the increase in sunlight and nutrients.

At other times, however, nutrients are scarce in aquatic environments. In late summer, for example, aquatic plants have used up most of the available nutrients in the water. Nutrients can be replaced through mixing of water due to the action of wind, waves, and currents. Some currents cycle nutrients from the ocean or lake bottom to the surface. These areas are usually rich in aquatic life.

DidYouKnow?

By estimating the amount of dissolved substances rivers carry to the oceans each year, scientists calculated it would take about 12 million years for all the world's rivers to transport the total mass of salts now in the oceans. Since the oceans are much older than 12 million years, we know that they cannot be getting saltier.

Temperature Mixing

In the fall, when air temperatures begin to cool, the surface temperature of water also begins to cool. The density of the surface layer increases and the surface water mixes with water deeper in the ocean and lake. When this happens, nutrients are often brought to the surface and this can result in an increase of phytoplankton in the fall. Cold water holds dissolved gases better. When the thermocline breaks down and water mixes in the fall, oxygen levels increase in surface waters.

Figure 5.79B Foraminifera are tiny marine organisms with shells made from calcium materials. They are among the most abundant organisms in the ocean. A large part of the thick sediments that cover the seabed are made from their remains.

A Steady State

If nutrients flush into aquatic habitats year after year, why is the level of nutrients and minerals, including salts, fairly constant in aquatic habitats? (Why, for example, are oceans not getting steadily saltier over time?) Salts, and other minerals leave the ocean and other aquatic habitats in a number of ways. For instance, chlorine leaves the ocean and enters the atmosphere in salt spray produced by waves. Some dissolved salts and minerals react with suspended solids in the water and fall to the bottom as solid sediments. Other chemicals are removed from water by organisms that use silica and calcium to make bones or shells (see Figure 5.79B).

You know that aquatic plants need nutrients, but can they have too many nutrients? Try the next investigation to find out.

INQUIRY

INVESTIGATION 5-H

SKILLCHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

Too Much of a Good Thing

Humans can affect the amount of nutrients that enter aquatic systems. Dish detergent, food, soaps, human waste, and fertilizers are all sources of nutrients that humans often contribute to water systems. How do you think the growth of aquatic plants will be affected by an increase in nutrients?

Question

How do fertilizers affect the growth of aquatic plants?

Hypothesis

Form and test a hypothesis about how fertilizers will affect the growth of aquatic plants.

Apparatus

six 1 L beakers or canning jars
1 L beaker with lid
250 mL measuring cup
graduated cylinder
stirring rod
index card
felt marker
test kit to measure dissolved oxygen, nitrates, and/or phosphates (optional)
microscope (optional)

Materials

chlorine-free tap water (allow tap water to sit for two days to eliminate the chlorine)
pond water
8-24-8 uncoloured garden fertilizer
masking tape

Safety Precautions

Fertilizers are toxic substances. Avoid getting them on your skin and wear protective safety goggles and an apron.

Procedure

1. Read through the investigation and **make a data table** to record your results.
2. Fill each beaker with 500 mL of chlorine-free tap water.
3. Add 100 mL of pond water to each beaker.
4. Make a solution of plant fertilizer by adding 15 mL of fertilizer to 1 L of chlorine-free water. This is the stock fertilizer solution.

5. Use the masking tape to label each beaker A to F. Add fertilizer solution to the beakers as follows: Beaker A – 1 mL; Beaker B – 2 mL; Beaker C – 4 mL; Beaker D – 8 mL; Beaker E – 16 mL. Beaker F gets no fertilizer solution.
6. To ensure that all of the beakers have the same amount of water, add the following amounts of chlorine-free water to the beakers: Beaker A – 15 mL; Beaker B – 14 mL; Beaker C – 12 mL; Beaker D – 8 mL; Beaker E – 0 mL; Beaker F – 16 mL
7. Place all of the beakers in sunlight.

8. On the index card, write the word **TURBIDITY** in the same size letters shown here. Turbidity measures the clearness of the water. To measure turbidity, try to read the word on the card by looking at it through the beaker of water.
   - If the print is easy to read, the turbidity measure is CLEAR.
   - If the print is fuzzy, the turbidity measure is SLIGHTLY CLOUDY.
   - If the print can be seen but not read, the turbidity measure is VERY CLOUDY.
   - If the print cannot be seen, the turbidity measure is OPAQUE.

9. At the same time every day, check the colour and **measure** the turbidity of the water in each beaker. **Record** your results in your data table.

10. If you have the equipment, measure the dissolved oxygen, nitrates, and phosphates in each beaker. **Record** your results in your data table.

11. If you have a microscope, look at a drop of liquid from each beaker each day and **record** the organisms that you see.

12. Continue to record your results for two weeks.

Skill FOCUS

For tips on making a data table, turn to Skill Focus 10.

Analyze

1. Which beaker was clearest? Which beaker was the most turbid?
2. How did the increase in the amount of fertilizer added to a beaker affect the growth of algae in the beaker?
3. Do you consider any of the water in the beakers to be polluted? Explain your answer.
4. Which variable was the responding variable in this investigation? Which variable was manipulated?

Conclude and Apply

5. The fertilizer that you used in this experiment contains phosphates. Why do you think many soaps and detergents are phosphate-free?
6. Write a statement explaining how too much plant growth in an aquatic habitat may have negative effects.

Figure 5.80A Too many nutrients in fresh-water lakes and ponds can cause populations of algae to increase rapidly. The algae reduce the oxygen supply available to other organisms in the water.

Nutrient Pollution

We think of nutrients as being good for a habitat, and in most cases they are. Problems occur when higher than normal levels of nutrients enter an aquatic habitat. For example, sewage from cities or run-off from agriculture can bring extra nutrients into a lake or the ocean. The nutrients come from the wastes of humans and animals or fertilizers that are added to the land to help plants grow. As you discovered when you completed the last investigation, more nutrients cause an increased growth of **algae**, another type of aquatic plant. The result is a population explosion of algae, called an **algal bloom** (see Figure 5.80A). As these plants die, they fall to the bottom of the lake or pond where they are broken down or **decomposed** by bacteria. Decomposition uses up the oxygen in an aquatic habitat. In severe cases the oxygen levels drop so low that animals living in the same habitat can die. This situation can occur in the ocean, too. However, tides and currents usually replenish the oxygen supply before animals are harmed.

Aquatic Food Chains

As on land, organisms in aquatic habitats are linked together by food chains—sequences of feeding relationships between organisms. The basis of food chains and food webs (several overlapping food chains) is plants and many unicellular organisms. These organisms make their own food by photosynthesis. Aquatic plants, both attached and floating, form the basis of aquatic food chains. Figure 5.80B shows a typical food web in the Pacific Ocean.

Looking Ahead

Do lakes or streams in your community have too many nutrients? Which aquatic food chains exist in local freshwater sources? Consider answering these questions in An Issue to Analyze, "Water Watch," at the end of the unit.

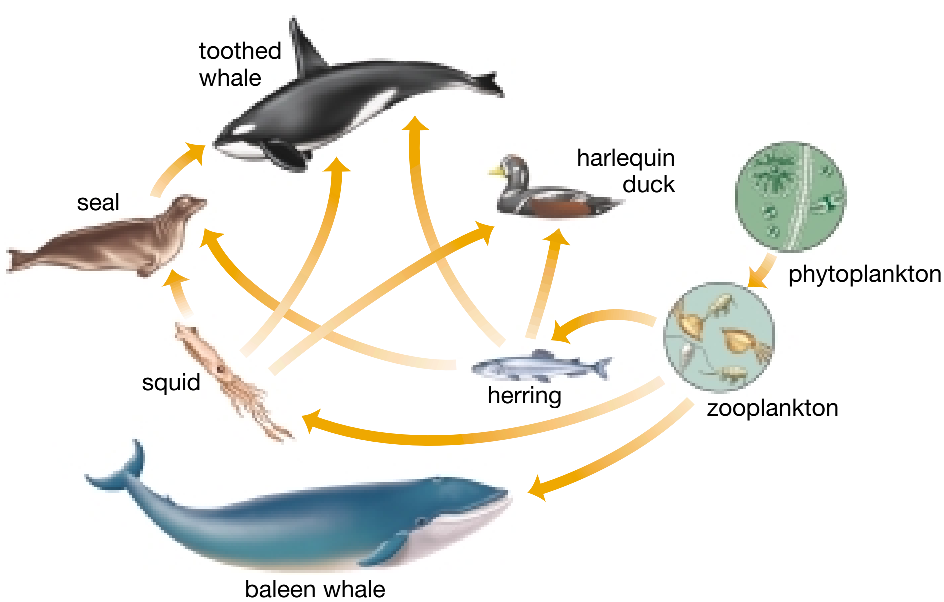


Figure 5.80B An example of a Pacific Ocean food web

Figure 5.81A Herring are preyed upon by many large marine animals.

DidYouKnow?

Native people on Canada's west coast place kelp or the boughs from hemlock trees in the water where herring spawn. The herring's eggs attach to the plants. The plants and eggs are removed from the water and dried for later consumption.

Some animals are important links in aquatic food chains. For example, in the Pacific Ocean, a small fish called herring (Figure 5.81A) is a vital link in the food chains of many marine animals. When these small fish come to the west coast each spring, they spur a feeding frenzy of birds, sea lions, whales, and other animals who time their annual movements to correspond with the yearly arrival of herring. These animals feed on herring or on the herring's eggs. A decline in the number of herring can seriously affect many links in marine food webs.

People fish for herring, as well. There are concerns that overfishing will affect the numbers of herring available to aquatic animals.

Fishing

Fishing can affect the balance of fish populations in lakes as well. In the Great Lakes, for example, the abundance and mix of fish populations have been altered over the past century. This change has been caused by fishing, introduction of new species by people, and pollution. Commercial fisheries (see Figure 5.81B) tend to capture species of larger fish and fish with the highest market price. As the populations of these fish decline, smaller, less commercial fish species may increase in numbers. In this way, fisheries alter food chains, competition among species, and use of the habitat. The total abundance of fish in an aquatic habitat may be similar, but the types and sizes of fish may be very different.

Figure 5.81B Fisheries were plentiful on the Grand Banks of Newfoundland before the collapse of the fish populations.

Toxins in Aquatic Habitats

Earlier you learned that aquatic plants use nutrients in the water to help them grow. However, plants can also take in pollutants that might be present in the water. Residues from pesticides, fertilizers, and industrial chemicals are often found in water and aquatic plants can absorb these toxins into their cells.

While this may not harm the plant directly, it can harm animals in the food chain. For example, suppose a phytoplankton absorbs a drop of toxin. A zooplankton may eat thousands of pieces of phytoplankton (all, potentially, with a toxin in them). Small fish then eat hundreds of zooplankton. In this way, the concentration of the toxin is magnified through the food chain. This is called **biomagnification**.

Figure 5.82 Animals that feed high on the food chain, such as osprey and killer whales, are susceptible to biomagnification of toxins.

Animals that feed high in the food chain are most seriously harmed by biomagnification. Birds such as osprey shown in Figure 5.82A, eat fish. When the pesticide DDT was still commonly used, osprey populations declined. The birds' eggs and the chicks did not develop properly and the chicks often died. The banning of DDT use has halted the decline of osprey populations, but DDT has not left the environment. Traces of DDT are found in many aquatic habitats and can still be measured today, even though it has been banned for decades.

Animals with a high concentration of fat in their bodies are especially sensitive to toxins in the environment. Killer whales like the one in Figure 5.82B, have been found with high level of toxins in their bodies. The toxins are stored in fatty tissues such as blubber. The accumulation of these poisons can lead to serious health problems, or even death.

Exploring Aquatic Habitats

There is still a lot to learn about aquatic habitats and the animals and plants that dwell in them. In recent decades, the invention of submarines, underwater cameras, and special diving suits has made it possible to explore far beyond the depths to which humans can scuba dive. The discovery of life around hot vents in the sea floor was one of the most exciting events to happen in scientific exploration in the last few decades.

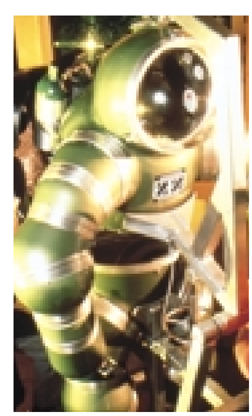
When deep-sea explorers first took underwater research vessels to the sea floor in the 1970s, they were amazed at what they saw. The explorers discovered new varieties of animals living 2.5 km below the ocean surface! These organisms do not use the Sun's energy or phytoplankton for food. Their source of energy is chemicals that flow from cracks, or **sea-floor vents**, in the ocean floor (see Figure 5.83).

Sea-floor vents are found along ocean ridges. Hot water flows from these vents, carrying dissolved minerals and gases from below the ocean floor. The most important chemicals are sulfur compounds such as hydrogen sulfide gas. Certain bacteria can use these chemicals to produce food and oxygen by the process of **chemosynthesis**. The bacteria form the base of food chains around the vents. They are eaten by tiny larvae and other organisms, which, in turn, support populations of giant clams, tube worms, crabs, barnacles, and other unique creatures of the sea floor. What other discoveries await us deep in lakes and oceans?

Figure 5.83 Sea-floor vents called black smokers form plumes of black iron sulfide particles. The temperature of the water here may be over 300°C when the vent erupts.

Cool Tools

Canadian engineers are some of the world leaders in underwater exploration technology. This "Newtsuit" is a flexible, one-person submarine. Divers can explore to a depth of 300 m without needing to be connected to the surface. The Newtsuit is used in research and construction projects.



TOPIC 5 Review

1. Draw a simple food chain found in a pond, lake, or the ocean.
2. What is chemosynthesis?
3. What human activity might cause an algal bloom in a lake? Explain.
4. Describe five adaptations that aquatic animals have for a life in water.
5. **Thinking Critically** Why does adding or removing species from an ecosystem often create unexpected problems?
6. **Thinking Critically** Draw a food web showing organisms' relationships in a pond or lake in your province.

TOPIC 6

Water Quality and Water Management

Figure 5.84A Many factors, including human activities, affect water quality.

Why do some organisms prefer to live in one stream but not in another? To answer questions such as this, you must look at water quality. In Topic 1, you learned that water is always on the move. Water flows through rivers, lakes, and oceans. It evaporates, condenses, and then falls back to Earth as rain and snow. During this cycle, the quality of water can be affected in many ways.

People use water for many things, including drinking, cooking, washing, manufacturing, and other activities. All of these activities add substances to the water. In order to make sure our water is clean and safe to drink, it is tested regularly. This is done to make sure the water is not contaminated with organisms or harmful substances that can cause diseases. If the water is not safe to drink, it must be processed to remove unwanted substances.

Canada has a seemingly endless supply of fresh water. However, some parts of Canada can experience water shortages. In order to have enough water for people, other animals, and plants, we must sustain our water resources. This will ensure that we will have enough water to meet the needs of today and the future.

What Determines Water Quality?

Fill a glass of water from a kitchen tap and hold it up to a light. What do you see in the water? Smell the water. Does it have an odour? Taste the water. Does it have a flavour? In most cases, your drinking water will be colourless, odourless, and flavourless. This means that there are no organisms or sediments in the water. Your drinking water has been cleaned to remove these unwanted substances. You will learn more about this process later in this

Figure 5.84B What is in a glass of water?

Figure 5.85 This electric kettle element shows deposits of salts left by water evaporation.

Topic. Even though your drinking water looks, smells, and tastes clean, that does not mean that there is nothing else in it. Water also contains **dissolved solids**, or salts, such as sodium, calcium, and magnesium.

If water contains a lot of dissolved calcium and magnesium, it is called **hard water**. Using hard water in your home can cause scaly deposits in your pipes, fixtures, and washing machines (see Figure 5.85). **Soft water** has less calcium and magnesium in it. Find out about the properties of hard water and where it is found in the next two Find Out activities.

Did You Know?

Some types of heart disease among people are more common in areas where there is soft water compared to areas where there is hard water.

Find Out ACTIVITY

Making Hard Water Is Easy

Dissolved solids in the water can affect how we use water. In this activity you will make some hard water and observe one of its properties.

Materials

250 mL beaker
2 jars with screw-top lids
250 mL distilled water
balance
calcium chloride ($CaCl_2$)
stirring rod
medicine dropper
liquid soap
50 mL graduated cylinder
commercial water softener

Procedure

Performing and Recording

1. To make hard water, fill the beaker with 250 mL of distilled water and add 25 g of calcium chloride.
2. Using the stirring rod, mix the contents until the calcium chloride has dissolved.
3. Fill each jar with 125 mL of hard water.
4. Place three drops of liquid soap in each jar, seal each jar with a lid, and shake gently.
5. Observe what happens in each jar and record your observations.
6. Add 10 mL of commercial water softener to one of the jars and shake again.
7. Observe what happens and record your observations.
8. Wipe up any spills as wet floors can be slippery.
9. Wash your hands after completing this activity.

What Did You Find Out?

Analyzing and Interpreting

1. Compare the contents of the two jars after you added the commercial water softener.
2. Where do you think you might find natural supplies of hard water?
3. What is the advantage of using soft water for washing?

Find Out ACTIVITY

Water Across the Nation

Water is not the same in all parts of Canada. In this activity you will graph the amount of total dissolved solids (calcium, magnesium, and other solids) in selected Canadian rivers.

Materials

atlas of Canada

Procedure

Performing and Recording
Communication and Teamwork

1. The table gives the total amount of dissolved solids in selected rivers across Canada. Use the data to make a bar graph and answer the following questions.
2. (a) Using an atlas, find out in which province or territory each river is found.
   (b) Which province or territory has the hardest water? The softest water?
   (c) Is there a pattern in the type of water found across Canada?
   (d) Why do you think there is a difference in the amount of total dissolved solids in the water across Canada? Explain briefly.

Total Dissolved Solids in Selected Canadian Rivers

River	Total dissolved solids (mg/L)
Fraser R.	95
Okanagan R.	215
Mackenzie R.	208
Athabasca R.	224
South Saskatchewan R.	294
Saskatchewan R.	299
Red R.	484
Nelson R.	192
Coulais R.	30
Thames R.	422
Niagara R.	220
St. Lawrence R.	222
Saint John R.	44
Morell R.	107
North East Margaree R.	81
Explois R.	16

Skill FOCUS

For tips on how to make a bar graph, turn to Skill Focus 10.

Dissolved solids are just one factor that can affect water quality. Organisms, chemicals, and sediments can also affect water quality. These substances can get into water from

- run-off from the land
- plants and animals
- soil and rocks
- human activities

The presence of different substances in the water determines how people use water. Water that is good for one use may not be good for another. For example, water that has a bad flavour may be suitable for irrigating crops, but not for drinking. In this Topic you will learn how the activities of people affect water quality and how water quality is measured.

Water and People

People are part of the water cycle. We take fresh water from rivers, lakes, and underground. We use it for drinking, cooking, washing, farming, manufacturing, and other activities. All of these activities add substances to the water. Many of these substances are pollutants that can harm living things. Run-off in watersheds can carry pollutants into water systems. Study Figure 5.86. It shows how different human activities can affect water quality.

DidYouKnow?

One drop of motor oil can contaminate 25 L of drinking water.

One gram of PCBs can make 1 000 000 000 L of water unsuitable for freshwater aquatic life.

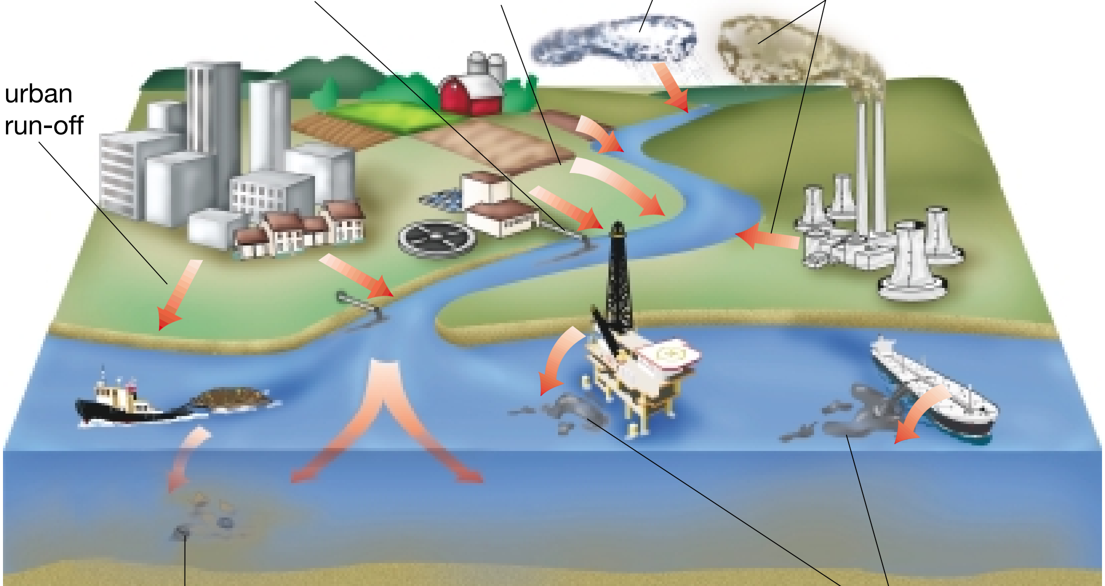


Figure 5.86 Sources of pollution in water systems

There are two main kinds of pollutants that can affect water quality. Some pollutants occur naturally in the environment and others do not. Nutrients occur naturally in water systems and are needed by organisms for growth and reproduction. However, you discovered in Topic 5 that too many nutrients in a water system can cause problems.

People add substances to the water that do not occur naturally in the environment. These are called **toxic substances**. Toxic substances are used in agriculture, manufacturing, production, mining, and refining. Many of these substances can kill organisms even if very small amounts end up in the water. For example, PCBs are chemicals used for making electrical transformers. PCBs can enter the water if they are accidentally spilled or improperly stored or disposed of. In the early 1970s, the use of PCBs was restricted in North America. However, these chemicals still cause environmental problems because they can remain in the water for a very long time.

Acid Precipitation

Pollutants can also enter water systems when toxic substances are released into the air. For example, acid precipitation is caused by dissolved sulphur dioxide and nitrogen oxides in the atmosphere. These are waste gases released by coal-burning industries, metal smelters, and automobiles. These gases combine with water vapour in the atmosphere to form sulphuric acids and nitric acids. These chemicals return to Earth in precipitation that can be more acidic than vinegar (see Figures 5.87A and B).

Pause & Reflect

If you were a scientist, how would you investigate the problem of acid rain? Which questions would you ask?

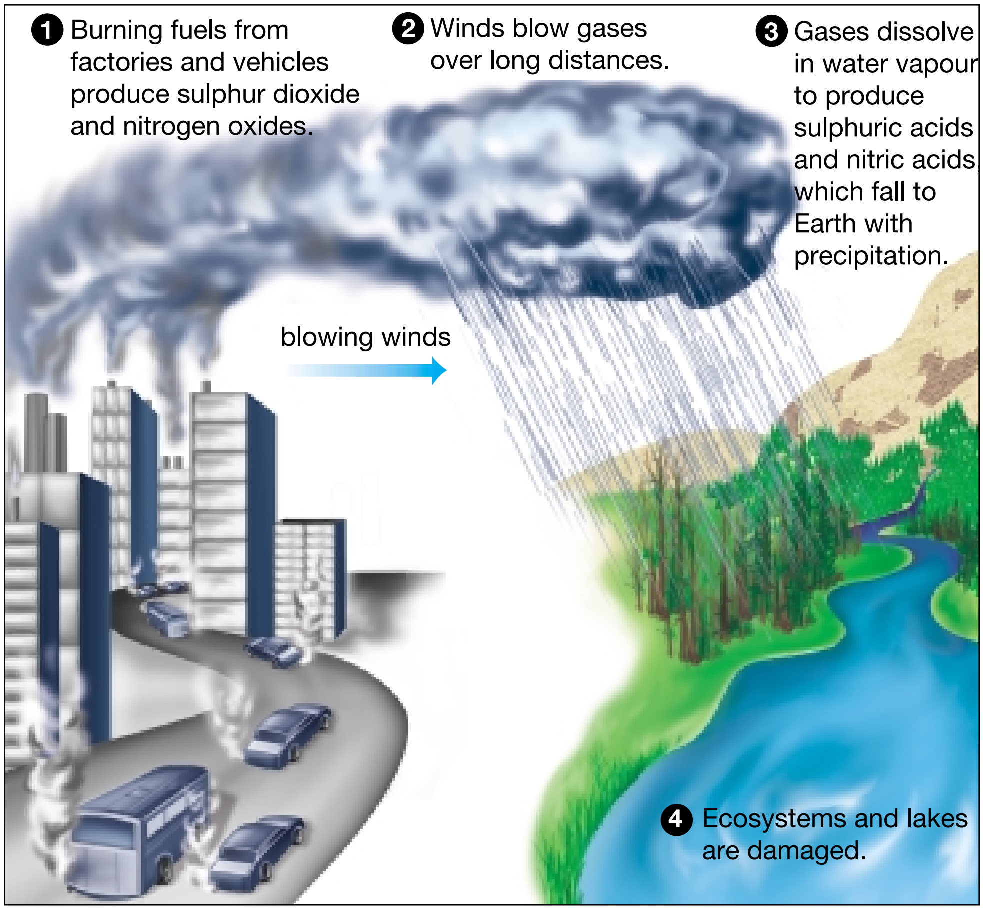


Figure 5.87A Polluting gases enter water systems when acid precipitation is produced.

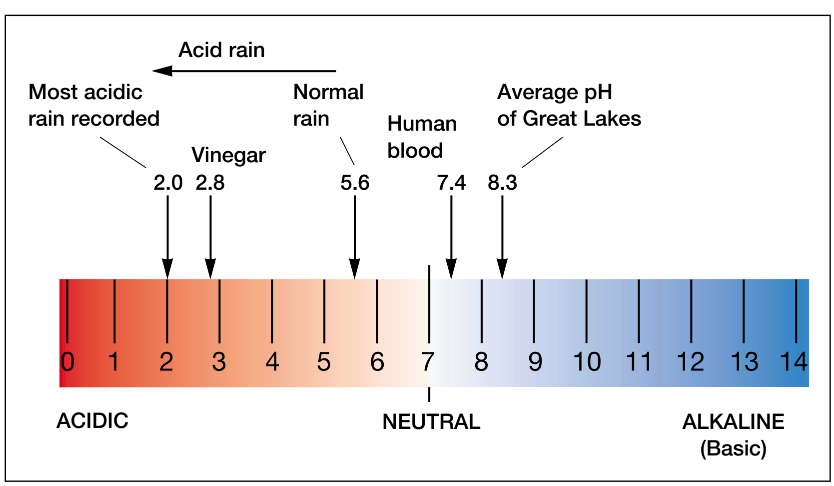


Figure 5.87B The pH scale is used to describe how acidic a solution is. A pH of 7.0 is neutral (neither acid nor base). The lower the pH number, the greater the acidity. Normal rainwater has a pH of 5.6. Acid precipitation has a pH below 5.6.

Winds carry atmospheric pollution from industrial areas to areas of lakes and forests. Here acid precipitation can slowly kill or damage plants and animals. When acid precipitation sinks into the ground, it can dissolve heavy metals in the soil and rock, such as aluminum, mercury, and lead. These dissolved metals might eventually work their way through the ground into streams and rivers, causing more damage to organisms.

Figure 5.88 These forests have been damaged by acid precipitation.

Math CONNECT

Like scientists, you can calculate the parts per trillion (ppt) of a substance in water. If one ppt is equal to 1 g per 1 000 000 000 L of the substance, how many ppt of salt are there if you dissolve 1 g of it in 1000 mL of water? (Hint: remember to convert millilitres to litres.)

Measuring Water Quality

How do we know that pollutants or other substances are in a stream or lake? You collected samples of water to determine the pH. Scientists also conduct water sampling. They analyze the samples in a laboratory using special instruments and techniques. Some measurements, such as temperature and oxygen content of the water, can be made in the field with portable equipment. The table below lists some variables that may be measured to determine water quality.

Selected Analyses to Determine Water Quality

Basic properties • temperature • rate of flow • oxygen content • colour • odour **Solids** • sediments • turbidity (cloudiness)	**Acidity** • pH **Nutrients** • phosphorus • nitrogen • total dissolved solids (salts)	**Toxic substances** • heavy metals (e.g., lead, mercury, zinc) • chemicals (e.g., PCBs, dioxin, furans, pesticides) **Organisms** • bacteria • plants and animals

Results from water sampling tell scientists what is in the water and in what amounts. In particular, scientists are interested in detecting toxic chemicals and heavy metals in water samples. The effects of these substances on human health may take many years to show up. That is why it is important to identify toxic substances in the water even if they occur in very small amounts. Special laboratory instruments can detect the presence of a toxic substance down to one part per trillion (ppt).

The Northern River Basins Study in Alberta is investigating the effect of different toxic substances within the ecosystem. Major findings of the study are shown in Figure 5.89. Results indicate that levels of toxic substances, such as dioxin and furan, have decreased since the late 1980s. Other findings have shown that some of these substances can be carried great distances downstream.

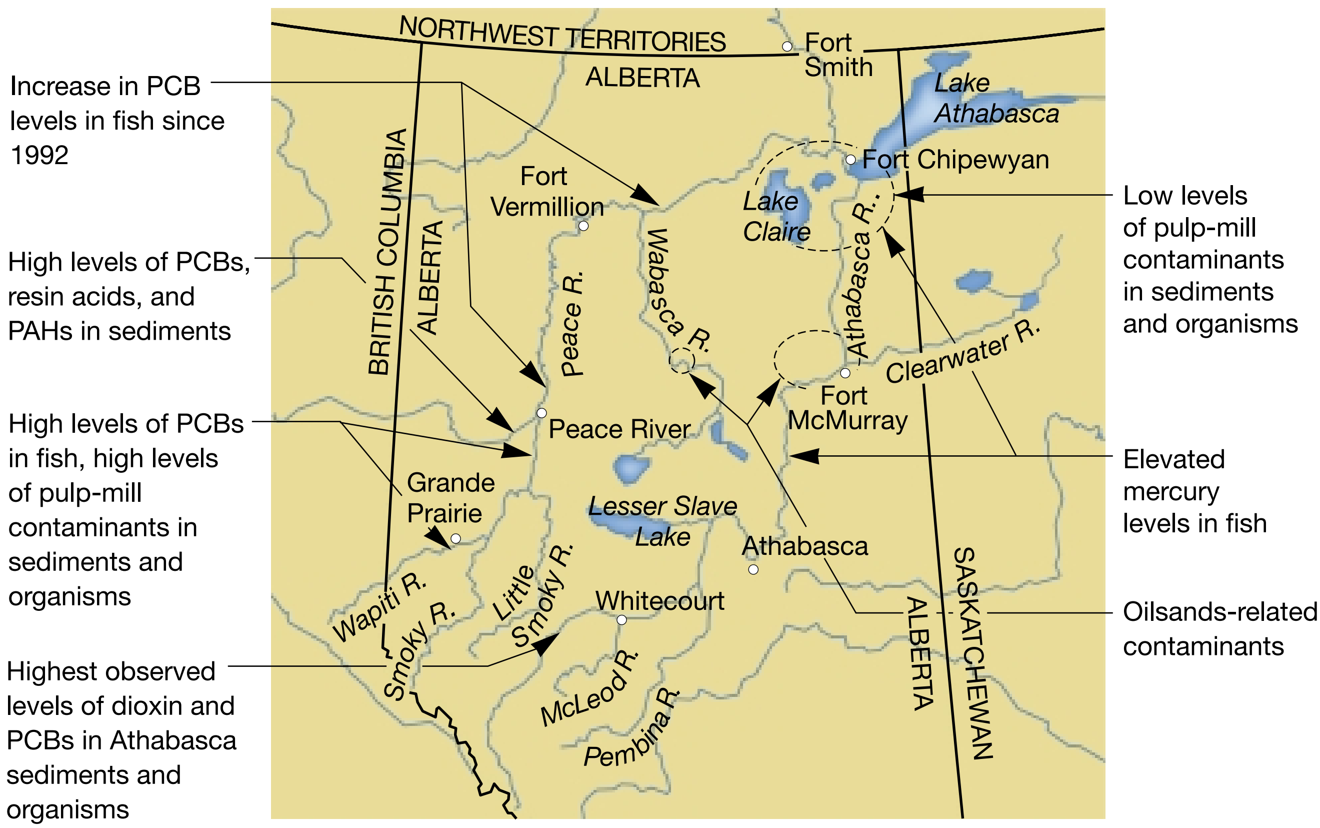


Figure 5.89 Pollutants in Alberta's northern river basins

INTERNET CONNECT

www.school.mcgrawhill.ca/resources/

What did the Northern River Basins Study learn? What recommendations did it make? What was the Alberta Government's response? To find out, visit the above web site. Go to the **Science Resources**. Then go to **SCIENCEFOCUS 8** to to find out where to go next. Use the information you find to prepare a short newspaper article.

Career CONNECT

Testing the Waters

Water quality is a serious issue. If our drinking water becomes polluted, it can make us sick. Even swimming in a contaminated lake can cause illness. That is why Gareth Gumbs's job is so important. He is an environmental chemist who works in a laboratory. Part of his job involves testing water samples to see if the water is safe. His experiments help people figure out if a landfill site is contaminating a town's water supply, for example, or if a beach is unsafe for swimming.

Gareth is also hired to do experiments to determine how human activity and industry are affecting water quality. For example, some lakes have high levels of acid rain. The acid can dissolve some of the surrounding rock and release toxic substances such as mercury into the water. In one study, Gareth and his colleagues analyzed many fish samples over the course of a year. They needed to find out how much mercury was in the body tissues of the fish because of the water they were inhabiting.

Gareth's job requires good problem-solving skills. In many cases, he must consider similar tests that other researchers have done, choose the one most suitable for the study he is working on, and then adapt the test to suit his needs.

Based on what you have learned about the career of environmental chemist, make two lists. In one, list the aspects of Gareth's job that appeal to you. In the other, list the aspects of his job that do not appeal to you. Give a brief explanation for the items in each list.

Gareth Gumbs

Organisms in the Water

In Topic 5, you learned that many different organisms live in streams, lakes, and oceans. They form important food chains that begin with microscopic plants and animals. Why do certain organisms live where they do? In order to survive, different species of organisms have different needs. For example, the caddisfly larvae shown in Figure 5.90 can only survive in unpolluted water that has lots of oxygen. Which kinds of water systems that you know have a large amount of dissolved oxygen? Other organisms can live in water that is slightly polluted. Various small worms and midgefly larvae can live in very polluted water. Scientists can determine the quality of the water by studying the numbers and kinds of different organisms that live in water systems.

Figure 5.90 Caddisfly larvae live in streams and rivers. They build small cases to protect themselves, using sand and pieces of plant material.

Micro-organisms, such as bacteria, occur naturally in water systems. Normally, these organisms pass through your body without harming you. However, when the number of certain bacteria gets too high, they can cause health problems. For example, the fecal coliform bacteria population can increase if raw sewage from cities or farms gets into groundwater, streams, and lakes. Outbreaks of the bacteria can pose a serious health risk to people.

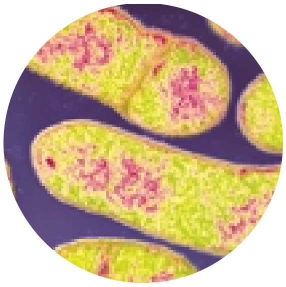


Figure 5.91A Botulism bacteria. Members of the Whitefish Lake First Nation are working with scientists to study the cause and effects of outbreaks of these bacteria among ducks on Utikuma Lake.

In Alberta, outbreaks of botulism, or food poisoning, in the water can kill thousands of ducks (Figure 5.91A). Scientists cannot prevent these outbreaks, but they are trying to understand more about what causes them. Aboriginal people have an extensive knowledge of the environment and have known about these outbreaks long before written records were kept. They are working with scientists to create a historical record of botulism outbreaks. Together they hope to find ways to limit these outbreaks in the future.

Bioindicator Species

In 1979 northern leopard frogs mysteriously disappeared from many places in south and central Alberta. These frogs were once common along rivers and lakes in prairies and parklands (see Figure 5.91B). Many different species of frogs were also disappearing from other parts of North America and the world. What had happened to all the frogs?

Scientists have been studying where the leopard frog lives, what it eats, and how it reproduces to find out why it is disappearing, but they are not sure. One factor may be contamination of the air, soil, and water with pollutants. Pollutants in water systems, such as acid precipitation, waste water, and pesticides, can affect the reproduction of leopard frogs. As a result, their numbers may drop long before people realize that there is a problem with the water quality.

Many different kinds of plants, birds, fish, turtles, and amphibians (frogs and salamanders) can help us monitor the health of ecosystems. Invertebrates (animals without backbones), such as crayfish, clams, and insects, are also useful for this purpose. For instance, changes in the numbers of stonefly, caddisfly, and mayfly larvae that live in streams can tell us about the amount of pollution present in the water. These organisms are called **bioindicator species**. They are much better at detecting changes in water quality than are the testing instruments made by people. In the next investigation, you will identify some bioindicator species that you will collect at a local stream.

Figure 5.91B Northern leopard frog

DidYouKnow?

Many Aboriginal people, like their ancestors, rely on memorized knowledge from generations of traditional activities. People using the land develop strong habits of observation. They memorize land, water, climate, and other natural patterns that they see and that others tell them about. This memorized information is called Traditional Ecological Knowledge.

DidYouKnow?

In some developing countries, organisms in the water are responsible for 80 percent of diseases among people. The most common of these are typhoid fever, cholera, and dysentery.

INQUIRY

INVESTIGATION 5-I

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Bioindicator Species in the Water

In order to find out about the health of an ecosystem, biologists need to know what sorts of organisms live in the ecosystem. They often collect samples of plants and animals to identify and count. In this investigation, you will visit a local stream and collect a sample of invertebrates.

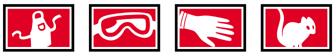
Question

What kinds of bioindicator species live in your local stream?

Prediction

Make a prediction about the quality of water in your local stream.

Safety Precautions



- Conduct this investigation only under the supervision of your teacher.
- Remain in very shallow water at all times.

Apparatus

field guide of aquatic organisms
tweezers
hand lens

Materials

bucket
trowel or small shovel
rubber boots
Large jar or 2 L clear plastic pop bottle with the top removed
pencil
notebook

Procedure

1. Work with a partner. Under the supervision of your teacher, you will visit a local stream to sample the substrate (bottom sediments) there. The substrate will also include different kinds of small organisms that can be used as indicators of water quality.
2. Using the shovel, take a sample of the substrate and place it in the bucket. The substrate may include mud, gravel, and small stones. Do not dig too deeply. Sample only the first 2–3 cm of substrate. Also add some water to the bucket. The best place to look for bioindicator species is in shallow parts of the stream where there is gravel or rocks. Turn over some rocks to see what organisms may be underneath. If you find some organisms, add them to your bucket. Different pairs of students should try to collect samples from different places along the stream. **CAUTION** Some streams can be very dangerous. Only visit a stream that your teacher has approved, and with the whole class.

CONTINUED

3. After returning to your classroom, add 1–2 cm of substrate to the bottom of the jar. Fill the rest of the jar with water from the stream. Place the lid on the jar.

4. Allow the contents of the jar to settle before beginning your observations. Sometimes you may have to wait a while before you **observe** any organisms moving in your sample. Make several observations over a period of several days.

5. Use the hand lens to see any organisms more closely.

6. Using the field guide and illustrations on page 505, **identify** the organisms in your sample.

7. **Record** your observations in your notebook.

8. After completing your observations, return all organisms to their natural habitat.

9. Wash your hands after completing this investigation.

Analyze

1. How many species of organisms did you identify?
2. How many of each species were there in your sample?
3. How did the species and numbers of organisms compare with those of the other teams?
4. Include all the data in a class chart. Determine the total number of species and how many of each were found.
5. Make a bar graph of the class data.

Conclude and Apply

6. Why do you think it is important to take samples from different places along the stream?
7. Based on information in the table, how would you rate the quality of the water in your local stream? Did your rating agree with your prediction of the water quality?

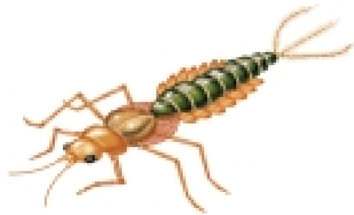
Extend Your Knowledge and Skills

8. Prepare a report on the life cycle of one of the organisms shown on page 459.

Some Invertebrate Bioindicator Species for Flowing Streams and Rivers

Can live only in clean water

stonefly larva



mayfly larva

dragonfly larva

beetle

caddisfly larva

Can live in slightly polluted water

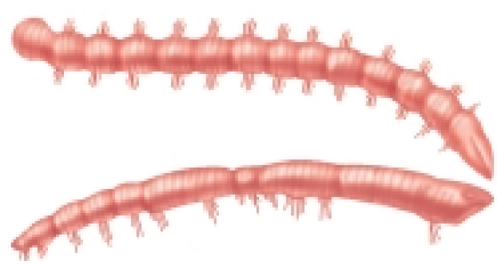
snail

leech

crayfish

Can live only in clean water

midgefly larva



segmented worms

Monitoring Water Quality

Figure 5.92 This researcher is taking a water sample from a farm irrigation stream to compare the water quality with samples taken at other times.

The governments of Canada and Alberta have set standards for water quality. They have established guidelines for maximum amounts of substances in the water, including pollutants. Water quality standards are set for

- drinking water for people
- protection of organisms living in or near water
- drinking water for livestock
- irrigation of crops
- recreation, especially swimming

How do we know that these standards of water quality are being met? Government scientists conduct water monitoring. They observe and test samples of water regularly. They also monitor water systems to look for changes in water quality over time (see Figure 5.92).

In the 1990s, scientists conducted a five-year study of the water quality in Alberta. The data they collected will be compared with future studies. In this way the scientists will know if the quality of the water is changing over time. One goal of this research is to help the agriculture industry reduce the amount of pollutants they produce. The study found that most of the pollutants from farms were within safe levels. Some, however, were too high. The researchers were able to recommend agricultural practices that helped resolve the water quality problem. In the Find Out activity on the next page, you will interpret some data about water monitoring and make some recommendations on how to improve the water.

Ask an Expert

Turn to page 470 to find out how Carole Mills researches contaminants in Canada's Arctic waters.

Water Management

How would you manage a water supply?

Imagine you have 1000 L of water to use any way you wish. How would you use it? You could take a shower, make a flavoured drink, or fill a birdbath. How long do you think your supply of water would last?

If you study a map of Alberta, you will see that most cities are built near a lake or river (see Figure 5.93). We depend on a constant supply of water for many of our activities. Maintaining a reliable water supply is an important issue for city planners and politicians. This is called **water management**.

Did You Know?

The average Canadian uses 326 L of water per day. That's 119 000 L of water per year.

Find Out ACTIVITY

Changes in Water Quality

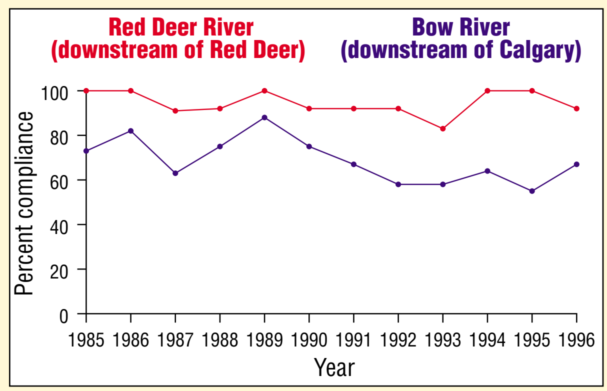
Imagine you are a scientist conducting water monitoring along the Red Deer River and the Bow River. You began with one set of tests, then returned to the same sampling locations to retest the water there each year. You have made graphs of your data and are ready to interpret your findings.

Procedure

1. Study the graph. It shows water quality in the rivers downstream from the cities of Red Deer and Calgary. Percent compliance means how clean the water is. For example, 100 percent compliance means that the water passed all the quality tests. Fifty percent compliance means the water passed only half of the tests.
2. Compare the water quality from 1985 to 1996.

What Did You Find Out? Analyzing and Interpre

1. In which river was the quality of the water better?
2. Did the quality of the water stay the same for all the years of the study? If not, why do you think the quality of the water changed?
3. These data were taken from water downstream from major cities. Think about how pollutants get into the water. What recommendations would you make to the government regarding how to improve the quality of the water?



Water quality in the Red Deer River and the Bow River, Alberta

Variations in the weather from year to year can make it difficult to balance the supply of water with the demand. Some areas get too little rainfall, while others get too much. Rain may fall in one season but not another. One way to make water supplies more reliable is to build a dam across a river. A dam holds back the water flow. This causes the river to flood land upstream, forming a lake or reservoir, as shown in Figure 5.94A on page 462.

Figure 5.93 Most cities in Alberta, such as Edmonton shown here, get their water supply from rivers.

Figure 5.94A Reservoirs used to store water can also be used for recreation.

However, dams can create problems. Flooded valleys may be a part of the traditional home of Aboriginal people. The water will kill the trees there and force many animals to higher ground. As well, toxic substances in the soil can make their way though the food chain into local fish. This may create health problems among people who eat these fish.

In areas where people do not live near rivers or lakes, they must drill wells to get water. You learned about groundwater in Topic 3. Sometimes wells must be dug very deeply in order to reach the aquifer far below the surface. Currently, there are 500 000 water wells in the province of Alberta. About 7000 new wells are dug each year.

DidYouKnow?

About 57 percent of Canadians drink water that has been processed by water treatment plants.

As well as maintaining enough water to use, water management involves the wise use of water. We must balance the needs of consumers, industries, agriculture, and wildlife. Figure 5.94B shows water use by different sectors in Canada. What sector uses the most water? What sector uses the least?

In order to meet the water needs of today and those in the future, we must sustain our water resources. In this Topic you will learn how we clean the water we need to use and what happens to it when it goes down the drain. You will also learn how you can help to sustain our water resources.

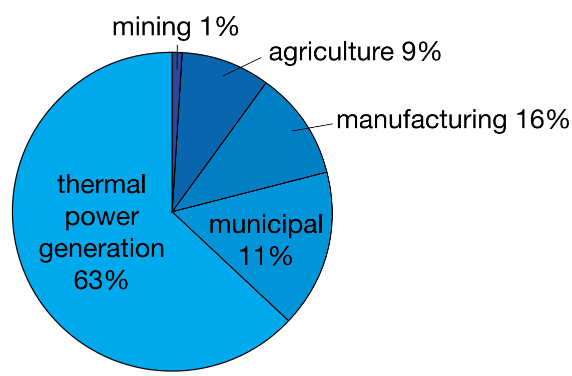


Figure 5.94B Water use in Canada in the 1990s

www.school.mcgrawhill.ca/resources/
Different regions of Canada have different needs and uses for water. To find out how water is used in your province, go the web site above. Go to **Science Resources**, then to **SCIENCEFOCUS 8** to know where to go next. How much water is used by each sector of society? How do these values compare with water usage by the whole country? How might you explain these differences? Present your analysis in a brief report.

Purifying Water

The water cycle moves water back and forth between the atmosphere, land, and the oceans. This process also purifies water as it recycles it. For example, most of the water vapour in the atmosphere comes from the oceans, but rainwater is fresh water, not salt water. Evaporation, followed by condensation, distils seawater, separating pure water from salts and other dissolved substances.

Although the water cycle can purify water, pollutants can enter the cycle at any point. Recall how air pollutants can enter the water cycle. In many cases, the water we use for drinking must be cleaned. This will make the water **potable**, or safe to drink. Many communities clean their water through **water treatment**. Figure 5.95 shows the stages involved in the treatment of drinking water. In the next investigation, you will design a method to clean water.

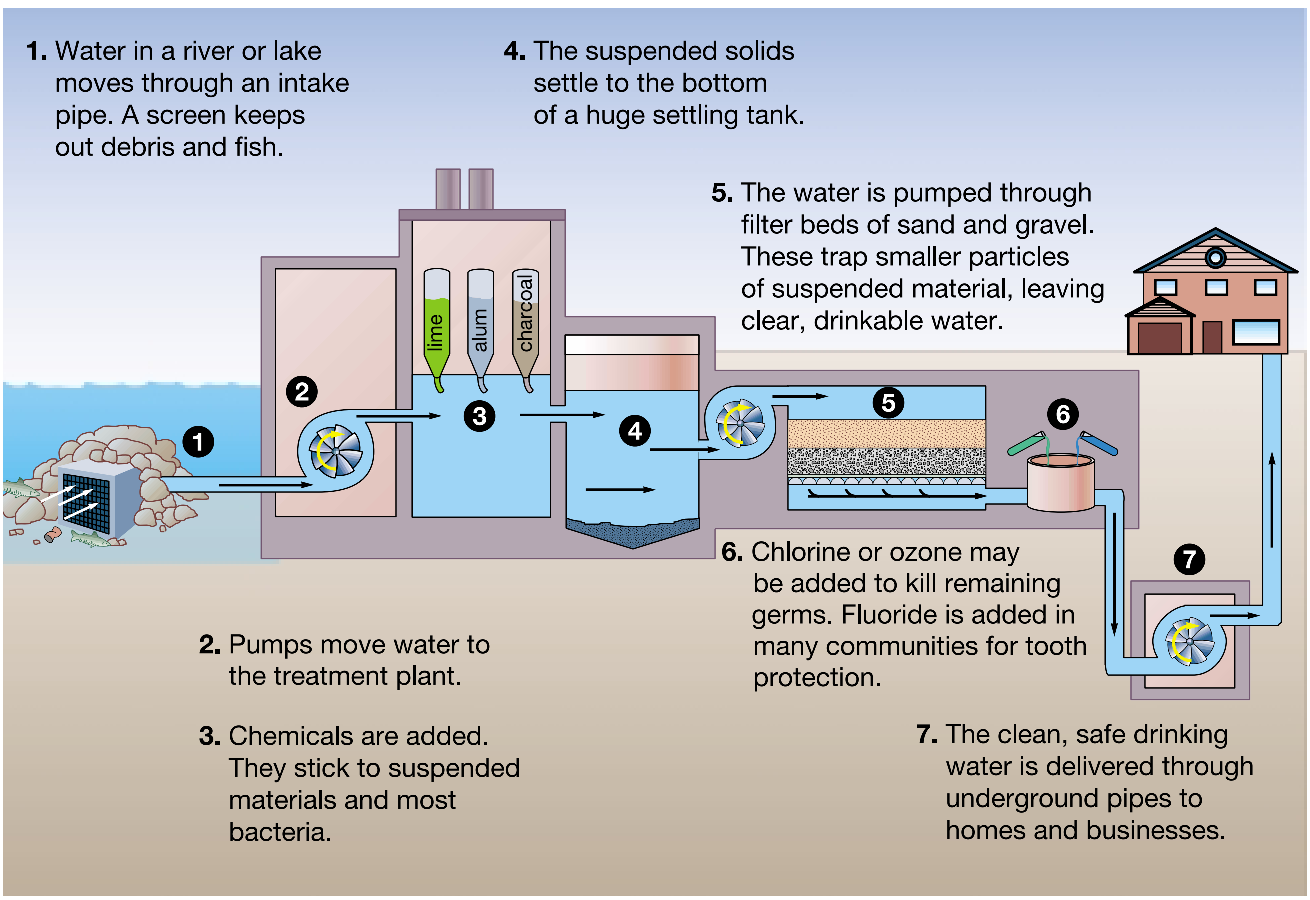


Figure 5.95 Stages in the treatment of drinking water

DidYouKnow?

In developed countries, such as Canada, the average person uses up to 500 L of water per day. In the world as a whole, the average person uses about 5 L of water per day. In most countries in Africa, Asia, and South America, 80 percent of the people have no access to clean drinking water. They do not have faucets in their home. Instead, they must walk long distances to a river or lake and carry the water back.

PROBLEM-SOLVING

INVESTIGATION 5-J

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

How to Clean Water

Imagine you are part of a team of engineers hired to provide water to a community. The only water source nearby is a muddy river. Design a system that will remove all the mud and suspended material from the river water, leaving it clear.

Challenge

Design and construct a model of a water-filtering system.

Materials

plastic containers, plastic tubing, filtering materials, funnel

Safety Precautions

- Do not test your water by drinking it. The goal of this investigation is to produce a filtration system that will remove mud and suspended materials from the water, but not necessarily any dissolved materials.
- Wipe up any spills and wash your hands after this investigation.

Design Specifications

A. Your filtration system should make the water as clear as possible.

B. The filtration system should be efficient and process water in a reasonable amount of time.

C. The filtration system should be easy to operate.

D. Availability of materials and cost factors might be included in your choice of materials.

Plan and Construct

1. In your group, select the materials from which to build your filtering system.
2. Make a sketch showing how your system will filter water.
3. Build your system and test it.

Evaluate

1. How successful was your system in cleaning water?
2. What improvements could you make to your system?
3. Would your water filtering system create other problems in the environment?
4. Would your system affect living organisms in the river?
5. Would your system be able to process the large volumes of water needed by a community? Explain.
6. If possible, have your samples tested by a water-testing laboratory.

Extend Your Knowledge

7. How does Earth filter water? Is your design similar to Earth's water-filtering process? Explain.

What happens to water after you use it in your home? It goes down the drain, but where does it go from there? The solid and liquid waste from homes, businesses, and industries is called **sewage**. In urban areas, underground pipes carry sewage to sewage treatment plants. In rural areas, sewage is stored in a large underground container, or **septic tank**. The contents of the tank are cleaned out regularly and taken to a sewage treatment plant. Treatment of the sewage removes some of the impurities. Once treated, the wastewater, called **effluent**, goes back into rivers, lakes, groundwater, and the sea. Effluent can also be used to irrigate crops.

Figure 5.96A A desalination plant in Mexico makes fresh water from seawater.

Sustaining Water Resources

Is water a sustainable resource? In other words, can we manage it so that we will have a reliable supply to meet present and future needs?

As the human population grows, demand for water increases. Increasing consumption of water has reduced the quantity of water in reservoirs and underground aquifers throughout the world.

Shortages of water have forced some countries to develop costly desalination plants. These plants produce fresh water by removing salts from seawater through evaporation (see Figure 5.96A). Two other methods of generating fresh water from seawater are distillation and reverse osmosis.

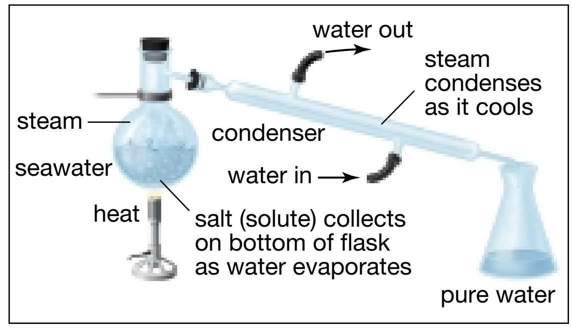


Figure 5.96B The process of distillation

In distillation, the solvent is heated to change it to a gas, then condensed to a liquid again, as shown in Figure 5.96B. Distillation can remove dissolved solids such as salts by leaving them behind as the pure water evaporates.

Figure 5.96C illustrates the process of osmosis, which you learned about in Unit 2. To reverse this process, you must exert greater pressure on one solution. In reverse osmosis, high pressure pushes water through the membrane, toward the pure water. Dissolved particles — for example, salts — are left behind.

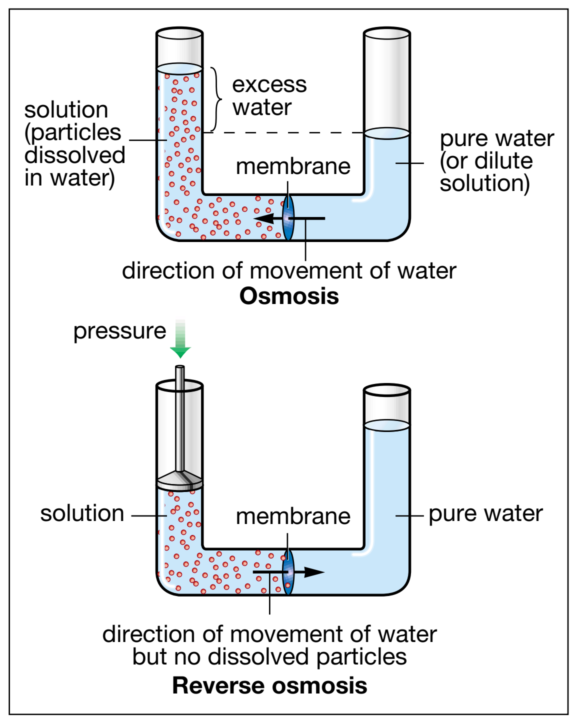


Figure 5.96C Osmosis and reverse osmosis

When reverse osmosis is used to desalinate seawater, large particles are first removed from the water by means of filters. After other contaminants have been removed, pumps produce the pressure needed to push the water through the membranes to remove the salt.

Each person has an impact on our water resources. If we all reduce our consumption of water and reduce the waste we put in water, we can work toward sustaining our supplies of clean water. The illustration shows some things that you can do to help keep our water clean.

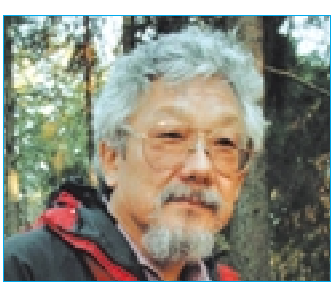
Use environmentally-friendly household products to do your cleaning.

Dispose of toxic substances, such as paint, solvents, and motor oil, at designated depots.

Consider using a canoe, rowboat, or sailboat rather than a motorboat.

Use compost rather than artificially produced fertilizers to do your gardening.

Across Canada



David Suzuki

Host of CBC TV's "The Nature of Things," David Suzuki is a household name in Canada. Dr. Suzuki is chair of a non-profit organization named after him, The David Suzuki Foundation. His foundation works to find solutions toenvironmental and social problems. The foundation also works to inform people about the problems we face so that the public can persuade the government to pay attention and change laws.

Dr. Suzuki began his career as a geneticist. He has been a professor at the University of British Columbia since 1969. He has won numerous awards for his contributions to science, environmental awareness, television, and radio.

The need to take greater care of our life-support systems, especially air, soil, water, and biological diversity, is something David Suzuki strongly promotes. He often speaks publicly to encourage others to change the habits of our consumer culture. One issue he is especially concerned about is that of dioxins leaking into the Great Lakes; another is the decreasing numbers of wild salmon on the west coast of Canada.

David Suzuki is the author of many books, including *Metamorphosis* (1987) and *The Sacred Balance* (1997, reprinted 1998). He lives in Vancouver, British Columbia.

INVESTIGATION 5-K

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Water Awareness

Think About It

How much do you know about the water in your community? In this investigation, you will take a closer look at a local water body.

In An Issue to Analyze on page 472, you will develop an action plan for this water body or another one in your community. Read through this investigation now and begin to gather ideas.

How Can Science Help?

Scientists use observation and careful measurements to learn about the quality of water in streams and lakes. By monitoring changes in water quality and in the plants and animals that live in or near water, scientists — and concerned citizens — can take action to prevent further problems.

Safety Precautions

- Conduct this investigation only under the supervision of your teacher.
- Remain in very shallow water at all times.
- Do not drink the water you are testing.

Apparatus

clip board

large jar or 2 L clear plastic pop bottle with top removed

thermometer

pH paper

rubber boots

portable water test kit (optional)

Materials

paper

pencil

Procedure

1. With your teacher, decide on a local lake, pond, or stream on which to focus your study.
2. Use the information about water that you gained in this unit to create a data sheet for studying the water body your class has chosen. As a group, brainstorm the information you might record. Your study might include:
   - a photograph or sketch of your site
   - the appearance of the water at the site
   - the odour of the water
   - the pH of the water
   - temperature (air and water)
   - presence of plants and animals (in and around the water)
   - evidence of human activity near the water (housing, industry, recreation, etc.)
   - evidence of pollution
   - other water quality measurements can be made using a water testing kit
3. Visit the water body and complete your data sheet.

Analyze

1. Use the information that you collected on your data sheet to create a "report card" for the water body you studied.
2. Have human activities affected the body of water that you studied? Is the water polluted? Explain how the evidence that you collected supports your answer.
3. Predict some ways in which human activities might impact the body of water in the future.

For long-term water management to succeed, water managers and engineers must study water as a part of a larger ecological system. Rivers, lakes, and wetlands carry out important functions as well as supply water. Rivers help to distribute fertile silt during floods. Wetlands act like sponges, holding and purifying water and preventing flooding. Bodies of water are important habitats for many species, including those that people use for food. As wetlands are drained, rivers diverted, and water habitats polluted, we lose much more than just water.

Figure 5.97 By looking after the waterways in their neighbourhood, people can help protect the larger system of which they are a part.

Much of the damage to water systems can be reversed. In many parts of the world, people are taking action to restore rivers and lakes to better health (see Figure 5.97). The first step is to stop pollution. Industrial and domestic wastes that were once dumped into rivers and lakes must now be disposed of in other ways or treated to remove harmful substances. Run-off into waterways can be reduced by planting protective buffer zones of trees, shrubs, and grasses along the edges of rivers and lakes. Plants also prevent erosion and help restore fish habitats.

The second step to make water supplies sustainable is conservation. It is far less expensive to avoid wasting water than to develop methods to obtain more.

The health of our water systems depends on everyone. The choices we make about how we use water will affect all people and all other living things. In order to sustain our water resources, it is important that we keep lakes, rivers, and oceans clean for today and for the future.

TOPIC 6 Review

1. Name three factors that affect water quality.
2. Describe three ways that human activities can affect water quality.
3. How can micro-organisms affect water quality?
4. Describe the importance of water monitoring.
5. Describe the stages in the treatment of drinking water.
6. **Apply** One of the keys to managing a sustainable resource is "getting more from less." Describe how this could be applied to water management.
7. **Thinking Critically** If the water cycle can purify water, why do we still need to protect our water resources and use them carefully?
8. **Thinking Critically** Make a concept map to show how animal wastes from a farm could impact a nearby pond. Identify the effects on water quality and suggest some solutions to reverse those effects.

Wrap-up TOPICS 5-6

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

diversity
detritus
algae
algal bloom
decomposed
biomagnification
sea-floor vents
chemosynthesis
dissolved solids
hard water
soft water
toxic substances
bioindicator species
water monitoring
water management
potable
water treatment
sewage
septic tank
effluent

Reviewing Key Terms

1. Explain the process of biomagnification. (5)

2. Pollutants in the water are always toxic substances. Is this statement true or false? Explain your answer. (6)

3. Write a sentence to describe the relationship among the terms in each group.

(a) detritus and decomposition (5)

(b) bioindicator species, water monitoring (6)

(c) biomagnification, toxic substances (5, 6)

(d) sustainable resource, water management (6)

(e) dissolved solids, hard water (6)

4. In your notebook, write the correct term to complete the following sentences. (6)

(a) In rural areas, sewage is stored in a ________.

(b) ________ contains few dissolved solids.

(c) Water that is safe to drink is called ________.

(d) Scientists conduct ________ to analyze the quality of water.

Understanding Key Concepts

5. Explain why plants are more abundant in cold water than in warm water. (5)

6. How can an organism, such as a frog, indicate water quality? (6)

7. Describe how acid precipitation can affect the quality of water and organisms that live in water. (6)

8. Explain what happens to water after you use it in your home. (6)

9. The illustrations on page 466 shows some ways that you can help to maintain a healthy environment. What other ways can you think of? Include your ideas in a poster. You may include drawings, or use photographs and magazine clippings to illustrate your ideas. Present your poster to the class during a poster session. (6)

UNIT 5

Ask an Expert

"What goes 'round, comes 'round." That saying has a different meaning for Carole Mills than it does for the rest of us. Carole is a biochemist and a contaminants researcher. She is the manager of the Contaminants Division of the Department of Indian and Northern Affairs in Yellowknife, Northwest Territories. She knows that whatever harmful chemicals humans throw into the environment will probably end up in the Arctic. These chemicals affect not only Canada's Aboriginal people and wildlife, but also people and wildlife in arctic regions around the globe. Because of her work, Carole was asked to represent Canada's indigenous people on the United Nations' committee to reduce the use of harmful contaminants throughout the world.

Q **What exactly is a contaminant?**

A A contaminant is something that ends up where it doesn't belong and where it can cause problems. The contaminants that I study are chemicals called organo-chlorines, heavy metals such as mercury, and radioactivity. These are materials that people use in industries or spray as pesticides, and so on. Unfortunately, these contaminants can make people and other animals very sick.

Q **Why are there contaminant problems in the Arctic? There isn't very much industry up there, is there?**

A No. In fact, most of the worst contaminants have been banned in Canada and many other countries for years. These contaminants are still being used in some countries, however, and when contaminants enter the environment, they don't stay in one spot. Rainwater can wash a chemical or other contaminant into a river, which flows into an ocean. Ocean currents could take it anywhere.

Some of these chemicals also evaporate, just as water does, and end up in the air. Once in air, they drift wherever the wind takes them. They can drift quite far in a short amount of time. When the Chernobyl nuclear reactor in the former Soviet Union exploded, for example, radioactivity from the disaster showed up in Arctic Canada in just a few days.

Q **Do these drifting contaminants create health problems for people all over the world?**

A Yes, they can cause health problems. The people in the Arctic are more at risk, however, for two reasons. First, northern animals, such as fish and walruses, are traditional foods of people living in the Arctic. When the food and water become contaminated, so do these animals. When the animals become contaminated, so do the people who eat them.

Q **What is the second reason?**

A The second reason is that more contaminants end up in the Arctic than in most other places on Earth because of something called "global distillation" or the "grasshopper effect." Since the contaminants can evaporate, they go through a cycle much like the water cycle. As the chemicals evaporate, they rise and may drift for a distance, then they cool and condense on the ground. When the temperature rises again, the chemicals evaporate again, and so on. If the vapour drifts north into arctic climates, however, the colder temperatures prevent the chemicals from evaporating, and so they are trapped here.

Q **What led you to study contaminants in the Arctic? Have you always lived in Yellowknife?**

A No, I grew up in Ottawa, but spent my summers in the Arctic with my Dene relatives. It was my job that brought me north full time. While I was getting my university degree in biochemistry, I did volunteer work in the environment department of the Assembly of First Nations. As soon as I graduated, the department hired me to work on the Eagle Project, a study of contaminants in the Great Lakes and their effect on local Aboriginal people.

After that, I worked with the Northwest Territories health department to study the effects of contaminants on the territories' people, and then with the Dene nation and Indian and Northern Affairs on similar projects. I moved up to Yellowknife in 1993 and I've been here ever since. It's wonderful to be closer to so many members of my family.

This researcher is testing water for contaminants.

EXPLORING Further

Dry Up

Carole says colder temperatures mean less evaporation. Try this activity to see for yourself. You will need some water, paper towels, scissors, a refrigerator, and a nearby countertop or other surface.

1. Cut two equal squares of paper towel.
2. Wet each piece of paper towel. Hold the pieces vertically over a sink until they stop dripping.
3. Lay one piece of paper towel flat inside the refrigerator. Lay the other piece flat on a nearby surface. Be sure the surface is free of any drafts. (If the refrigerator has open shelves, lay the other piece on a baking rack on the counter so it is exposed to similar air circulation.)
4. Check your paper towels periodically. Which appears to be drying faster? Is Carole's observation accurate?

An *Issue* to Analyze

A COMMUNITY ACTION PLAN

Water Watch

Think About It

Across Canada, community groups — including school groups — are volunteering to help protect streams and lakes within their communities. Throughout Alberta, students participate in the Alberta River Watch in which they monitor and test local rivers as part of river float trips. In Cochrane, Alberta, a significant percentage of households have volunteered to reduce their water use. These households have installed water-saving features such as toilet dams (which reduce the water used in each flush) and low-flow shower-heads. Throughout British Columbia, community groups are "adopting" local streams as part of the Streamkeepers program. As Streamkeepers, interested individuals monitor water quality, improve habitat, and reduce pollution. Is there a body of water in your community that could use your help? In this activity, you will devise a community action plan for a local steam, lake, or pond. You could also do a project on water conservation and water use.

Background Information

1. Collect newspaper articles on local water-related issues. Post the articles on a classroom bulletin board. As a class, decide on the local water body or water issue that you will focus on for this activity. You may choose to use the same water body that you studied in Decision-Making Investigation 5-K.

2. As a class, brainstorm how you could gather the following types of information:
   - historical information, such as photographs and records of the historical use of water
   - maps, such as contour (topographic) maps
   - ideas for water-related projects that you could carry out
   - experts you could contact to help you with your project and to give you more information about the water body

   Use concept maps or other graphic organizers to record your ideas.

3. In small groups, complete the tasks you outlined in step 2.

4. Create a bulletin board display and post the information you gather.

5. As a class, decide on the type of project that you would like to carry out.

Plan and Act

1. Develop a community action plan to protect or improve the quality of the body of water. The following steps should be part of your plan. Divide the tasks among small groups of students.
   - **Set goals** What are the goals of your project? What would you like to accomplish?
   - **Ask permission** Is the water body on land that is public or private? Which people should you contact to gain permission to carry out your project?
   - **Outline safety precautions** Establish rules and guidelines for safety.
   - **Establish steps and timelines** What will be done and when will you do it?
   - **Plan a public relations strategy** How will you tell others about your project? How will you get your community involved? Possible strategies include producing flyers, pamphlets, or posters, or creating a web site that community members can access.

Analyze

1. What were some of the challenges and successes of your project? If you did the project again, what might you do differently?
2. How important was planning to the success of your project?
3. How did your understanding of science and water-related issues help you carry out this project?

UNIT 5 Review

Unit at a Glance

- Water on Earth is recycled endlessly in the water cycle.
- Not only the quantity of water on Earth but also its quality are important environmental concerns.
- About 97 percent of the water on Earth is salt water. Only about 3 percent of the water on Earth is fresh water. Most of this fresh water is frozen in large masses of ice.
- Both glacial erosion and glacial deposition have affected and continue to affect the surface features of Earth.
- Icefields, glaciers, and snow in high mountains act as natural fresh-water storehouses.
- Studying ancient ice can reveal clues about the climates of the past.
- Many scientists believe that one reason for global warming is the increase of greenhouse gases in Earth's atmosphere.
- Fresh water exists both above ground as surface water, and below ground, as groundwater.
- Land use can affect the run-off of water and the health of a watershed.
- The rate of flow of a stream affects how much erosion takes place, as well as the amount of sediment the stream transports.
- By studying the quantity, quality, and characteristics of sediment in a stream or river, scientists and engineers can determine the impact of pollutants on the aquatic environment.
- Large withdrawals of groundwater are resulting in aquifer depletion in many areas.
- Groundwater contamination can spread the effects of dumps and toxic spills far beyond the site of the original contamination.
- Ocean water is salty because rivers and groundwater flowing over rocks on land pick up salts and carry them to the ocean.
- Ocean waves change shorelines and form beaches.
- Tides result mainly from the pull of the Moon's gravity on the ocean. The Sun's gravity has a smaller, less noticeable effect on tides.
- Ocean currents affect the climate and the sea life of the regions to which they move.
- The diversity of fresh-water and salt-water organisms varies from habitat to habitat.
- Both plants and animals develop adaptations to enable them to survive in aquatic environments.
- As on land, organisms in aquatic habitats are linked together by food chains and food webs.
- Biomagnification can increase the concentration of a toxin in a food chain.
- Various scientific tests can measure the properties and quality of a supply of water.
- Bioindicator species can tell us about the type and amount of pollution in a particular body of water.
- Maintaining a safe, reliable water supply involves careful water management and balancing the needs of people, industries, agriculture, and wildlife.

Understanding Key Concepts

1. Name the three states in which water occurs and describe where you would find a naturally-occurring example of each state.
2. In what form is most fresh water found?
3. Where is most liquid fresh water on land located?
4. How does the water cycle help purify water?
5. Give two reasons why a puddle might disappear.
6. Explain, using diagrams or words, how precipitation falling on a mountainside ends up in the ocean.

7. **(a)** How is a valley glacier formed?
   (b) How is a continental glacier formed?

8. What does it mean to say that a glacier is
   (a) advancing?
   (b) retreating?

9. Why do sea levels fall during an ice age?

10. How many major ice ages have there been during the past three million years?

11. What two characteristics of land produce run-off?

12. Copy the following diagram into your notebook and add the missing labels.

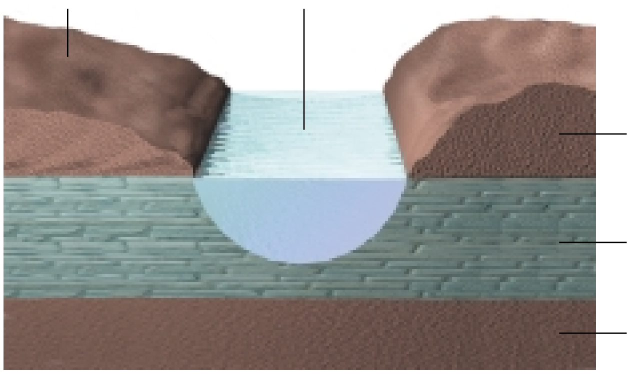
13. What is the difference between a watershed and a well?

14. What conditions produce a hot spring?

15. Describe two ways in which wetlands can benefit people.

16. Name an advantage and a disadvantage of using groundwater as a source of drinking water.

17. Copy the diagram of a water table shown here. Add the missing labels.



18. What is meant by salinity?

19. Explain why ocean water is salty.

20. What causes waves?

21. Describe what causes currents in the ocean.

22. Define plankton, phytoplankton, zooplankton, sea-floor vent, chemosynthesis, algal bloom.

23. Why are pollutants in the sea not made harmless by dilution?

24. What is meant by the term "water quality"?

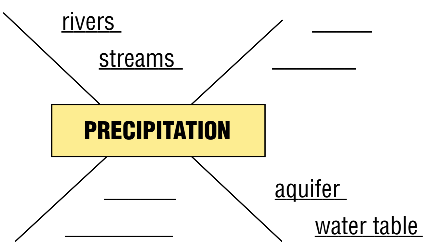
25. How can air pollution in one place produce water pollution in another place some distance away? Give an example.

26. Give an example of how a human activity causes pollution to enter a watershed and describe an effect of the pollution.

27. Identify ways in which individuals in your community can reduce water pollution, avoid wasting water, and encourage others to sustain water resources.

Developing Skills

28. Copy and complete the spider map of precipitation shown below.

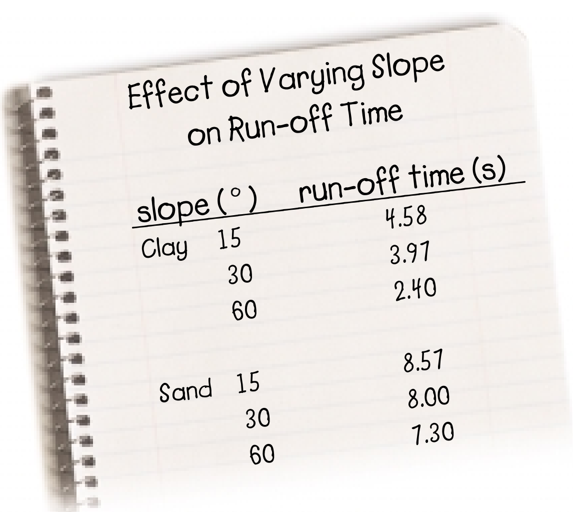


29. The data shown below were obtained by students using a stream table to compare the run-off time of 200 mL of water from a surface of sand and clay. The experiment was repeated with the stream table placed at three different angles of slope.

(a) Make a graph of the data, with angle of slope on the horizontal axis (*x*-axis) and run-off time on the vertical axis (*y*-axis). Use one coloured line to show run-off times on clay, and another coloured line for run-off times on sand.

(b) What is the relationship between angle of slope and run-off time?

(c) From which surface, and at which angle, would the greater volume of water run in 1 min?



Effect of Varying Slope on Run-off Time

	slope (°)	run-off time (s)
Clay	15	4.58
	30	3.97
	60	2.40
Sand	15	8.57
	30	8.00
	60	7.30

30. Make a graph showing how ocean temperature varies with depth.

Problem Solving/Applying

31. Some icebergs are several kilometres long. If melted, they could provide billions of litres of fresh water.

(a) What areas of the world would benefit most from using icebergs as a source of fresh water?

(b) What practical problems would arise in moving icebergs from the polar regions to other parts of the world?

(c) For each problem in (b), suggest a solution.

32. Someone tells you it is a waste of time to drill for water in a desert. Explain why you agree or disagree.

33. A farming family had been getting plenty of water from their well for many years. One winter, a developer completed a new housing development on land close to the farm. The family did not notice any change in their water supply until the end of the following summer, when their well ran dry. Explain what happened. How could the family avoid this problem next year?

34. How can the volume of run-off from an area be reduced? Why would you want to control run-off?

35. Consult library resources or search the Internet for information about world ice distribution patterns over several geological time periods. Draw a map showing these changes in ice distribution on Earth.

36. You are standing on a beach watching a large beach ball floating about 200 m offshore. Waves are rolling in and breaking on the beach, but the ball seems to remain in the same place. Explain this observation.

37. Describe some ways in which people can restore polluted streams and rivers so that they are suitable for fishing and swimming.

38. Why is water sustainability an international problem?

Critical Thinking

39. If you could compare a map of North America before the last ice age with one after the last ice age, you would see that lakes and rivers have different locations. Why?

40. How might the logging of trees pollute a river?

41. Suppose an apartment dweller in a large city on a lake discards used paint thinner down the drain. (This is *not* a recommended practice.) Where might this pollutant end up? What effects might it have on a watershed?

42. The peak season of water flow in a watershed is different in northern Alberta than in southern Alberta. Explain how the peak seasons are likely to differ, and why.

43. Why is the weather close to a lake different from the weather farther away from the lake?

44. Explain why a sandy beach cannot be considered a permanent feature of the shoreline.

45. Why is it useful to know what the sea floor looks like?

46. The Gulf Stream is an ocean current that flows across the Atlantic Ocean. This current carries warm water from the Straits of Florida north to Newfoundland and then east to northern Europe. How does the Gulf Stream affect the climate of northwestern Europe?

47. A younger student says, "I don't eat fish, so it won't affect me if the sea is polluted." Explain why you would agree or disagree with the student's statement.

Pause& Reflect

Now that you have completed this unit, go back to the Focussing Questions on page 362. Write answers to these questions in your Science Log.